IABSE

SYMPOSIUM

MANCHESTER 2024

Construction's Role for a World in Emergency

REPORT

International Association for Bridge and Structural Engineering (IABSE)

IABSE
Symposium Manchester
2024

Publisher

IABSE

Jungholzstrasse 28,

8050 Zurich

SWITZERLAND

Phone: +4143 443 97 65

Email: secretariat@iabse.org

Web: www.iabse.org

in cooperation with

Manchester Metropolitan University

ISBN: 978-3-85748-204-5

https://doi.org/10.2749/manchester.2024

Distributed by

structurae

IABSE
Symposium Manchester
2024

CONSTRUCTION'S ROLE FOR A WORLD IN EMERGENCY

10-12 APRIL, 2024

Proceedings

Table of Content

Preface

The title for the 2024 spring conference was deliberately selected to be provocative and to issue a challenge. Why? Because we want delegates to arrive prepared to think, to examine their own position and to contribute.

It is several decades since we first heard the warnings that inaction in the face of climate change would see the world drift into an ever more parlous state. Nowadays, there is no shortage of warnings and predictions of dire consequences. Thankfully, there are also many instances of individual and collective endeavour around the world to mitigate and even reverse some of the changes. But our situation is akin to a nation's spending on healthcare: however much we do there will always be legitimate calls for it to be more.

In setting up this conference we wanted to both showcase examples of construction projects, products and practices that addressed the 'Green Agenda' - not in political or promotional ways but through objectively proven techniques - and to encourage delegates to think what they, personally, should do. It was some 20 years ago that the then President of the Royal Academy of Engineering, Lord Browne, made it clear that it would engineers, not be journalists and politicians, who would make the greatest contributions to combating climate change. In her Presidential Address to the Institution of Structural Engineers in January this year, Tanya de Hoog set down a series of ways in which members of the Institution could each readily assist by making small changes to their day to day professional behaviour.

So learn from the technical presentations and discussions, take profit from the ad hoc conversations and be encouraged by being part of an international forum that has come together because it cares. IABSE is often referred to as a 'Force for good'. Let us all ensure that Spring 2024 in Manchester makes that force even more powerful.

Professor D A Nethercot OBE, FREng, FTSE, NAE
Chair of the Scientific Committee
Emeritus Professor of Civil Engineering
Imperial College London, UK

Scientific and Organising Committee

Organising Committee

Ian Firth *(Chair)*
Mark Bulmer
Ed Dablin
David Knight
Fernando Madrazo-Aguirre
Francisco Martin
Tom Osborne

Scientific Committee

David A. Nethercot *(Chair)*
Andreas Lampropoulos and Yong Wang *(Vice Chairs)*

Technical Secretaries

Jeanette Muñoz Abela
Fiona Walport

Members

Hector Beade-Pereda
Corneliu Bob
Marc Bonello
Mikael Braestrup
Eugen Brühwiler
Dion Buhagiar
Christian Cremona
Laszlo Dunai
John Duntemann
Stephen Hicks
Niels Peter Hoj
Naeem Hussain
Martin Kirk
David Knight
Andreas Lampropoulos
Fernando Madrazo-Aguirre
Andrew Martin
José C. Matos
Shunichi Nakamura
David Nethercot
Fathy Saad
Mahesh Sankaran
Bert Snijder
Meini Su
Harshavardhan Subbarao
Brian Uy
Tina Vejrum
Thomas Vogel
Yong Wang
Jan Wium
Xiang Yun
Riccardo Zandonini
Daia Zwicky

List of Sponsors and Exhibitors

Gold Sponsors

Freyssinet
Mott MacDonald

Silver Sponsors

COWI
USL Speciality Products
Roughan & O'Donovan
Krafton

Bronze Sponsors

Acrow Bridge
DYSE
TY Lin

Exhibitors

ACROW Bridge
ArcelorMittal
Bridge design & engineering
Bridges to Prosperity
Cast Connex
COWI
Dewesoft UK Ltd
DYSE
EMJ Plastics
Fairfield Engineering Solutions
Fatzer AG
Freyssinet
General Technologies
HRC Europe
IABSE
Krafton
Luna
LUSAS
Mageba sa
MIDAS IT UK
MISTRAS Group
Mott MacDonald
Outokumpu Oyj
Roughan & O'Donovan
SOFiSTiK AG
Spencer Group Engineering
Surviot Monitoring
Structurae
Teufelberger Redaeilli
TY Lin
USL Speciality Products

Media Partners

Bridge design & engineering
Structurae

Supported by

The Royal Academy of Engineering
The Institution of Civil Engineers
The Institution of Structural Engineers

Official Event Charity

Bridges to Prosperity

Keynote Lectures

Engineering in an Emergency

Wednesday April 10th 2024. COWI ROOM (and USL ROOM by relay) at 09:45

Will Arnold, Head of Climate Action, Institution of Structural Engineers

Will is a Fellow and staff member of The Institution of Structural Engineers, responsible for bringing sustainability into all aspects of the institution's work. He is well-known for his work on embodied carbon policy in the UK, including on Part Z and the UK Net Zero Carbon Buildings Standard.

Reasonable Skill. And Care

Wednesday April 10th 2024. COWI ROOM (and USL ROOM by relay) at 10:15

Martin Knight, Founder and Managing Director, Knight Architects

Martin is one of the leading UK architects specialising in the design of bridges and transport infrastructure. He is a Fellow of the RIBA, IABSE and the Institution of Civil Engineers and an Honorary Fellow of IStructE.
He founded international bridge designers Knight Architects in 2006 and his award-winning practice has completed more than sixty bridges in the UK and internationally, with projects under construction in Finland, Germany, Poland, New Zealand, Norway, Sweden and the UK. Their approach to design has been hailed as exemplary by bodies including the National Infrastructure Commission and the Design Council in the UK and Baukultur Bundesstiftung in Germany.
Martin frequently serves as a client and industry advisor, including as member of the Design Review Panel of the Design Commission for Wales since 2006. He was appointed a UK Design Council Ambassador in 2021 and is a judge for the BCIA Awards and the Structural Awards.

Engineers and climate action: are we rising to the challenge?

Thursday April 11th 2024. COWI ROOM (and USL ROOM by relay) at 09:45

Savina Carluccio, Executive Director, International Coalition for Sustainable Infrastructure

Savina is a global advocate of the role of civil engineers in tackling our society's biggest challenges. Over the last two decades sha has advised governments, infrastructure owners and operators, multi-lateral development banks and NGOs to develop and implement sustainability and resilience in infrastructure. Prior to ICSI, she worked as an infrastructure advisor at Arup and was Head of Guidance and Standards at the Resilience Shift. She also serves a member of Institution of Civil Engineers' Advisory Board on sustainable and resilient infrastructure and of the ASCE Global Sustainability Planning Committee.

Low carbon technologies to be challenged in the supply chain of concrete structures

Thursday April 11th 2024. COWI ROOM (and USL ROOM by relay) at 10:15

Akio Kasuga, Executive Vice President and CTO, Sumitomo Mitsui Construction.

Dr. Akio Kasuga has been designing and building many bridges and has developed many new bridge technologies. He received fib outstanding structures in 2006 and 2018, Trophy Eugene Freyssinet 2013 and Albert Caquot Prize 2021 from AFGC. He was the President of fib from 2021 to 2022. He was awarded as the Honorary President of fib in 2023.

In plain sight?

Friday April 12th 2024. COWI ROOM (and USL ROOM by relay) at 15:30

Dervilla Mitchell CBE, Director and Deputy Chair, Arup

Dervilla is a Civil Engineer with an illustrious career who started out as a structural design engineer and progressed to lead major building projects. Noteworthy projects span from Portcullis House and the London 2012 Athletes Village to smaller endeavours like Saga HQ and Goodwood Paddock redevelopment. Her aviation involvement includes designing terminal buildings at T5 Heathrow and T2 Dublin. Former Executive Chair of Arup's UK, India, Middle East, and Africa Region, responsible for over 6000 people and currently Deputy Chair of Arup Group. A decade on the Prime Minister's Council for Science and Technology shaped her commitment to the Net Zero agenda, and she currently chairs the National Engineering Policy Centre's decarbonizing group. Also active in promoting diversity in construction and encouraging youth to pursue engineering careers. Recognised with a CBE in 2014, she holds honorary doctorates from University College Dublin (2016) and Imperial College London (2021).

Session Plan

Wednesday, 10th April 2024

Plenary Session:

COWI ROOM

09:15 **Opening Session**

Keynote Session: Keynote Lecture:

09:45 **Keynote 1**
Engineering in an emergency - page 28
Will Arnold:

10:15 **Keynote 2**
Reasonable skill. And care
Martin Knight:

10:45 Tea/coffee break

A1 Designing for longevity, resilience and extreme events

11:15 COWI Room

The effect of horizontal loads caused by rapidly rising river water on the bearing capacity of masonry arch bridges - page 59
Hans De Backer

Efforts of Seismic Retrofit: The Future Challenge of Innoshima Bridge Beyond 40 Years of Service - page 67
Hongxin Wang

Global Trends in Bridge Collapse Incidents in 2023: an Analysis of Regional Patterns and Causative Factors - page 75
Paul Mullins

Masonry arch bridges in the 21st century - page 83
Matthew Gilbert

Construction and Testing of a CFRP-prestressed Railway Bridge Prototype - page 90
Andreas Näsbom

B1 Competence, professionalism, ethics and Designing and building for net zero

11:15 USL Room

Ethical challenges and greenwashing – challenges for structural engineers - page 99
John Armitage

Data-driven and Production-oriented Tendering Design using Artificial Intelligence - page 107
Linda Cusumano

Specimen Design and Advanced Material Testing for 3D Printing Concretes - page 115
Marc-Patrick Pfleger

Shifting the Density Discourse: the Future of Soft Density - page 124
Audrey-Frédérique Lavoie

Carbon emissions, net zero, lifespan and circularity interaction strategies - page 133
David Collings

C1 Regeneration, rehabilitation and adaptation of existing structures

11:15 ROUGHAN & O'DONOVAN ROOM

Inspection and retrofitting of Danube bridge - Ruse- Giurgiu - challenges and innovative approaches - page 139
Alexander Jiponov

Proposal for cable replacement method incorporating arch structure in aging cable-stayed bridges - page 148
Kazuhiro Miyachi

Unified Explanation of Cracks for Long-Span Prestressed Concrete Box Girder Bridge Using Spatial Lattice Grid Model - page 156
Dong Xu

Evaluation of the behaviour of old beam-plate bridges - page 165
Muhammad Farjad Sami

Structural Assessment of the M6 Bromford Viaduct Against Ground Movements - page 173
Christos Mitsarakis

Rehabilitation of the Outeiro Bridge with emergency strengthening of the superstructure damaged by barges impact - page 182
Pedro Almeida

D1 Smart Structures - designing responsive, adaptive & progressive solutions

11:15 KRAFTON ROOM

Development and validation of a train-bridge interaction model - page 190
Sharon Deceuninck

Towards Cyber-Secure and Hazard-Resilient Smart Civil Structures - page 199
Miguel Cid Montoya

Effect of Initial Web Out-of-Flatness Imperfections on the Shear Strength of Low-Frequency Sinusoidal Plate Girder - page 208
Parfait Masungi

Developing computational design techniques to meet the increasing demand for more complex and sustainable bridges in Southeast Asia - page 218
Mike Tapley

Additively Constructed Seismically Protected System for Bridge Infrastructure - page 227
Anthony Mackin

12:30/12:45 Lunch break

A2 Designing for longevity, resilience and extreme events

13:30 **COWI Room**

B2 Special Session - The Trans-Pennine Route

13:30 **USL Room**

C2 Regeneration, rehabilitation and adaptation of existing structures

13:45 **ROUGHAN & O'DONOVAN ROOM**

Strengthening of a Curved and Skew Supported Prestressed Hollow Box Girder - page 354
Maria Kierzek

D2 Regeneration, rehabilitation and adaptation and Smart Structures - designing responsive, adaptive & progressive solutions

13:45 KRAFTON ROOM

Microcracks assessment during unloading for structural elements reuse - page 361
Sissel Albrecht Kahr

Damage characterisation using Sentinel-1 images: Case study of bridges in Ukraine - page 367
Nadiia Kopiika

Structural assessment of corbels and half-joints in existing bridges - page 376
Rob Vergoossen

Evaluation on a load-carrying capacity of the stiffened plates subjected to biaxial forces considering the local buckling of the longitudinal ribs - page 385
Kousuke Yasuda

Load Transfer Mechanism of Single-sided frictional joints with high strength countersunk head bolts - page 393
Misato Konishi

15:00 Tea/coffee break

A3 Reducing waste - productivity, efficiency and resource economy

15:30 COWI Room

Influence of CO_2 Emission Pricing on the Degree of Reuse in Building Projects - page 402
Lars Magnus Knutstadmarka Johnsen

Effect of Topology Optimization Parameters on Additively Manufactured Space Frame Nodes - page 409
Luke Farrugia

Development of cold-bonded lightweight concrete aggregates using biowaste - page 419
Daia Zwicky

Properties of Cementitious Materials with Reclaimed Cement - page 428
Shahriar Abubakri

Lateral stiffness design and optimization for over-track residential towers in metro depots - page 435
Shuang Wu

B3 Designing and building for net zero

15:30 USL Room

Bracklinn Falls Footbridge: Efficient Modular Design - page 443
David Knight

C3 Regeneration, rehabilitation and adaptation of existing structures

15:30 **ROUGHAN & O'DONOVAN ROOM**

D3 Smart Structures - designing responsive, adaptive & progressive solutions

15:30 **KRAFTON ROOM**

Thursday, 11th April 2024

Keynote Session: Keynote Lecture:

09:45 **COWI Room**

Engineers and climate action: are we rising to the challenge? - page 37
Savina Carluccio

Low carbon technologies to be challenged in the supply chain of concrete structures - page 46
Akio Kasuga

10:45 Tea/coffee break

A4 Designing for longevity, resilience and extreme events

11:15 **COWI ROOM**

Two-dimensional transient thermal analysis of drilled-pile wall exposed to extreme temperatures and discussion on frost mitigation methods - page 573
Summer Shahzad

A New Method for Calculating the Shear Stiffness of RC Beams with Web Diagonal Cracks - page 581
Dong Xu

Predicting Fractures in Reinforcing Steel Bars: A Low Cycle Fatigue CNN Approach - page 587
Islam Mantawy

Ultimate Shear Strength of Welded Stainless and Carbon Steel Girders - page 596
Kentaro Kato

Streamlining a Transitional Shelter Design: A DFMA-Driven Approach for Efficient Design and Assembly - page 604
Cheryl Lyne Roxas

B4 Designing and building for net zero

11:15 **USL ROOM**

Assessing the carbon footprint of bridges and a strategy to deliver carbon reductions - page 613
Philip Chalk

As bridge engineers, are we designing efficient structures? - page 622
Gareth Davies

A broadened approach to the environmental assessment in bridge design - page 631
Vazul Boros

Reuse of cast-in-place concrete slabs in new structures - page 639
Matthias Dietz

Sustainable concrete used in the Uithoornlijn project - page 647
Michaël Menting

C4 Regeneration, rehabilitation and adaptation of existing structures

11:15 ROUGHAN & O'DONOVAN ROOM

D4 Designing and building for net zero

11:15 KRAFTON ROOM

12:30/12:45 Lunch break

A5 Designing for longevity, resilience and extreme events

13:30 COWI ROOM

B5 Special Session - Net Zero Bridges (Panel discussion)

13:30 **USL ROOM**

Panelists: **Daniel Green** (Expedition Engineering)
Brian Duguid (Mott MacDonald)
Ben Sibert (Arup)
David Wilson (Atkins Realis)

C5 Regeneration, rehabilitation and adaptation of existing structures

13:45 **ROUGHAN & O'DONOVAN ROOM**

D5 Smart Structures - designing responsive, adaptive & progressive solutions

13.45 **KRAFTON ROOM**

Sustainability as a key design factor from the structure conception stage - page 855
Jose Maria Lorenzo Romero

Deep reinforcement learning algorithm based optimization method for the multiple storey braced steel frame structure under global stiffness constraints - page 864
Bingjie Du

Experimental study and finite element analysis on seismic behavior of flat vertical-diaphragm stiffened concrete-filled SHS column joints - page 871
Xin Zhao

15:00 Tea/coffee break

A6 Designing for longevity, resilience and extreme events

15:30 COWI ROOM

Advancements in Shear Resistance Prediction for Concrete Beams: A New Shear Model - page 879
Dong Xu

Overturning of Freestanding Cylindrical Structures Subjected to Pulse-like Ground Motions - page 887
Xun Zhou

Evaluation of Resilience in Displacement Restrain Brace with initial story stiffness and Buckling Restrained Brace - page 896
Akine Otani

Heating and Thermal Conductivity Effect Inside High Damping Rubber Bearing at Low Temperature - page 904
Jie Shen

Vibration design and dynamic testing for long cantilevel composite floors equipped with vibration rods in office tower - page 913
Xin Zhao

B6 Designing and building for net zero

15:30 USL ROOM

Fabrication's role in a world in emergency: reducing environmental impact by collaboration - page 922
David Knight

Analysing embodied carbon for rural trail bridges in East Africa - page 929
Lucy Cryer

Load Bearing Behavior of 3D Printed Prestressed Segmental Concrete Girders - page 938
Marc-Patrick Pfleger

Super-Low-Carbon Footbridge Design - page 947
Ben Curry

Sustainability and Beauty in Bridge Design - page 955
Hector Beade-Pereda

C6 Regeneration, rehabilitation and adaptation of existing structures

D6 Reducing waste - productivity, efficiency and resource economy

Friday, 12th April 2024

A7 Reducing waste - productivity, efficiency and resource economy

B7 Special Session: Climate ethics - what should we do? (Panel discussion)

09:15 USL ROOM

Panelists: **Catherine Ramsden** (Useful Simple Trust)
David Leversha (WSP)
Paul Sanders (COWI)
John Armitage (Ramboll)

C7 Industry Sessions: Freyssinet - Aging structures - repair or renew? Practical and pragmatic engineering to deliver resilient and sustainable structures.

Mott MacDonald - Innovating to Improve Infrastructure

09:15 ROUGHAN & O'DONOVAN ROOM

D7 Industry Sessions: USL Speciality Products - Advanced Chemical Water Management Systems for Bridge Deck Asset Protection

Fatzer - Building Strong Connections. Design, Manufacture and Installation of Structural Rope Assemblies and Related Parts

09:15 KRAFTON ROOM

10:45 Tea/coffee break

A8 Reducing waste - productivity, efficiency and resource economy

11:15 COWI ROOM

B8 Regeneration, rehabilitation and adaptation of existing structures

11:15 **USL ROOM**

C8 Designing for longevity, resilience and extreme events

11:15 **ROUGHAN & O'DONOVAN ROOM**

D8 Designing for longevity, resilience and extreme events

11:15 **KRAFTON ROOM**

Design and detailing of durable and sustainable Post-Tensioning structures with polymer ducts according to fib bulletin no. 75 - page 1218
Klaus Lanzinger

A Finnish Case Study of U-Trough Underpasses in high water table conditions for Gravity vs Anchored Structural System - page 1225
Manish Mehta

Shake Table Studies of Precast Bridge Columns with Lap Splice Connections by UHPC - page 1234
Jianfeng Gao

Chain reaction failure analysis for tied arch bridges considering cable corrosion - page 1243
Yukari Aoki

Effects of material properties on slipping behavior in high-strength bolted frictional GFRP joints - page 1251
Toshie Habukawa

Interdisciplinary data collection for empirical community-level recovery modelling - page 1260
Blythe Johnston

12:30/12:45 Lunch break

A9 Reducing waste - productivity, efficiency and resource economy

13:45 **COWI ROOM**

Productivity increase in the design and construction of bridges - page 1268
Johan Lagerkvist

Soho Loop Cantilever Footbridge - page 1277
Ed Dablin

Re-use of wind turbine steel towers for pedestrian bridges - page 1285
Torben Forsberg

Design and construction of the flyover in the intermodal ferry terminal in Świnoujście - page 1295
Dawid Wisniewski

Optimization Process of Railway Segmental Bridges Constructed by Balanced Cantilever Method - page 1303
Jindrich Potucek

B9 Regeneration, rehabilitation and adaptation of existing structures

13:45 **USL ROOM**

Teaching Reuse of Existing Structures at the University of Sheffield - page 1310
John Carr

Challenging prior decisions relating to existing bridges - page 1316
Peter Campbell

Sustainable salvation of deficient RC bridges by means of the UHPFRC Technology - page 1325
Eugen Brühwiler

M5 Exe and Exminster Viaducts - Strengthening and Safeguarding - page 1332
Riccardo Stroscio

Extended linear finite element calculation of a 70-years old prestressed concrete viaduct - page 1340
Rene Veerman

C9 Designing for longevity, resilience and extreme events

13:45 ROUGHAN & O'DONOVAN ROOM

Climate Resilience of Long-Span Bridges through Early Stage Aerodynamic and Climate Consulting - page 1348
David Hamlyn

Bridge hangers as cruciform sections – Advantages and behaviour under wind loading - page 1358
Miguel Candeias

Design of the Bataan-Cavite Interlink Bridge (BCIB) Project in The Philippines - page 1366
Marwan Nader

Structural configuration of negative bending moment zone in continuous MVFT girder bridge - page 1375
Zhihua Xiong

Ship impact loads on construction pits of bridges - page 1383
Claus Kunz

D9 Designing and building for net zero and Reducing waste - productivity, efficiency and resource economy

13:45 KRAFTON ROOM

Stainless steel as a structural material in the drive toward net-zero bridges - page 1390
Andrew Backhouse

Advanced steel solutions for a sustainable and economic bridge infrastructure - page 1399
Mike Tibolt

Environmentally conscious structural design and material selection of short-span bridges - page 1407
Ákos Kővári

The impact on structural embodied carbon of using loads obtained from wind tunnel testing vs code based loads - page 1415
Tung Nguyen

Probabilistic modelling of building stock properties for urban mining - page 1424
Lombe Mutale

15:00 Tea/coffee break

Keynote Session: Keynote Lecture:

15:30 COWI Room

In plain sight? - page 54
Dervilla Mitchell

16:00 **Closing Session**

Full Papers

Engineering in an Emergency

Will Arnold

The Institution of Structural Engineers, London, UK

Contact: will.arnold@istructe.org

Abstract

In 2023, the world was 1.5°C warmer than pre-industrial levels. Globally, we have now lost lost two thirds of our wildlife, and are still struggling to bring people above the poverty line. Meanwhile the use of construction materials is responsible for 15% of global emissions, 30% of waste generation, and 50% of resource extraction. But perceived 'easy wins' for reducing such impacts keep being disproven, and whilst digital technologies, MMC and AI are all touted as the saviours of material reduction, today's structures are more inefficient than ever. The industry therefore needs to step back and revisit our basic goals and mindsets. We must scrutinise and be held to account for the damage we are inflicting on the climate, ecosystems, and humanity, to treat all living beings with equal sanctity rather than as things to balance against the demands of our paying clients, and to start acting in a wholly positive and regenerative, way.

Keywords: materials; structures; design; climate; net-zero; embodied carbon; ecology; biodiversity; regenerative design

1 Introduction

At a time when yet more and more records continue to be broken year on year, are we really treating the phrase "climate emergency" seriously enough?

The global construction industry has made countless commitments around the world. Materials producers have set out roadmaps, design firms have committed to halving emissions, and clients and funders are making more and more 'net zero' promises. Yet if you walk onto a construction site today, you would be forgiven for thinking that there is no such emergency. New road bridges rise out of the ground in the same way they were doing a few years ago, whilst the automotive industry they support gets on with decarbonising. Retrofit of buildings is on the rise in some cities, but in most places it is still perceived as 'second best' to new-builds. A handful of projects are trialling new materials for the first time, but these are few and far between. And across all of this, a lack of effective regulation increases cost and complexity when trying to design in a low-carbon manner.

How do we change this? Is it enough to for just some of us to reduce carbon on just some of our projects? Will short-term economics remain the only hard line that cannot be crossed, with all other aspects of sustainability treated as secondary? And why are we focussing on carbon, when the rest of our ecosystem is breaking down too?

This paper summarises the problem as we know it today; highlights the biggest and most impactful decisions that must be made on our projects now; and demonstrates how we must now move our north star away from simply doing a little less damage, and towards repairing and restoring the ecosystem that provides us with our only home.

https://doi.org/10.2749/manchester.2024.0028
Distributed by structurae

Engineers and climate action: are we rising to the challenge?

Savina Carluccio

International Coalition for Sustainable Infrastructure (ICSI), London, UK

Contact: savina.carluccio@sustainability-coalition.org

Gemma Cowan

International Coalition for Sustainable Infrastructure (ICSI), London, UK

Contact: gemma.cowan@sustainability-coalition.org

Abstract

'*Despite the overwhelming evidence that we are not doing enough, there is still substantial resistance to talking about the possibility of living in a world where we temporarily overshoot 1.5°C.*'

- Debra Roberts IPCC Co-Chair WGII AR6.

It is crucial for engineers to consider the implications of living in such a scenario, where common sense suggests that changes in critical natural systems may become irreversible and take urgent action to mitigate, respond and adapt to the threats posed by climate change.

This paper reflects on the role of engineers in climate action. It frames the challenges and opportunities for the profession to drive action, presenting examples of what is being done by the global engineering community. It sets out what will be needed from engineers in terms of innovation and changing mindsets, as well as the required skills, training, and capacity building. Finally, it argues that engineers should be bolder, louder, and more visible in advocating for climate action.

Keywords: climate action; engineering; resilience; adaptation; infrastructure; advocacy; capacity building.

1 Introduction

1.1 The urgent need and opportunity for resilience and adaptation to a changing climate

In 2023, the estimated overall losses from disasters triggered by natural and climate-related hazards was a staggering $250 billion [1]. In addition to the damage losses, the economic shockwaves are far-reaching, for example, losses in productivity as a result of broken supply chains and unquantifiable losses such as lost education and mental health impacts. While absolute economic losses are concentrated in high-income countries, the human cost of disasters falls overwhelmingly on low- and middle-income countries.

Our built environment and supporting infrastructure systems are increasingly complex, interdependent, and reliant on sophisticated digital technology. These systems have become fragile due to fragmented governance and under-investment and are now operating in an uncertain future.

Embedding and enhancing resilience is becoming essential to better prepare for the threats we can anticipate and to respond to those we cannot predict or avoid. Resilience should be to all hazards, but climate change has become an area of urgent focus because it introduces greater levels of uncertainty and can exacerbate pre-existing hazards and risk drivers, substantially amplifying the negative consequences of disasters when they occur.

Climate mitigation and decarbonisation efforts have taken up much of the conversation about climate to date. However, the IPCC AR6 Synthesis Report [2] conveys the urgency of implementing resilience and adaptation measures alongside

https://doi.org/10.2749/manchester.2024.0037
Distributed by structurae

Low carbon technologies to be challenged in the supply chain of concrete structures

Akio Kasuga

Sumitomo Mitsui Construction, Tokyo, Japan

Contact:akasuga@smcon.co.jp

Abstract

Cement used in structural concrete accounts for 60% of all cement. Thus, the amount of CO_2 emission by cement in structural concrete in a year is about 5% of the amount emitted by mankind. LCA of structural concrete should consider not only the materials at the product stage but also the maintenance phase at the use stage after construction. A rough indicator is presented to grasp the CO_2 emissions of structural concrete. And low-carbon technologies currently in use is introduced. Then the need for multi-cycle structural concrete with a circular economy is presented. Moreover, it is estimated that CO_2 emissions due to disasters in the use stage could be enormous. The carbon neutrality of structural concrete is not a risk but an opportunity for us.

Keywords: carbon neutrality; LCA; multi-cycle; disaster; ESG investments.

1 Introduction

In 2020, with the world in the midst of a pandemic, more than 100 countries and regions declared themselves carbon neutral by 2050. At the same time, humanity experienced severe restrictions on activity due to the corona lockdown and saw a 3% drop in global GDP in 2020. But this was accompanied by only a 7% reduction in CO_2 emissions. In other words, we simultaneously recognised the difficulty of achieving net zero CO_2 emissions by 2050. Achieving carbon neutrality requires cost and technological innovation.

Cement used in structural concrete accounts for 60% of all cement [1]. Therefore, the amount of CO_2 emitted by cement in structural concrete in a year is approximately 5% of the amount emitted by mankind. Concrete users will eventually have access to zero carbon materials, but it is not possible to wait until then. The supply chain is already demanding low carbon technologies that need to be addressed.

Indeed, low carbon concrete has been developed and put into practice by various organisations. However, the Life Cycle Assessment (LCA) of structural concrete shows that CO_2 is not only emitted during the production stage, but also during the use stage due to maintenance. Structural concrete, which is responsible for a large proportion of humanity's CO_2 emissions, has the potential for innovation. And we must recognise that this is not a risk for us, but a great opportunity [2].

2 CO_2 emissions in the supply chain of concrete structures

Figure 1 shows the construction supply chain according to the European standard EN15978. Below this is the classification of the construction

https://doi.org/10.2749/manchester.2024.0046
Distributed by structurae

In plain sight - Engineers, Engineering and Ethics

Dervilla Mitchell FREng FIAE FICE FIEI

Arup

Contact: Dervilla.Mitchell@arup.com

Abstract

Engineering is everywhere and underpins so much of what we expect and need in our daily lives, yet engineers are not generally prominent in society and are perhaps not valued for the role they play.

As Dervilla reaches the later stages of her career in Arup she is reflecting on what is it to be an Engineer, what is Engineering and how do we behave ethically than enables our profession (in the widest sense) to be valued and have a strong reputation in the public eye.

She is considering the changing perceptions of engineers, with a particular focus on the changes she has seen during her career; whether they be the way we work, the tools we use or the diversity in our workplaces.

She will highlight the challenges and opportunities we face and look in particular at some of the ethical dilemmas as we need to navigate in a world where climate change remains a challenge and increasing use of technology and data requires us to adapt and change at an ever-increasing pace.

Keywords: engineer, engineering, ethics, reputation, Arup

1 Introduction

Engineering is everywhere and underpins so much of what we expect and need in our daily lives, yet engineers are not generally prominent in society today and are perhaps not valued for the role they play.

Engineering is defined as

- the branch of science and technology concerned with the design, building, and use of engines, machines, and structures and
- the action of working artfully to bring something about.

This is perhaps a bit dry and based upon the engineers I know this definition does not capture the imaginative, creative and collaborative team players that I see working across our profession.

The word engineering comes from the Latin word *ingenium* which I am informed means innate quality particularly in mental power, and that has largely been my experience of engineers. They are frequently both clever and creative shaping the world around them. They are sometimes visionary, but all have the power to turn ideas into reality.

One of the most rewarding aspects of a career in Engineering is the breadth and variety of the role we can and do play. As Engineers we have the opportunity to deal with large scale challenges as well as looking at things in detail.

https://doi.org/10.2749/manchester.2024.0054
Distributed by structurae

The effect of horizontal loads caused by rapidly rising river water on the bearing capacity of masonry arch bridges

Philippe Van Bogaert, Hans De Backer

Civil Engineering Department, Ghent University, Belgium

Contact: philippe.vanbogaert@ugent.be

Abstract

Many masonry arch bridges have a culturally significant history, as well as aesthetic appeal, as the arch shape adds to a balanced appearance. Some of these arch bridges are crossing rivers, which have fast rising torrent water, especially after winter. The bridge piers are then exposed to horizontal loads from wave impact and debris. These loads can occur several times a year and are therefore not accidental. Numerical simulations of the case of Devil's Bridge (Bulgaria) demonstrate that nonlinear FE-analysis, on the basis of Mohr-Coulomb's law, is not entirely fit for this type of structure. Determining the shear strength, after cracking is inaccurate, because of the material's brittle character. The torrent wave causes such kind of failure, whereas first the debris impact causes local damage, the latter fostering the failure. Therefore, maintenance of stones and joints of such bridges is of capital importance.

Keywords: historic masonry arch bridge, river torrent load, debris, nonlinear FE-analysis, lateral load on bridge pier, shear in masonry.

1 Introduction

Arched masonry bridges are found in many countries of Western and Continental Europe. Some are dating from the Roman period. Most of these are considered as heritage structures and maintained through monumental care. However, the majority of masonry arched bridges date back from the 19^{th} and early 20^{th} century and are still serving well. Obviously, the construction methods implemented to build these bridges are outdated. Nevertheless, their history may be both culturally significant and have aesthetic value, since the arch shape appeals to the human soul and adds to a balanced appearance.

Apart from those which are seriously degraded, the load-carrying capacity of masonry arch bridges is satisfactory. This would imply regular checking of the condition of these bridges, carrying out maintenance and verifying their strength and stability.

A typical degradation of brickwork vaults consists of the spalling and subsequent failure of the intrados stone layer. This is mostly due to excessive vertical loads, combined with poor maintenance. However, resistance to vertical loads of masonry arch bridges seems to be controlled, verified and assessed adequately. Yet, apart from seismic effects and foundation's equilibrium, less attention has been given to the resistance to horizontal loads. An important type of horizontal loads on the infrastructure of masonry arch bridges is the effect of impact of river water.

One of the effects of climate change is river flooding, either by excessive rain or by melting of upstream ice from mountains. Such sudden torrents of small rivers happened in July 2021 in the Eastern part of Belgium and in the Eiffel region in

Efforts of Seismic Retrofit: The Future Challenge of Innoshima Bridge Beyond 40 Years of Service

Hongxin Wang, Takao Kaneda, Masahiro Nishitani, Yasuaki Kaneda

Honshu-Shikoku Bridge Expressway Co. Ltd, (HSBE), Japan

Contact: hongxin-wang@jb-honshi.co.jp

Abstract

Innoshima Bridge, which was opened for traffic in 1983, is a three-span, two-hinged stiffening truss girder suspension bridge with a center span of 770 meters, featuring a double-deck structure with the upper level for motor vehicles and the lower level for bicycles and pedestrians. In response to large-scale earthquakes, the bridge is required to have the performance that limits seismic damage to a minimum and enables a swift rehabilitation of its functionality. The results of the seismic performance evaluation revealed damage to various members in the bridge. Therefore, it is decided to conduct seismic retrofit to the damaged members, such as installation of viscous dampers to reduce the seismic forces, addition and replacement of the structures around the wind tongues, and some other reinforcements. This paper presents a report on the seismic performance verification and retrofit design of Innoshima Bridge.

Keywords: suspension bridge; double-deck structure; seismic performance verification; seismic retrofit design; viscous damper.

1 Introduction

Japan consists of four main islands and numerous surrounding islands. Two of the main islands, Honshu and Shikoku across Seto Inland Sea, are connected by Honshu-Shikoku Bridge Expressways, which consist of three routes, Kobe-Awaji-Naruto Expressway, Seto-Chuo Expressway and Nishi-Seto Expressway (Figure 1). Innoshima Bridge (spans: 250 m + 770 m + 250 m = 1,270 m) (Figure 2), opened to traffic in 1983, is the first suspension bridge of the Honshu-Shikoku Bridges on the Nishi-Seto Expressway, the westernmost route of Honshu-Shikoku Bridge Expressways. As shown in Figure 3, Innoshima Bridge is a 3-span, 2-hinged stiffening truss girder suspension bridge, featuring a double-deck structure (Figure 4) with the upper level for motor vehicles and the lower level for bicycles and pedestrians.

Two tower links are installed on each main tower location (at the side and center span), and two end links are installed on each anchorage location. One wind shoe and one wind tongue are installed at each main tower location (at the side and center span) and each anchorage location.

The seismic design of the bridge at the time of construction was based on the original seismic design code [1]. However, according to the latest findings, an inland near-field earthquake was not considered in this code, and there is a concern that a large-scale earthquake exceeding the original design seismic force would occur. In response to large-scale earthquakes, such as the anticipated Tonankai-Nankai earthquakes in the near future, the bridge is required to have the performance that limits seismic damage to a minimum and enables a swift rehabilitation of its functionality [2] as an important structure with no alternative route.

Global Trends in Bridge Collapse Incidents in 2023: an Analysis of Regional Patterns and Causative Factors

Paul Mullins

Jacobs, Kuala Lumpur, Malaysia

Contact: paulmullins@gmail.com

Abstract

Bridge collapses represent critical failures in infrastructure systems with significant implications for public safety, economic stability, and transportation networks. This paper presents an investigation into the occurrence of bridge collapse incidents worldwide during 2023. Drawing upon a dataset sourced from global news outlets, the study offers an analysis of regional trends and underlying causes, with a view to providing insights for design, construction, and maintenance practices. The study aggregates more than 170 incidents, enabling a reasonably detailed examination of the distribution of bridge collapses across different regions. The paper focuses on extracting statistical patterns and trends, revealing potential hotspots of collapse incidents that warrant further attention and preventive strategies. The findings underscore the urgency of adopting proactive measures to address structural vulnerabilities and systemic shortcomings, contributing to the overall resilience of transportation networks.

Keywords: bridge collapse, causative factors, infrastructure safety, scour, bridge engineering

1 Introduction

Bridges are generally important pieces of infrastructure, whether they be major crossings spanning hundreds of metres or simple footbridges linking remote communities. However, as is well understood, they are not infallible. Bridges collapse for a variety of reasons and when they do can be considerably disruptive, not only in terms of the immediate effects on human life but they can often lead to environmental and economic damage to communities.

This paper draws upon a dataset compiled from global news reports throughout 2023, sourced from various online portals. The dataset encompasses a total of 173 bridge collapses, spanning a spectrum of sizes and types, from simple pedestrian bridges linking communities in remote areas to substantial pieces of critical infrastructure.

The paper looks at the data to extract statistical patterns and trends before looking to some actions that could be implemented to minimise future collapses. Climate change and structural health monitoring are also discussed in the paper. Case studies for collapses which garnered significant media attention during 2023 have also been included.

2 Summary of the Data

2.1 Data Collection

The data for this study was collected through systematic monitoring of online news sources. This was set up to track and gather information on

https://doi.org/10.2749/manchester.2024.0075

Masonry arch bridges in the 21st century

Matthew Gilbert, Colin Smith, Serena Amodio
University of Sheffield, Sheffield, UK

Contact: m.gilbert@sheffield.ac.uk

Abstract

Masonry arch bridges have proved to be resilient, long-lasting structures, and continue to form a crucial part of the railway and regional highway networks of the UK and many other countries. Given this, and the comparatively low embodied carbon associated with natural stone as a building material, the masonry arch form looks set to once again become attractive to designers. However, some aspects of their behaviour remain poorly understood. This can unfortunately lead to existing bridges being needlessly strengthened (or even demolished and replaced), or, alternatively, being subjected to loading regimes that cause long-term damage. In this contribution key elements of the recently published CIRIA C800 guidance on the assessment of masonry arch bridges are highlighted, including how the presented advice may in future be applied in the design of new bridges.

Keywords: masonry; arch bridges; assessment; design.

1 Introduction

There are currently around one million masonry arch bridges in service around the world, with the majority being over a century old. These bridges are now carrying traffic that is significantly different to that anticipated by their builders. Masonry arch bridges incorporate one or more arched elements and have a wide range of construction details. Given the significant numbers of these bridges in use, it is crucial for bridge owners to manage them effectively, enabling them to direct limited maintenance budgets appropriately. A key aspect of this management involves gaining insights from periodic assessments of bridges.

In the mid-20th century, the MEXE assessment method was developed to evaluate the load carrying capacity of masonry arch bridges [1]. This method sought to ascertain service load capacity and encompassed both calculation-based and observational components. However, due to issues with the underpinning assumptions, the calculation-based aspect of the method [2], the observational component has arguably proved more valuable, albeit it does not provide a predictive capability. Shortcomings of the MEXE method have led to a decline in its usage in recent years, with the current UK assessment code for highway bridges [1] now specifying that the MEXE method is unsuitable for bridges with spans less than 5m or greater than 18m. Instead, limit analysis methods (following Heyman [3]) have become more prevalent. These methods determine the Ultimate Limit State (ULS) load, with a safety factor often subsequently applied to establish a Serviceability Limit State (SLS) load, due to the absence of widely accepted SLS criteria for masonry arch bridges.

Assessing a masonry arch bridge necessitates the availability of a competent engineer, who has access to effective assessment tools. However, two issues can adversely affect the accuracy of an assessment:

- A significant number of assessment engineers lack familiarity with masonry arch bridges and

Construction and Testing of a CFRP-prestressed Railway Bridge Prototype

Andreas Näsbom, Karel Thoma, Walter Kaufmann

ETH Zurich, Switzerland

Contact: naesbom@ibk.baug.ethz.ch

Abstract

This paper presents a new single-span railway bridge system, currently under development by the authors in cooperation with the Swiss Federal Railways and further partners, combining high-performance concrete, stainless reinforcing steel and CFRP prestressing for maximum durability. A significant milestone in the project was the successful construction and testing of a 6,5 x 1,7 m^2 prototype consisting of four pretensioned longitudinal girders; each prestressed with 12 Ø8,2 mm sand-coated CFRP rods. The paper discusses selected aspects of the sustainability of the novel material combination and the construction of the prototype. Furthermore, the structural behaviour of the prototype is analysed, focusing on its response under shear forces.

Keywords: sustainability; bridge engineering; precasting; CFRP-prestressing; pretensioning; stainless steel

1 Introduction

1.1 Motivation and Aim

If replacing existing rail infrastructure becomes necessary, (i) fast construction, (ii) durability and (iii) the ecological footprint of the new structure during its service life are critical. To advance in the first of these key aspects – aiming at minimising track closures to ensure efficient operation – the authors are currently developing a system for precast CFRP-prestressed concrete T-beam bridges in the span range of 2–10 m. The project is carried out in cooperation with several industrial and research partners (see acknowledgements). The basic concept is depicted in Figure 1 (a) and (b) [1, 2]. Together with non-corrosive and fatigue-resistant sand-coated CFRP rods (pretensioned and anchored via bond in the C80/95 high-performance concrete), stainless reinforcing steel ensures high durability and structural safety by providing sufficient deformation capacity. This study shows the construction and testing of a prototype of the proposed system.

1.2 Sustainability

In order to ensure that the system's benefits are not outweighed by a disproportionate environmental impact, a brief comparative life cycle analysis (LCA) between the proposed and an established design, looking only at the global warming potential (GWP), was conducted. The functional unit of the LCA is a bridge girder with 6 m span and 4,5 m width accommodating one railway track without edge girders. Both designs (see Figure 1 (b) and (c)) fulfil all serviceability, fatigue and ultimate limit state requirements; the prestressed system remains uncracked under service loads. The life cycle inventory [3] of both

https://doi.org/10.2749/manchester.2024.0090
Distributed by structurae

Ethical challenges and greenwashing – challenges for structural engineers

John Armitage

Ramboll, Southampton, UK

Contact: john.armitage@ramboll.co.uk

Abstract

In the face of the climate emergency, but also threats to biodiversity, and with exploitation of limited resources posing serious threats, it is easy to resort to 'greenwashing', noting small changes which have been provided when large changes are needed to even meet current commitments. However, many of the standard solutions to net zero, such as use of increased proportions of GGBS in concrete, are themselves constrained by limitations to availability of scarce resources.

This paper gives the author's personal response to these challenges, considering ways in which structural engineers can avoid just 'greenwashing', but instead aim to do good as well as just avoiding harm. Engineers must have excellent professionalism and competence, and strong ethics.

Keywords: Sustainability, climate, ethics

1 Introduction and challenge

Civil and structural engineering has a great potential to do good, but also to do harm. Herbert Hoover, President of the United States, was an accomplished engineer and wrote the following in 1954 (albeit in less inclusive language than today):

'*The great liability of the engineer compared to men of other professions is that his works are out in the open where all can see them. His acts, step by step, are in hard substance. He cannot bury his mistakes in the grave like the doctors. He cannot argue them into thin air or blame the judge like the lawyers. He cannot, like the architects, cover his failures with trees and vines. He cannot, like the politicians, screen his shortcomings by blaming his opponents and hope that the people will forget. The engineer simply cannot deny that he did it. If his works do not work, he is damned. That is the phantasmagoria that haunts his nights and dogs his days. He comes from the job at the end of the day resolved to calculate it again. He wakes in the night in a cold sweat and puts something on paper that looks silly in the morning. All day he shivers at the thought of the bugs which will inevitably appear to jolt its smooth consummation.*

On the other hand, unlike the doctor, his is not a life among the weak. Unlike the soldier, destruction is not his purpose. Unlike the lawyer, quarrels are not his daily bread. To the engineer falls the job of clothing the bare bones of science with life, comfort, and hope. No doubt as years go by people forget which engineer did it, even if they ever knew. Or some politician puts his name on it. Or they credit it to some promoter who used other people's money with which to finance it. But the engineer himself looks back at the unending stream of goodness which flows from his successes with satisfactions that few professions may know. And the verdict of his fellow professionals is all the accolade he wants.' [1]

This is quoted in full as he details the professional challenges faced so comprehensively, yet we now operate with far more awareness of climate and resource challenges, and visibility of how engineers' activities have shaped the 70 years since this was written. How should we respond?

https://doi.org/10.2749/manchester.2024.0099
Distributed by structurae

Data-driven and production-oriented tendering design using artificial intelligence

Linda Cusumano, Rasmus Rempling, Robert Jockwer

Chalmers University of Technology, Gothenburg, Sweden

Nilla Olsson

NCC Sweden AB, Malmoe, Sweden

Mats Granath

University of Gothenburg, Gothenburg, Sweden

Contact: linda.cusumano@chalmers.se

Abstract

Construction projects are facing an increase in requirements, making requirement management labour intense. Therefore, this research project explores possibilities to automate the requirement analysis in the bidding phase and link these requirements to verifications in the production phase. The first part of the research targets the requirement analysis and applies natural language processing techniques for automation possibilities. The second part of the research explores production data as a data-driven verification method and how the data can be used in knowledge feedback loops. The results show that applying natural language processing techniques for analysing construction project requirements is a possible step towards systematic requirements management. Furthermore, production data can be used as a knowledge base for quality improvement in construction companies.

Keywords: requirements; NLP; verifications; production-data; knowledge.

1 Introduction

Construction projects are experiencing increased regulatory and client requirements due to the industry's increased focus on sustainability [1]. Introducing new requirements can be challenging since the construction industry lacks systematic requirements management. The requirements found in tendering procurements in construction projects show problems such as openness to multiple interpretations, lack of relations between requirements, and requirements unnecessary prescribing design solutions [2]. There is also a lack of traceability and match with proper verifications and validation methods [3].

Today, the methods for analysing requirements are mainly manual, resulting in requirement management quickly getting overwhelming. Consequently, the construction industry tends to trust craftsmanship and gut feeling rather than

Specimen Design and Advanced Material Testing for 3D Printing Concretes

Elisabeth Radl, Marc Pfleger, Julian Karolyi, Markus Vill

University of Applied Sciences Vienna, Building and Design

Contact: marc-patrick.pfleger@fh-campuswien.ac.at

Abstract

This paper deals with the design of concrete samples for the material testing of 3D-printable concrete mixtures. Due to the rapid advancements and increasing pilot projects in the field of 3D printing in construction, it is of great importance to develop standards and design principles that allow a comparison of different material compositions in cast and 3D-printed specimen forms. Starting from general theoretical background of concrete 3D printing and over all characteristics of concrete objects which are built up by multiple material layers, typical issues are identified. From theoretical correlations with the properties of the currently common 3D printing processes, an orthotropic material behaviour can be derived.

Keywords: 3D concrete printing, test specimen, test setups, material testing

1 Introduction

Due to the increasing level of automation on construction sites, innovative construction methods are coming into focus. Additive manufacturing of concrete components in particular is gaining in importance. This technology enables the efficient production of concrete components without the use of elaborate formwork, which in turn can lead to material savings and thus to the responsible use of resources. Since various international research projects show that material efficient and therefore sustainable production of structural concrete components using additive manufacturing is possible, it is essential to elaborate standards and design principles allowing to compare different material admixtures in casted and 3D printed specimen shapes.

For the additive manufacturing of concrete components, various processes can be employed, distinguished by their operating principles. These can be categorized into selective binding, extrusion methods, shotcrete processes, and slipform methods. Among these, extrusion methods represent the most well-known and extensively developed techniques in 3D printing. These are printing processes in which a pre-mixed material, such as a specially formulated concrete, is pumped through a controllable nozzle, the extruder, and pressed to form strands.

Due to the manufacturing process, an additively manufactured test specimen cannot be assumed to have a homogeneous cross-section. In the multi-layer extrusion process, individual strands of material are placed on top of each other in layers to create a three-dimensional object. Accordingly, joints or contact surfaces form between the individual layers, which are assumed to have a negative effect on the strength properties compared to a homogeneous body. In principle, a distinction can be made between two types of joints. On the one hand, there are horizontal contact areas between superimposed printing strands and, on the other hand, vertical contact areas between two adjacent printing strands.

https://doi.org/10.2749/manchester.2024.0115
Distributed by structurae

Shifting the Density Discourse: The Future of Soft Density

Audrey-Frédérique Lavoie (MPA), Kely Galopoulou (MSc), Zehra Lara Tekbas (MSc)

UCL Sustainability Lab, UCL School of Management, University College London (London, UK)

Contact: audrey-frederique.lavoie.22@ucl.ac.uk

Abstract

This study by UCL Sustainability Lab, Mott MacDonald, and the IStructE explores the factors influencing the sustainability of the built environment in its urban ecosystem. The research extends beyond structural engineering to a holistic view of sustainable urban development. With more than half of the global population living in urban areas, effective sustainable urban densification strategies must be deployed to address multiple climate and housing challenges. This project aims to bridge disciplinary gaps in the built environment sector, identify characteristics of sustainable urban ecosystems, and establish a guide for integrating urban development with sustainability. Focusing on transportation, green spaces, and carbon emissions, the research suggests soft-density strategies as optimal, highlighting the necessity of a multidisciplinary, collaborative approach that avoids one-size-fits-all solutions.

Keywords: *urban development; high-rise buildings; carbon footprint; urban densification; transportation; sustainability; soft density.*

1 Introduction

Today, 55 percent of the world's population lives in urban areas, expected to reach 68 percent of a growing population approaching ten billion by 2050 [1]. As cities grow, their expansion and complexity [2], especially in the context of climate change and the built environment accounting for more than 40 percent of global emissions [3], become critical with the sustainable implementation of urban density being the principal challenge. The question is not whether density is bad or good, but rather at what price and how. Planners and decision-makers need to focus on optimum density for each location while considering the impact on humans and the global environment [4]. Urban density has become a highly debated topic [5, 6] and exacerbated by the coronavirus pandemic due to social isolation, intensified by the lack of spaces in dense areas. Planners, developers, and politicians need to consider what higher density should look like and how it can be as sustainable possible to achieve our climate ambitions.

1.1 Concepts

Sustainable Built Environment Ecosystems

Sustainability focuses on providing an environmentally friendly, cost-effective and just life without compromising future generations' ability to fulfil their own needs [7, 8, 9, 10]. Al-Kodmany's framework, the '3 Ps' (people, profit, planet) was used in the bibliometric analysis, literature review and case studies [7]. It organises issues related to tall building development around sustainability, from structural systems and materials to in-outdoor spaces relationships and urban ecosystem integration.

Density

Urban density could be defined as the population-to-area ratio. The OECD considers high urban density as over 1,500 inhabitants per km^2 [11]. In the United Kingdom, density is often measured differently by dwellings per hectare. While the UK is the third most densely populated in Europe, it has fewer people per dwelling (2.3) compared with the rest of Europe (e.g., Spain 3; Ireland 2.9). Density does not just imply the urban form; in some cases, high-density developments were used to support tall buildings proposals representing only one possible high-density model. While tall

https://doi.org/10.2749/manchester.2024.0124
Distributed by structurae

Carbon Emissions, Lifespan and Circularity Interaction Strategies

Dr David Collings

ARCADIS, Guildford, UK

Contact: david.collings@arcadis.com

Abstract

Capital and whole life carbon emissions; circularity, waste and reuse; useful lifespan; net zero and other sustainability issues are often assessed independently. However, there is a significant interaction between these sustainability issues. In this paper the interactions are highlighted and good and poor strategies to combining them are outlined. Examples from published sources are used to illustrate the interactions and strategies. The paper is based on recent research by the author and others in industry and academia. The carbon-circularity- life interaction is primarily focused on bridges and transportation infrastructure. The paper highlights the key differences between infrastructure and building structures, on which much of the current circularity, waste and reuse considerations are aimed.

Keywords: Carbon emissions; circularity; life span.

1 Introduction

Capital and whole life carbon emissions; circularity, waste, reuse; useful lifespan; net zero and other sustainability issues are often assessed independently. However, there is a significant interaction between these sustainability issues. In this paper the interactions are highlighted and good and poor strategies to combining them are outlined.

1.1 Definitions

The term carbon is used in this paper as a shorthand for the carbon dioxide equivalent of all greenhouse gases (the global warming potential) measured in tonnes (tCO2e). The term capital carbon [1,2] is the combined carbon emissions at product and construction stage associated with the creation of the asset, it accords with life cycle stage A using EN 15978 [3]. Operational Carbon is the emissions associated with the operation and maintenance of the asset (EN 15978 stage B) Whole life carbon combines both capital and operational carbon together with any end-of-life carbon (EN 15978 stages C, D). Circularity is where, assets and materials are kept in circulation through repair, maintenance, reuse, refurbishment and recycling for as long as possible.

2 Carbon Footprint

To limit carbon emissions and then reduce them we need to understand where and how much we use now.

2.1 Capital Carbon

Estimates of the carbon footprints of infrastructure [1] bridges [2,4,5] and buildings [6] are well documented. In Figure 1 below, the total capital carbon of transport infrastructure is plotted versus the total asset length (data plotted on log-log axis to allow the full range of the data to be viewed). The trend shows an increased carbon with asset

https://doi.org/10.2749/manchester.2024.0133
Distributed by structurae

Inspection and retrofitting of Danube bridge – Ruse – Giurgiu – challenges and innovative approaches

Alexander Jiponov

University of Architecture, Civil engineering and Geodesy, Sofia, Bulgaria

Contact: ajiponov@gmail.com, ajiponov_fte@uacg.bg

Abstract

The current article would summarize the activities related with the inspection and retrofitting of a bridge between Bulgaria and Romania across the Danube river, which connects the cities of Ruse (Bulgaria) and Giurgui (Romania).

The structure is built in the period 1952 - 1954. The main part of the bridge is a steel double deck truss with 160m and 80m spans and it combines 2 types of transport - road and railway traffic. There is a moving part of the superstructure which could be lifted when there is a high-water level, and the ships has to pass. The approaches part consists of steel 2T beams united with reinforced concrete prefab elements. The foundation type used for that structure is caissons. The total length of the bridge is approximately 2,2km. There is a combination of issues which compromise the road deck - heavy and intense traffic, poor maintenance, sultry weather conditions and that leads to the need of repair and rehabilitation of the bridge. Some challenges and new approaches would be described in the following paper.

Keywords: Bridge retrofitting, Inspection methods, Digital twin.

1 Introduction

The Danube Bridge also known as the "Friendship Bridge" is a steel bridge over the Danube River connecting the Bulgarian bank to the south with the Romanian bank to the north and the cities of Ruse and Giurgiu respectively. It is one of only two bridges connecting Romania and Bulgaria, the other one being the "New Europe Bridge" between the cities of Vidin and Calafat Figure 1.

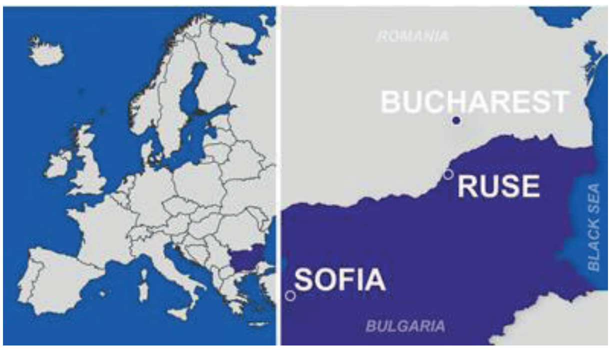

Figure 1. Location of the bridge

The bridge was built according to a Soviet project and was put into exploitation in 1954. Since the fall of the communist regimes in both countries, the bridge got the more functional name of "Danube bridge". The structure is a double deck steel truss – upper level for road traffic and pedestrians and lower level with a one-track railway line. The central part of the bridge is mobile and can be lifted for oversized boats passage.

https://doi.org/10.2749/manchester.2024.0139
Distributed by structurae

Proposal for cable replacement method incorporating arch structure in aging cable-stayed bridges

Kazuhiro Miyachi, Masato Tonegawa, Shota Nagasawa

Tokyo Denki University, Saitama, Japan

Contact:miyachi@g.dendai.ac.jp

Abstract

This study introduces an innovative cable replacement method to address corrosion on an aged cable-stayed bridge with an added arch structure. Through cable influence line analysis, strategies were explored to minimize structural impact during replacement in side spans and central span. As a result, it has been confirmed that the allowable stress of the cables at the crane installation position is within acceptable limits for all cases, and even in the most the highest stress is reduced to about 90 percent. Additionally, strengthening replaced cables or using auxiliary cables during outer cable replacement offer potential for a complete cable replacement. The study also examines the process of erecting an arch rib over the sea, providing a solution for mitigating tension in corroded or broken cables. The proposed cable replacement procedure suggests processes for removal and installation, potentially extending the lifespan of deteriorated cable-stayed bridges.

Keywords: cable-supported bridges; corrosion; breakage; reconstruction method; cable-stayed arch bridges.

1 Introduction

In Japan, the aging of established social infrastructure is rapidly progressing. According to the forecast of infrastructure aging by the Ministry of Land, Infrastructure, Transport and Tourism from 2018 to 2033, the percentage of facilities among the 720,000 road bridges exceeding 50 years since construction is expected to increase from approximately 25% to about 63% [1]. The lifespan of bridges varies based on structure, materials, and environmental factors, generally around 50 years. Consequently, contemplating the replacement of approximately 40% of the bridges is imperative, requiring substantial investments in time, funds, and human resources.

Cable-supported bridges such as cable-stayed bridges and suspension bridges face severe corrosion and breakage issues in their cables, with reported collapse incidents [2,3,4]. The cable dehumidification system [5], a corrosion prevention measure, is applicable only to large bridges, leaving preventive maintenance challenges for small to medium-sized suspension bridges unresolved.

To address these challenges, previous study proposes a solution by combining arch structures with aging cable-stayed bridges to enhance longevity and facilitate maintenance. The introduction of arch structures to aging cable-stayed bridges significantly reduces axial forces, bending moments on the main girder, tension in the cables, and bridge deflection under basic design loads. Furthermore, the inclusion of arch structures triples the ultimate strength compared to the original cable-stayed bridge. The aesthetic

https://doi.org/10.2749/manchester.2024.0148

Unified Explanation of Cracks for Long-Span Prestressed Concrete Box Girder Bridge Using Spatial Lattice Grid Model

Hao Zhang, Wei Dou

Anhui Transport Consulting & Design Institute Co., Ltd., Hefei, China

Dong Xu, Qinlong Jia

Tongji University, Shanghai, China

Contact:2210388@tongji.edu.cn

Abstract

Sustained excessive deflection is a widespread problem of long-span prestressed concrete box girder bridges. Meanwhile, various cracks are widely present in such bridges. However, some cracks are not interpretable according to traditional beam element model. In this paper, a refined finite element model called the spatial lattice grid model (SLGM), developed by the authors, which fully considers the three-dimensional effects of the box girder, is used to conduct a comprehensive analysis of the cracking causes of a long-span bridge having detailed inspection data. The analysis includes cracks that cannot be accurately or even cannot be explained by traditional beam element model. For this research, a unified identification and explanation of all structural cracks discovered during bridge inspection is achieved only using one model. The methodology presented in this paper will lay the foundation for subsequent research on the sustained excessive deflection problem.

Keywords: Concrete box girder bridge; Excessive deflection; Crack identification; Spatial lattice grid model.

1 Introduction

Due to excellent mechanical properties and economic efficiency, long-span prestressed concrete box girder bridges are widely used in bridges with spans ranging from 100 to 300 meters. However, the sustained excessive deflection phenomenon is the main problem faced by such bridges. A typical case is the Koror-Babeldaob Bridge [1] located in the Republic of Palau, which has a 240m main span and experienced 1.54m of deflection during the 18-year period from 1978 to 1996 and collapsed after only 3 months of strengthening. In recent years, due to the lag in construction time, China has also begun to encounter many similar deflection problems [2-4]. Unfortunately, despite the numerous research efforts [5-8] that have been made on this issue, no definitive conclusions have yet been reached.

A noteworthy observation is that cracking issues often coincide with excessive deflection in bridges, and the forms of cracks exhibit a diverse range. The impact of cracking on structural performance encompasses two main aspects: 1) diminishing structural stiffness, including flexural and shear stiffness; 2) compromising the structural durability, leading to material degradation. This can result in

https://doi.org/10.2749/manchester.2024.0156
Distributed by structurae

Evaluation of the behavior of old beam-plate bridges

Hans De Backer, Amelie Outtier, Muhammad Farjad Sami

Ghent University, Ghent Belgium

Contact: Hans.DeBacker@UGent.be

Abstract

In this paper, the case study of a railway bridge in Antwerp, Belgium will be performed. This bridge is constructed using precambered steel-concrete girders, also known as preflex beams. This was the standard solution for railway bridges at the time of construction, namely the end of the 1960s. Nowadays, bridges of this kind have been in use for more than fifty years and suffer different types of deterioration. For some bridges, longitudinal cracks have been found along the length of the precambered girders, which is also the case for the bridge considered here. To be able to get a better understanding of the state of the bridge using modern guidelines, a detailed 3D finite element model will be made, based on the original design notes dating from the 1960s. With this model, the compliance of the bridge with current guidelines, namely the Eurocode, will be verified. Furthermore, the results will be compared with reality since a detailed site investigation and inspection of the bridge have been carried out. The extremely deteriorated state of the bridge is discussed in detail.

Keywords: existing bridge, concrete beams, preflex, deterioration, monitoring, inspection.

1 Introduction

In Belgium, the standard solution for railway bridges consists of precambered steel-concrete girders, also known as preflex beams. Many of these bridges have been in use for more than fifty years and suffer different types of deterioration. For some railway bridges, longitudinal cracks have been found along the length of the precambered girders. Due to the high number of such bridges and the large impact on overall mobility of the retrofitting of such infrastructure, a better understanding of their state using modern guidelines is needed.

The case study of a railway bridge constructed in 1969 crossing the ringway around Antwerp will be used to conduct this research. In recent years, the state of the bridge has deteriorated, leading to cracks and crumbling concrete in several places. The beginning of the deterioration is not known, but it started between 5 and 15 years ago. Several inspections have taken place which show that the most damage occurs in bridge decks B and C. In 2022, an engineering firm specializing in research and consulting related to existing concrete structures, SANACON, performed an exploratory concrete investigation on the preflex beams of the bridge [1]. The conclusion of this investigation was that the crack formation could not be linked to durability issues but must be linked to a structural deficiency.

In the following of this master's dissertation, bridge deck C will be discussed further, and the cause of the cracks will be investigated. A detailed 3D finite element model will be made, based on the original design notes dating from the 1960s. With this

Structural Assessment of the M6 Bromford Viaduct Against Ground Movements

Thomas Wood, Christos Mitsarakis, Stuart Moore

Mott MacDonald, London, UK

Contact: Tom.Wood@mottmac.com

Abstract

As part of the HS2 Phase One project, geotechnical and structural assessments were performed by Balfour Beatty VINCI and their designers Mott MacDonald – Systra DJV in engagement with National Highways to demonstrate that the existing M6 Bromford Viaduct can withstand the effects of ground movement from the HS2 Bromford Tunnel. Initially, a linear elastic analysis indicated the need for extensive strengthening. After an in-situ concrete compressive strength testing scheme, a refined assessment was performed employing advanced non-linear analysis and structural verifications, including consideration of progressive development of cracking, non-linear soil structure interaction, and a hybrid methodology for assessing the capacity of reinforced concrete pile caps. This paper discusses how the refined assessment methodology exploited the existing structure's available capacity reserves and eliminated the need for extensive strengthening works.

Keywords: Structural assessment; reinforced concrete; non-linear analysis; settlement; pile caps; concrete cracking; bridge strengthening

1 Introduction

1.1 Background

As part of the HS2 Phase One project, Balfour Beatty VINCI and their designers, Mott MacDonald – Systra DJV, were instructed by HS2 to perform a Phase 3 Potential Impact Assessment (PIA) of the National Highway's (NH) M6 Bromford Viaduct. The purpose of this assessment was to assess the effects of ground movements on the viaduct due to the construction of the proposed twin-bore HS2 Bromford Tunnel, which crosses under the viaduct at skew as it approaches Birmingham.

The geotechnical assessment estimated the ground movements resulting from the completion of the first and second tunnel bores. Following an optimisation of the tunnel alignment and application of modern tunnelling techniques, the maximum greenfield foundation settlements were estimated to range between zero and 14mm. Preliminary analysis concluded that settlements less than 5mm had negligible effects on the viaduct and therefore further structural assessment was required only for settlements between 5mm and 14mm. The portion of the viaduct experiencing this range of settlements comprised of 34 piers along a length of approximately 550m, which is hereinafter referred to as the zone of influence (ZOI).

1.2 Description of structure

M6 Bromford Viaduct is a 4.4km long bridge constructed circa 1968-1972 with the typical span (between expansion joints) of 15,164m within the ZOI. The steel-concrete composite superstructure comprises longitudinal universal steel girders with an in-situ reinforced concrete deck slab. The longitudinal steel girders are simply supported on sliding steel bearings, which are supported on reinforced concrete piers (bents) comprised of a reinforced concrete crossbeam supported on two, three or four reinforced concrete columns. As the bearings are 'free sliding', the longitudinal and transverse restraint of the deck is achieved by the

https://doi.org/10.2749/manchester.2024.0173
Distributed by structurae

REHABILITATION OF THE OUTEIRO BRIDGE WITH EMERGENCY STRENGTHENING OF THE SUPERSTRUCTURE DAMAGED BY BARGES IMPACT

Pedro Afonso de Oliveira Almeida

Dr. Civil Engineering, Structures, Professor of the Polytechnic School of USP, CEO of LSE

Contact:palmeida@usp.br

Adler Almeida Silveira (CEO) and Leila Martins Pamplona

Secretary of State for Transport of Pará - SETRAN

Contact:leilanmartins@yahoo.com.br

Evelly Beatriz da Paixão Silva

Technological Research Institute – IPT, Engineer Civil of LSE Infra

Contact: evelly.beatriz@lsetech.com.br

Abstract

The collapse of one of the supports of the central section of the bridge compromised the overall stability of the deck, leading to the immediate shutdown of its operation on January 16, 2022. Therefore, the occurrence of the collapse of the AP4 support after 37 years of operation led to the immediate isolation of the population of Outeiro Island, which today has 80,000 inhabitants, who use the bridge daily, with a volume of motor vehicles in the order of 4,500 per day. Therefore, as a premise, both the emergency strengthening and retrofitting of the Outeiro I Bridge were carried out with the partial operation. Considered an urban bridge over the Maguary Canal where there are large shipyards and docking ports for barges convoy that transit on the Belém-Manaus waterway route, the solution considered the duplication of the navigation channel with the construction of the cable-stayed bridge on the central section, making it safe for both heavy vehicle traffic and navigation with 2 navigation channels with a width of 80m and 100m and 12m height.

Keywords: Evaluation of the collapse structure emergency strengthening and retrofitting project of the damaged superstructure with revitalization of the Outeiro Bridge 1.

1 Introduction

The Outeiro I Bridge was the first fixed crossing between the mainland and the island of Caratateua (Outeiro), built in a steel girder the Maguary Canal with 360m in length and 11,40m width, in 1986, with 37 years of operation, in the Metropolitan Region of Belém, Pará, Brazil. The population of Outeiro Island has grown over the 37 years, reaching today *80.000* inhabitants, who depend on the bridge daily, leading to a volume of motor vehicles in the order of 4.500 per day, in addition to motorcycles, bicycles and pedestrians.

The Outeiro I Bridge is, therefore, an urban bridge and crosses the Maguary Canal to access the industrial area of Belém, where there are large shipyards and ports for convoys of barges that transit the Belém-Manaus waterway route, with typical barges of 18,0m wide (beam) by 90,0m long coupled to pushers of up to 15,0m in length.

The state of emergency was installed on the morning of January 17, 2022, when the collapse of one of the supports of the central section of the 180,0m long bridge occurred. The collapse of the AP4 support was due to the frequent impacts of barges transiting the Maguary Canal, leading to the

https://doi.org/10.2749/manchester.2024.0182
Distributed by structurae

Development and validation of a train-bridge interaction model

Sharon Deceuninck, Harikrishnan Venugopal, Mia Loccufier, Wim De Waele, Kris Hectors, Hans De Backer

Civil Engineering Department, Ghent University, Belgium

Contact: sharon.deceuninck@ugent.be

Abstract

In this paper, a train-bridge interaction model is presented to simulate the behaviour of a bridge during the passage of a train. Two modelling methods are compared: the direct integration method (DIM) and the intersystem iteration method (ISIM). First, a simply supported bridge subjected to a moving spring-mass is modelled using both methods and validated with an analytical solution. Subsequently, incorporating damping into the model adds an extra layer of complexity, rendering the search for analytical solutions unfeasible. The validation of the more complex models is accomplished by comparing them to similar simulations documented in the existing literature. The focus lies on finding an efficient model that could be used by engineers to assess the structural condition of railway bridges. The dynamic interaction model gives a more accurate prediction of the behaviour of the bridge under the passage of the train than including the dynamic amplification factor (DAF) in the static calculation.

Keywords: wheel-rail interaction, direct integration method, intersystem iteration method.

1 Introduction

The European project 'Sustainable bridges' [1] highlighted how sustainability is becoming more important in the (re)construction of railway bridges. The goal is to have a modal shift in the use of transport and stimulate people to prefer public transport or the bicycle instead of the car. Therefore, public transport options must become more attractive. Especially for rail transport, the capacity and the number of trains should be increased. The focus of the European project lies on Railway bridges wherefore it is not directly possible to enlarge the railway network, so the quantity of train passages will be enlarged. By increasing the capacity of the trains, the axle loads will become larger and result in a shorter end-of-life span of the railway bridges. To guarantee the safety of the design, measurements and safe life predictions of the railway bridges must be performed. To reduce the uncertainty on fatigue life predictions, more accurate structural assessments are required. Typical evaluations are based on quasi-static stress calculations enlarged with a dynamic amplification factor. With this method stresses due to local dynamic modes are ignored resulting in underestimation of the stress or in other cases the DAF is overly conservative. Hence stress calculations that account for the actual structural dynamics would lead to more accurate fatigue life estimates.

2 Importance of a dynamic interaction model

The research of dynamic wheel-rail interaction models dates back to 1949 when Willis and Stokes [2] perform real experiments of a moving mass over a simply supported beam. In their study, they compared the vertical deflection at midspan of the beam, for various velocities V of the mass, with the vertical deflection caused by a beam loaded with a static point load the midspan. Figure 1 illustrates the vertical deflection at midspan observed in the experiment.

https://doi.org/10.2749/manchester.2024.0190
Distributed by structurae

Towards Cyber-Secure and Hazard-Resilient Smart Civil Structures

Miguel Cid Montoya, Carlos Rubio-Medrano

Texas A&M University - Corpus Christi, Corpus Christi, Texas, USA

Ahsan Kareem

University of Notre Dame, Notre Dame, Indiana, USA

Contact: miguel.cidmontoya@tamucc.edu

Abstract

The accelerated growth of urban areas in the last decades has led to an unprecedented increase in the construction of wind-sensitive structures, e.g., long-span bridges, tall buildings, wind turbines, and solar trackers. To effectively control undesired wind- and earthquake-induced responses, a plethora of operational technology and cyber-physical systems have been introduced, including supervisory control and data acquisition systems, programmable logic controllers, and remote terminal units. All these systems are potential targets for cyberattacks and have already been attacked in other sectors, including energy, industry, education, and health. This study analyzes this threat to critical infrastructure, quantifies its potential damage, and develops possible countermeasures and cyber-defenses so the structural engineering community can effectively address this emerging challenge.

Keywords: Cybersecurity; Smart structures; Active structural control; Wind-induced responses; Operational technology; Cyber-physical systems; Cyber-secure aero-structural design.

1 Introduction

Controlling wind- and earthquake-induced responses is a challenging and fundamental step in designing structures sensitive to natural hazards, such as tall buildings, long-span bridges, wind turbines, and solar trackers. Design modifications and countermeasures, such as shape, stiffness, and mass tailoring, as well as passive control devices, such as dampers, have been shown to be effective in the past. However, more demanding design scenarios involving ambitious contemporary designs and climate adaptation require adopting further actions. As a result, smart structures equipped with active and semi-active mass dampers, flaps, dynamic facades, suction and jet systems, and active tendons and bracing systems are gaining momentum to counteract potentially disastrous earthquake or wind actions adequately [1]. As shown in Figure 1, these active devices are part of more complex systems involving Operational Technology (OT) and Cyber-Physical Systems (CPS), which include Industrial Control Systems (ICS) that are composed of Supervisory Control and Data Acquisition systems (SCADA), Programmable Logic Controllers (PCLs), and Remote Terminal Units (RTU). All these systems are under the threat of cyberattacks, as has already happened in other sectors, such as energy [2],

https://doi.org/10.2749/manchester.2024.0199
Distributed by structurae

Effect of Initial Web Out-of-Flatness Imperfections on the Shear Strength of Low-Frequency Sinusoidal Plate Girders

Parfait M. Masungi, Maria E.M. Garlock

Princeton University, Princeton, NJ, USA

Spencer E. Quiel

Lehigh University, Bethlehem, PA, USA

Contact: pmasungi@pricnceton.edu

Abstract

Slender steel plate girders with deep webs provide flexural and shear strength to resist large loads. However, under shearing forces, web plates are susceptible to shear buckling. During the forming and fabrication of plate girders, initial out-of-flatness imperfections on the web plate are introduced and have demonstrated to reduce the shear buckling strength. Existing measures to enhance the shear buckling strength and improve the behavior of flat steel plate girders include welded stiffeners or corrugated web plate profiling. These methods introduce practical and fabrication challenges as well as increased labor and material for fabrication. Therefore, to overcome these challenges and improve the performance of steel plate girders, the authors propose an alternative to enhance the shear buckling strength of thin steel plates by imposing a low-frequency sinusoid (LFS) shape along the web's longitudinal axis. This paper evaluates the effect of initial web out-of-flatness imperfections on the shear strength and behavior of plate girders fabricated with LFS webs. Additionally, comparisons with numerically developed LFS plate girder specimens are provided. Overall, this work demonstrates that LFS webs can enhance the shear strength, design, efficiency, and economy of plate girders.

Keywords: steel; shear buckling; low-frequency sinusoidal web; bridges; finite element; plate girders, shear strength

1 Introduction

Welded steel plate girders with flat slender webs bounded by a top and bottom flange have been used for many years in the construction and design of bridges. Plate girders with slender webs provide resistance to large shear forces over short and long-span longitudinal lengths [1]. However, when subjected to shearing forces, slender webs are limited and susceptible to shear buckling failure. Furthermore, the shear strength of slender webs can decrease due to inevitable geometric web out-of-plane (out-of-flatness) imperfections that develop during fabrication and erection from the forming, welding, and assembly process [2]. To prevent shear buckling and enhance the shear strength of slender webs in the design and construction of plate girders, transverse stiffeners are welded to the web and flanges as shown in Figure 1(a) [3]. Also, corrugated webs with trapezoidal, triangular, or sinusoidal geometries as shown in Figure 1(c) have been utilized to enhance the shear strength of slender webs. Even though the use of transverse stiffeners or corrugated webs provides increases in the shear strength, these enhancement strategies have adverse impacts

https://doi.org/10.2749/manchester.2024.0208
Distributed by structurae

Developing computational design techniques to meet the increasing demand for more complex and sustainable bridges in Southeast Asia.

Mike Tapley

Mott MacDonald, Liverpool, UK

Contact:mike.tapley@mottmac.com

Abstract

The economic growth being seen in Southeast Asia is driving a significant investment in infrastructure, particularly in the major cities of the region. Constructing elevated highways and railways in an already congested urban environment requires innovative solutions, adopting prefabricated modular construction techniques to form curved/longer span bridges and viaducts.

The form of these bridges challenges the engineer, but the adoption of computational design techniques has granted the designer a key tool which permits agility in determining the arrangement while simplifying the approach to optimisation.

Computational design and prefabrication are closely aligned with the drive for sustainability in construction. Large sections of the bridges are fabricated in a factory or workshop based on the same 3-D model prepared for delivery of the design. The efficient use of materials and resources becomes intrinsic to the design process in finding the most suitable form and geometry. The manufacturing process leads to less site-based plant and a smaller workforce, working in a safer environment.

Keywords: computational design, prefabrication, sustainable solutions.

1 Introduction

Infrastructure in Southeast Asia continues to grow at a rapid rate. Urbanisation and the need for rail and road links between major cities together with increasing congestion within these cities, are driving the need for major viaducts and longer span bridges across the region.

Viaducts have traditionally been constructed using precast beams with the deck being cast in situ. This form of construction works well in a rural environment where viaduct is straight, and the large beams can be handled and placed without impacting the local residents. In a congested city, the alignment is likely to be curved and the handling of long bridge beams far more challenging. Consequently, alternative approaches using segments rather than beams have been adopted, but this change comes with challenges as a segmental bridge requires different skill sets for both the designer and the contractor.

With there being more river crossings and sea crossings for new road and rail links, the need for long span bridges has risen significantly in Southeast Asia, with clients frequently requiring "landmark" structures that form a focal point to developments and infrastructure schemes. The complexity of such structures has to be addressed by the designer, who needs to satisfy the client with an elegant and aesthetically interesting bridge, while also meeting the demand for structural efficiency.

Computational design provides the designer with the tools to review a number of options in a small period of time and to quickly develop an optimised solution for both viaducts and long span bridges. It also provides the design engineer with the agility to

https://doi.org/10.2749/manchester.2024.0218
Distributed by structurae

Additively Constructed Seismically Protected System for Bridge Infrastructure

Islam M. Mantawy, Anthony Mackin, Jenna Migliorino, Hamdy Farhoud

Rowan University, Glassboro, NJ, USA

Contact: mantawy@rowan.edu

Abstract

Conventional design for bridges in seismic-prone areas relies on ductility concept by concentrating the damage at columns' ends. This approach is adequate for life safety; however, bridge columns exhibit significant damage and residual deformations resulting in expensive repairs or need for full replacement. Several seismic protective systems were developed over the last few decades to minimize the damage and enable repair after strong earthquakes like rocking systems, dampers, and seismic isolation systems. This paper proposes an innovative system that integrates several seismic protective concepts to achieve self-repair and deconstruction through additive construction. In this proposed system, protected elements such as bridge bent caps, columns and footings are additively constructed. In addition, the columns are designed to rock at interfaces between the columns and bent cap/footing and external elements are added to dissipate energy to promote resiliency.

Keywords: accelerated bridge construction, seismic, repair, deconstruction, additive construction.

1 Introduction

Bridge design concepts in seismic-prone areas have been in place to ensure life safety by concentrating the damage at plastic hinges at beam/footing column connection with sufficient ductility. However, these design concepts do not account for functional recovery. Successful functional recovery boosts the economy, requires minimum to zero recovery time (rapidity), and achieves sustainability goals.

Resilience is defined as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. Resilience is assessed using 4R-Methodology including robustness, rapidity, redundancy, and resourcefulness, as shown in Figure 1-a. Emerging technologies such as accelerated repair, hazard protective systems (HPS), self-repairing structure, accelerated upgrade and additive construction, and machine learning based structural health prediction (ML-SHM). Hazard protective systems such as seismic isolation and low damage structures can reduce functionality losses and increase robustness as depicted in Figure 1-b. Finally, Self-repairing structures which backup structures systems that engage at higher hazard intensity can minimize functionality loss and reduce downtime (rapidity) as depicted on Figure 1-c. Finally, ML-SHM can enhance resilience by reducing impeding factors caused by mobilizing equipment, inspection crew, and in-house structural assessment that may lead to shorter

https://doi.org/10.2749/manchester.2024.0227
Distributed by structurae

The New Pooley Bridge – Reconnecting a Community

Héctor Beade-Pereda, Laura Langridge

Knight Architects, London, UK

Contact: l.langridge@knightarchitects.co.uk

Abstract

The new stainless steel arch bridge for Pooley Bridge replaces a 250-year-old historic structure in a UNESCO World Heritage Site lost to flooding in 2015. The designers balanced key project constraints and community desires through the design process including an extensive public stakeholder engagement process. Resilience, durability, transparency in the landscape and speed of construction were all raised as critical, and the resulting design balances these aspects with an efficient and novel design that achieves a good balance of carbon cost to value.

Keywords: Resilience; stainless steel; arch; replacement bridge; community engagement; design for climate change.

1 Introduction

The village of Pooley Bridge is the north-eastern gate into the Lake District National Park, a UNESCO World Heritage Site with a uniquely beautiful landscape in north-west England. The village provided a crossing over the River Eamont for more than 250 years through a Grade-II listed 3-span stone arch bridge, built in 1764, which served as a critical link in the daily life of the area. The historic Pooley Bridge was not only important as a functional structure but was also a source of identity and pride for the community of Pooley Bridge – which owes its name to the river crossing.

In December 2015, Storm Desmond brought a 1 in 435-year flood, causing significant damage to the area and leading to scour beneath the river piers and to the ultimate collapse of the entire structure. This was a devastating loss to the community and their sense of identity. The shock after its abrupt removal was partially relieved by the installation of a temporary bridge three months later to avoid a 16km detour. However, it did not address the extraordinary context, and its ongoing presence was also a daily reminder of loss and vulnerability.

Figure 1. The Historic Pooley Bridge before it was washed away during the flooding in 2015

2 Design Process

2.1 The challenge

Following a tender, bridge specialists Knight Architects, in collaboration with Mott MacDonald, were appointed by Cumbria County Council (CCC) in mid-2017 for the concept design of a new bridge

Nonlinear aerostatic stability of a curved 275-m span suspension footbridge between Spain and Portugal

Miguel Cid Montoya

Texas A&M University – Corpus Christi, Corpus Christi, TX, USA

Juan Quintela, Santiago Hernández, José Ángel Jurado

Universidad de La Coruña, La Coruña, Galicia, España

Contact: miguel.cidmontoya@tamucc.edu

Abstract

This study reports the nonlinear aerostatic stability studies carried out for a suspension footbridge with a curved deck spanning 275 meters over the Miño River between Spain and Portugal. The footbridge's aerostatic performance is controlled by its highly aesthetic but complex three-dimensional configuration, the high slenderness of the deck, the construction process, and the aerodynamic characteristics of the triangular 4.5-meter-wide bluff deck cross-section, which demands a detailed aerodynamic study. The analysis is conducted using a nonlinear modal-based method recently developed by the authors. The deck's rotation is driven not only by the aerodynamic moment-induced rotation but also by the drag-induced rotation due to the configuration of the cable supporting system and, very significantly, by the lift-induced rotation due to the deck's curvature.

Keywords: footbridges; curved decks; suspension bridges; aerostatic stability; wind tunnel; dynamic analysis; root-finding algorithms; lift-induced rotation

1 Introduction

Curved footbridges are a very popular design alternative given their remarkable aesthetic attributes and its efficient structural performance. Notable examples are the Gateshead Millennium Bridge, Gateshead, UK, with 126 meters of main span, the Ponte de Mare, Pescara, Italy, which spans 172 m, and the Puente de Santa María de Benquerencia, Toledo, Castilla-La Mancha, Spain, 2011, spanning 170 m. However, the increasing span lengths adopted in contemporary projects turns wind-resistant analysis an important part of their design.

This study reports the nonlinear aerostatic stability studies carried out for a footbridge linking Goián-Tomiño (Pontevedra), Spain, with Vila Nova de Cerveira (Minho), Portugal. This suspension footbridge designed for pedestrians and cyclists spans 275 meters over the Miño River. Two pylons support the three-dimensional curved main cable of the suspension system that sustains the curved deck, as shown in the visualizations presented in Figure 1. The footbridge's aerostatic performance is

https://doi.org/10.2749/manchester.2024.0243
Distributed by structurae

Nonlinear Creep Analysis of Long-span Prestressed Concrete Bridges

Shiyu Wu, Zhao Liu, Teng Tong

School of Civil Engineering, Southeast University, Nanjing, China

Corresponding author: **Zhao Liu**

Contact: mr.liuzhao@seu.edu.cn

Abstract

Long-span prestressed concrete (PC) bridges tend to have larger deflection than code-based estimation after several years of operation. Even though creep is usually blamed as one of the most influential time-dependent factors, most current creep models do not give sufficient attention to nonlinear creep behaviour due to higher compressive working stress. In this study, a nonlinear creep model characterized by a stress-sensitive amplification factor is proposed based on experimental data from literature. The model is embedded into the rate-type formula using several user subroutines in Abaqus. Furthermore, a computational framework is established which involves the intertwined effects of concrete creep, shrinkage, and the influence of steel strands relaxation. Finally, a long-span rigid frame box girder bridge is analysed resulting in a good estimation with the in-situ measurement in terms of the long-term deflection.

Keywords: Prestressed concrete bridge; Time-dependent behaviour; Balanced cantilever method; Nonlinear creep; Relaxation; Prestressing loss

1 Introduction

Long-span PC bridge structures often encounter the common challenge of gradual and disproportionate vertical deformation [1], particularly those built using the method of balanced cantilever construction in segments, for instance the KB bridge in Palau that the deflection of midspan reached 1.61 m and collapsed after serving 19 years [2]. Multiple potential factors contribute to the interpretation of the causes of the bridge structural degradation, such as underestimated concrete creep and shrinkage strain [3], accelerated relaxation of prestressing strands due to seasonal temperature variations [4], as well as the destructive impacts of heavy traffic loads [5]. However, creep has potentially harmful effect on the structural behaviour, durability, and operational characteristics of concrete infrastructure [6]. Notably, once the magnitude of enduring stresses exceeds the linear threshold, creep deformation exhibits a nonlinear response in relation to stress intensity, obviously exceeding the predictions generated by a linear viscoelastic model [3]. In view of this, a nonlinear creep calculation model must be established to analyze the creep effect accurately.

In the last decade, numerous researchers have addressed the evaluation of nonlinear creep behaviour of concrete. For example, Bažant et al. [7] introduced a nonlinear creep function by modifying the creep rate based on current stress level. Hamed [3] studied nonlinear creep effects in concrete under different uniaxial compressive stress with four series of specimens, and compared several nonlinear creep calculation models with the test data, it appeared that the models were conservative. Dummer et al. [8] extended the damage-plasticity model to describe the nonlinear time-dependent behaviour of concrete. To account for the nonlinear creep effect in the design and analysis of structures, using the creep coefficient or compliance function dependent on the amplification factor with the stress magnitude is a practical and effective method [9]. Some widely used models for calculating the nonlinear creep

https://doi.org/10.2749/manchester.2024.0252
Distributed by structurae

Design and Construction of an Arch Bridge over Railway Line no. 132 in Poland using BIM Tools

Michal Majka, Patryk Stempin, Dawid Wisniewski
ASECon (Advanced Structural Engineering Consultants), Wroclaw, Poland

Contact: mm@asecon.pl

Abstract

This paper presents the design and construction for the new road-over-rail bridge in Dabrowa, Poland. The bridge is a replacement to the existing structure which significantly deteriorated over the years since the 1960s when it was built. Before the decision was taken to replace the existing bridge, a comprehensive study had been undertaken to investigate the possibilities of refurbishing the existing structure in order to minimise the CO_2 and environmental impact of the project. Ultimately, a decision was made to replace the bridge, driven by the functional constraints related to the very low vertical clearance, which would significantly restrain any future enhancements to the railway line forming a part of the Trans-European Transport Network (TEN-T). The paper discusses non-conventional technical solutions that were applied to the design and construction of the bridge.

Keywords: arch bridge, plate hangers, BIM tools, TEN-T railway network, temp. railway shielding structure.

1 Introduction

The paper discusses the design process as well as construction of the new road-over-rail bridge along the National Road no. 46 in Dabrowa in Poland, crossing over one of the main railway lines in the country. In particular, certain non-conventional technical solutions and aspects of the design adopted to improve the longevity and resilience of the bridge, are presented, including:

- the structural arrangement consisting of stiff steel box girders strengthened with flexible arches and equipped with flat-plate hangers with rigid connections in order to counteract the out-of-plane buckling of the arches;
- the use of weathering steel in locations with difficult access, such as underside of the deck in order to simplify the future maintenance in the vicinity of the railway overhead lines, in the spirit of reducing the life-cycle costs;
- the use of the temporary shielding structure protecting the railway line and infrastructure, in order to minimise the impact of the construction on the railway traffic, to minimise the need for the rail closures and possessions and hence, to reduce the social costs of the project;
- the use of the three-dimensional BIM-based models and tools in the detailed design and construction to simplify the handling of the complex geometry in design, to simplify the fabrication and to allow for efficient changes in construction.

The bridge crosses over a double-track electrified railway line no. 132 between Bytom and Wroclaw in Poland, in km 111+736 of the line forming a part of the Third Trans-European Corridor within the TEN-T Rail Network. The structure is located on a stretch of the national road network with a high intensity of average daily traffic (ADT)

https://doi.org/10.2749/manchester.2024.0260
Distributed by structurae

Fatigue Design of Van Brienenoord Bridge Deck

Rupert Gibson, David Gration
Arup, London, UK

Daan Tjepkema
Arup, Amsterdam, Netherlands

Frank van Dooren
Rijkswaterstaat, Utrecht, Netherlands

Contact: rupert.gibson@arup.com, daan.tjepkema@arup.com

Abstract

The remaining life of steel bridges is often governed by fatigue cracking in the orthotropic steel deck (OSD). Since the design and construction of many of the steel bridges in Europe's motorway system, the number and weight of the trucks they must carry has significantly increased. This has led to many bridges being deemed understrength, compared to contemporary design guidance, and experiencing local fatigue damage. This is a problem facing the Dutch national bridge authority, Rijkswaterstaat (RWS), and many other governments globally as decades old steel bridges need renewing, strengthening or sometimes, in the case of OSD, an inspection and repair program.

Rotterdam's Van Brienenoord bridge [1] is the busiest in the Netherlands, and renewing the twin-tied arch bridge requires a newly designed OSD. The key challenges were to sustainably extend the life of the bridge to its 100-year design life whilst minimising hindrance to traffic and maintaining the aesthetic of what is a national icon. Given the extreme sensitivity of fatigue calculations to stress magnitude, the aim of the work was to develop a state-of-the-art accurate method for predicting the design, or remaining, life of OSD. Traditional methods tend to underestimate fatigue demand.

Keywords: sustainable design; steel bridges; local fatigue; orthotropic steel deck; renovation; 100-year life.

1 Introduction

The design of a new OSD for Van Brienenoord Bridge (VBB), see Figure 1, used state-of-the-art fatigue calculations developed by Arup over the past 15 years with input from RWS and TNO (Toegepast Natuurwetenschappelijk Onderzoek). Over this time Arup have assessed and renovated several bridges, developing an in-depth knowledge of a range deck types and configurations.

The aim of the work was to develop an accurate method for predicting either the remaining or design life of OSD. Traditional methods tend to underestimate fatigue demand as they fail to capture all the local effects that contribute to the build-up of stress in the weld. Hence, one of the main aspects of the modern approach to local fatigue assessments is the detailed finite element (FE) model with hot-spot stress extraction. Fatigue calculations are

https://doi.org/10.2749/manchester.2024.0268
Distributed by structurae

Adaptive pathways for critical infrastructure resilience

Nisrine Makhoul
École Spéciale des Travaux Publics, ESTP, Paris, France

Dimitra V. Achillopoulou
James Watt School of Engineering, University of Glasgow, Glasgow, UK

Rolands Kromanis
Faculty of Engineering Technology, University of Twente, Enschede, The Netherlands

Contact: nmakhoul@estp.fr

Abstract

Climate change is triggering hazard events more frequently and the costs of the consequences on the built environment are higher. This induced the advent of resilience-based engineering. More recently adaptive pathways (APs) were presented to allow adaptive management as well as dynamic and flexible decision-making. APs allow, specifically in climate change contexts, the consideration of stressors that occur incrementally or cumulatively and amplified hazard scenarios. Thus, an AP framework enhanced with emerging technologies is proposed for critical infrastructure. It benefits from the resilience and sustainability of emerging technologies throughout the lifetimes of critical infrastructure. This advanced AP framework is supported by continuous assessment of the infrastructure performance, continuous monitoring, and implementation of mitigation measures if needed. The Hollandse Bridge case study is offered to demonstrate the framework.

Keywords: adaptive pathways; critical infrastructure; resilience; sustainability; monitoring.

1 Introduction

Critical infrastructure (CI), specifically transportation infrastructures and assets are suffering from excessive use and aging due to population and urbanization growth, product transportation, and frequent natural disasters aggravated by climate change (e.g., extreme temperatures and storms). Frequent natural hazards resulted in aggravated impacts on infrastructure, communities, and the environment. Maintaining the optimal CI functionality became a substantial challenge (1). Therefore, there is a crucial need to strengthen CI and improve its management strategies.

Climate change induces daily stresses that accumulate over time and amplify hazard scenarios. Thus to preserve the CI functionality, disaster-mitigation strategies have shifted their focus from disaster response to preparedness and prevention ((2), (3)).

To address this, in the last decade adaptive pathways (APs) were proposed as a dynamic and

https://doi.org/10.2749/manchester.2024.0277
Distributed by structurae

The Transpennine Route Upgrade & Project West 3

Graham Thomas

Associate Director, Ove Arup & Partners, Leeds

Contact: graham.thomas@arup.com

Abstract

The Transpennine Route Upgrade (TRU) is a major railway infrastructure project located in the North of England, which is part of the UK Governments levelling up agenda, improving connectivity between main Northern economic centres. The TRU Project between Huddersfield and Dewsbury is the key intervention which unlocks capacity, journey time and reliability objectives along the route.

Keywords: Transpennine Route Upgrade; Network Rail Infrastructure Projects, Network North

1 Introduction

This paper provides a brief introduction and overview of the Transpennine Route Upgrade (TRU) programme, and more specifically the large-scale intervention being undertaken between Huddersfield and Westtown (Dewsbury), otherwise known as TRU Project W3 (West 3). For further information and current progress news refer to Network Rail's dedicated website [1]

This introduces following papers, which describe some of the key civil engineering interventions being delivered as part of the W3 Project.

2 TRU Scheme Overview

TRU is a multi-billion-pound, transformative, long-term railway infrastructure programme that will improve connectivity in the North, principally West-East, between the major economic centres of the Northwest (Liverpool & Manchester) and Yorkshire-Humber (Leeds, York & Hull).

The core TRU programme covers 122km (70 miles) of existing route between York and Manchester, but also covers significant diversionary route upgrades to facilitate construction and future operational resilience.

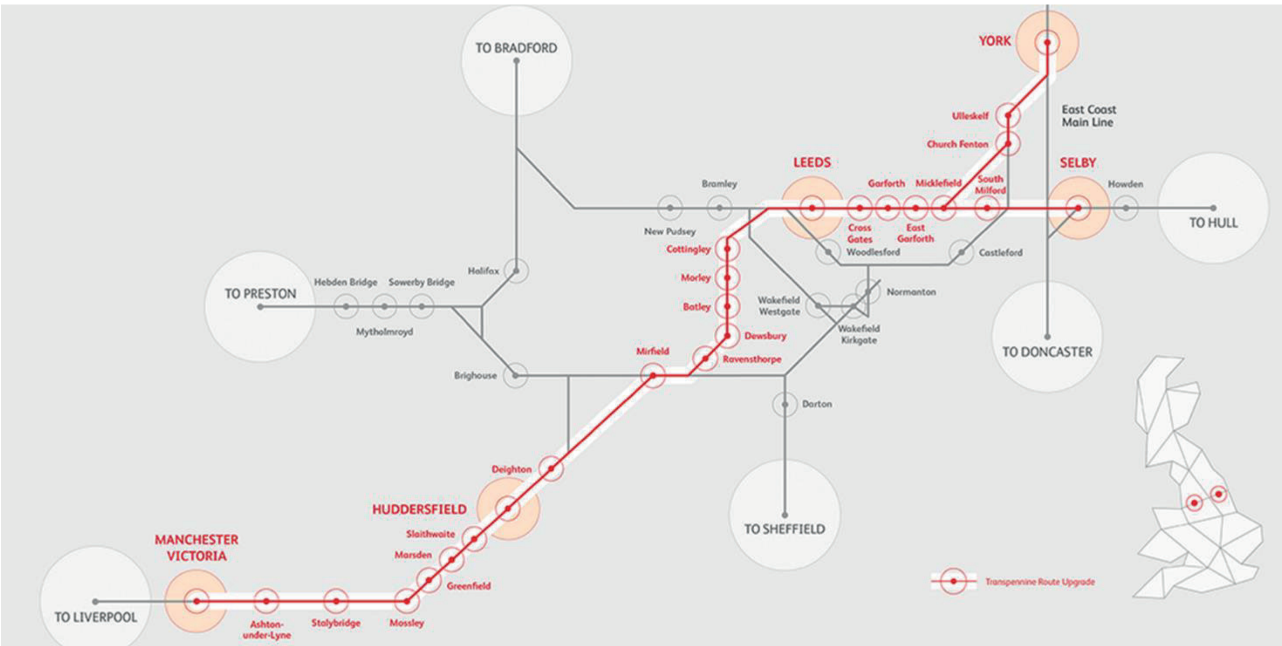

Figure 1, TRU Location & Route Map

https://doi.org/10.2749/manchester.2024.0286
Distributed by structurae

The Legacy of the Past: Geotechnical challenges from coal mining impacting major rail infrastructure.

Paul McEwen, Sue Thomson, Richard Deakin

Ove Arup &Partners Ltd, Birmingham and Leeds, UK

Contact: Paul.McEwen@arup.com; Sue.Thomson@arup.com; Richard Deakin@arup.com

Abstract

The legacy from a long history of mining, quarrying and subsequent landfilling can present significant geotechnical challenges to infrastructure schemes. When upgrading existing rail lines through congested urban corridors there is little opportunity to avoid the risk. Understanding the legacy of the past and the risk posed to the construction and operation of both existing and new track and structures is key to building resilient structures and a sustainable railway for the future. The paper discusses how the coal mining risk was managed and through dialogue with Network Rail a balanced approach (considering safety, cost and resilience) was adopted to determine appropriate mitigation. It then discusses the challenges implementing drill and grout mitigation in a live rail environment, around buried infrastructure, through landfill areas and adjacent to water courses. All required as mitigation for a new flyover and viaduct structure between Huddersfield and Dewsbury.

Keywords: Coal mining; risk assessment; mine workings; mitigation; grouting; structure interaction.

1 Introduction

The Transpennine Route Upgrade (TRU) is delivering major upgrades to lines and stations between Manchester, Leeds and York in the North of England. Increasing capacity and electrifying the route will deliver faster, more reliable and greener journeys for the local communities. Between Huddersfield and Dewsbury, the 14km section of route known as West 3 (W3) (herein referred to as 'the route') is discussed in further detail here. The route is geotechnically interesting, with challenging ground and major structural interventions both around the existing live railway, and off track.

The route crosses a landscape with a legacy of historical coal mining, quarrying and subsequent landfill, which introduce risks that need to be understood and managed to provide long term, sustainable and resilient assets.

Geologically, the route is underlain by the Pennine Lower Coal Measures (PLCM) bedrock, including a number of coal seams. Evidence of likely working of seams has been found in a significant number of the ground investigation (GI) holes. This has greatly aided the development of robust ground models and assessing the risk of collapse or settlement and thus the need for mitigation or not, early in the design process.

Alongside the development of outline designs, mining risk assessments (MRA) and a mining risk mitigation strategy were developed in consultation with Network Rail (NR). It wasn't economically viable to mitigate all possible risk. Therefore, a refined risk assessment process was needed to consider the cost of mitigation vs likelihood and impact of possible shallow working collapse causing a major event to the railway. Through this

https://doi.org/10.2749/manchester.2024.0294
Distributed by structurae

Transpennine Route Upgrade – Huddersfield Viaduct

Reuse of the Old

Sonam Norbu, Aiken Harrap, Will Spencer

Ove Arup & Partners Limited, Leeds, UK

Contact: sonam.norbu@arup.com

Abstract

Huddersfield viaduct is a Victorian masonry arch structure with a number of metallic spans. It is a grade II listed structure of varying condition that needs to be strengthened and modified to fulfil the requirements of the Transpennine Route Upgrade. This structure will accommodate additional tracks as well as portions of the amended platforms and electrification infrastructure. Line speeds are to be increased to 100mph on the Fast lines and 75mph on the Slow lines.

This paper describes the design challenges that have been overcome through a mixture of modern analysis techniques combined with traditional engineering design and judgement to develop the solution presented. The proposed works are as follows:

- Span 1 is to be replaced with a modern steel deck to accommodate the new station layout.
- Span 4 is strengthened and re-articulated.
- Span 5 is to be infilled to deal very weak masonry.
- Span 29 is to be reconstructed using prestressed beams.
- The masonry spandrel walls are to be stabilised using inclined anchors to tie back to the masonry piers.
- The masonry arches are to be repointed and repaired where necessary.

Challenges have arisen from working within the confines of an old historic site that continues to serve a busy operational railway. It is a credit to the project that the majority of this structure has been saved from reconstruction to be reused and upgraded to serve the modernised railway.

https://doi.org/10.2749/manchester.2024.0302
Distributed by structurae

Baker Viaduct: On Track to Better - The Design of a New Railway Viaduct for the 21st Century

Chris Jackson, Francisco Rodriguez Salas

Arup, Birmingham, UK

Contact: chris.jackson@arup.com

Abstract

The Trans Pennine Route Upgrade is a major, multi-billion-pound programme of railway improvements which will bring better journeys to passengers travelling across the Pennines between Manchester, Huddersfield, Leeds and York. As part of the scheme a new 350m long, four track viaduct is needed near the town of Dewsbury, West Yorkshire.

In addition to the sustainability benefits realised through transformational transport improvements, the design of the viaduct has focussed heavily on efficient and optimised design for both construction and operation and used wide ranging expertise to optimise the solution. Key features include:

- Splitting the structure into modules to eliminate rail expansion joints – minimising maintenance and disruption in service
- Use of composite diaphragms to maximise structure stiffness, reducing foundation demands from rail loads
- Use of a 'product' design approach to optimise off-site fabrication and manufacture of the structure
- Precast deck panels optimised for delivery to site by road and to minimise pollution risk during construction
- Enhanced safety in construction from careful detailing of the precast deck
- Automated design processes to allow a high level of design refinement, reducing steel and concrete quantities
- Foundations designed to minimise disturbance to contaminated ground on the site

This paper will outline the design of the structure and the automation used to create the design, covering key challenges, solutions and innovations adopted.

Keywords: Track Structure Interaction, Composite Bridge, Diaphragms, Carbon Calculation Transpennine Route, Rail, Viaduct

1 Introduction

1.1 TRU Overview

The Transpennine Route Upgrade (TRU) is a multi-billion-pound programme of railway improvements which will bring better journeys to passengers travelling across the Pennines between Manchester, Huddersfield, Leeds and York.

The project will speed up journeys between towns and cities across the north of England. The fastest journey times are forecast to be 63-66 minutes between Manchester and York and 41-42 minutes between Manchester and Leeds.

Estimation of Construction Year of Medium to Long Road Bridges in Zambia using Satellite Imagery

Bennie Hamunzala, Koji Matsumoto

Hokkaido University, Sapporo, Japan

Contact: bennie.hamunzala.p8@elms.hokudai.ac.jp

Abstract

Using the age of the road bridges as one of the inputs, deterministic and probabilistic deterioration models are used to determine the deterioration rates and predict the future physical condition of these structures. This study attempts to estimate the year of construction of 27 road bridges in Zambia. The Technique assumes that the normalized difference water index 2 (NDWI_2) at the target bridge point (TBP) shows detectable differences before and after the construction of a road bridge. Landsat 5 Thematic Mapper in conjunction with Landsat 7 Enhanced Thematic Mapper Plus was used in the Google Earth Engine. Sequential t-test analysis of the regime shift method was applied with a cutoff length $l = 2$ to $l = 12$, and significance level $\alpha = 0{,}05$, to interpret the estimated year of construction from NDWI_2. The results confirm that it is possible to accurately estimate the year of construction of road bridges in Zambia using this method.

Keywords: satellite imagery; construction year; road bridges; normalized difference water index 2; regime shift; bridge management; bridge target point; Landsat.

1 Introduction

Using the year of construction of road bridges as one of the key parameters, deterministic and probabilistic deterioration models facilitate the calculation of deterioration rates and the prediction of the future physical condition of road bridges. This valuable information helps to prioritize bridges, formulate plans and budgets for future works, and develop strategies for routine maintenance and inspections [1, 2].

In the previous study [3], a Technique was developed to determine the estimated year of construction of the road bridges by correlating the regime shift of the normalized difference water index 2 (NDWI_2) with the actual year of construction of the road bridges in Nago City in Japan. The study yielded $R^2 = 0{,}33$ for 44 road bridges with an overall length < 100 m. The current study attempts to apply the same Technique to assess and determine the estimated construction years of road bridges in Zambia. For over 90% of the road bridges in Zambia, the year of construction is not known, and, bridge's overall length < 100 m. The study examines 27 road bridges, of which 23 have an overall length > 100 m and 4 have an overall length < 100 m. The inclusion of bridges with an overall length > 100 m is motivated by the fact that they can only be detected to a limited extent by pixelated satellite images due to problems such as insufficient reflectance as well as absorption and scattering effects. In addition, bridges with an overall length > 100 m are classified as particularly critical.

The Technique assumes that the normalized difference water index 2 (NDWI_2) at the bridge target point (TBP) shows detectable differences before and after the construction of a road bridge.

Fatigue life prediction of orthotropic steel decks based on Phase Field model

Zhihua Xiong

Northwest A&F University, Yangling, Shaanxi, China

RWTH Aachen University, Aachen, Germany

Xuyao Liu, Di Di

Northwest A&F University, Yangling, Shaanxi, China

Nils Rittich, Markus Feldmann

RWTH Aachen University, Aachen, Germany

Contact: zh.xiong@nwsuaf.edu.cn

Abstract

The Orthotropic Steel Deck (OSD) is prone to fatigue crack due to initial defects caused by welding and the cyclic loading. Instead of sharp crack path tracking in OSD fatigue crack failure modeling, Phase Field (PF) approach uses diffuse damage localization, which has been adopted in simulating the crack propagation in OSD. The Nominal Stress method was used to simplify the OSD into a two-dimensional model, and the initial defects and residual stresses were incorporated in the model. Based on the PF model, the remaining fatigue life of typical welded details in an OSD was predicted. An Ultra High-Performance Concrete (UHPC) strengthening technique was presented, and the schemes before and post strengthened were compared under the same test conditions. The results show that the PF model is efficient in assessing the remaining fatigue life of OSD, and the fatigue life of OSD can be improved by this strengthening scheme.

Keywords: steel bridge; fatigue; crack; Phase Field; orthotropic steel deck.

1 Introduction

Orthotropic Steel Decks (OSD) have been widely used in long-span steel bridges because of lightweight, high structural stiffness and bearing capacity. Fatigue cracking at the joint of rib-to-deck (RTD) is usually an issue in OSD maintenance, which naturally draws a lot of studies on fatigue life in OSD. In terms of fatigue performance of the RTD, Wang et al. [1] evaluated the fatigue performance of OSD with respect to multiscale concerns through experiment combined with extended finite element method. Cheng et al. [2] studied the fatigue crack propagation process, characteristic fatigue life and fatigue failure mechanism of RTD connection under cyclic load. Chen et al. [3] considered the welding residual stress of double-sided welded joints of RTD, and investigated the

https://doi.org/10.2749/manchester.2024.0328
Distributed by structurae

Renewing Short-Span Existing Bridge Decks with CFRP Tendons for Durability

Yuki Onishi

Yamau Co., Ltd., Fukuoka, JAPAN

Kohei Yamaguchi

Nagasaki University, Nagasaki, JAPAN

Contact: ohnishi@yamau.co.jp

Abstract

Many short span bridges have sound substructures, but their superstructures have deteriorated and often have seismic performance problems. Considering factors such as the aging population, declining population, and financial constraints within the local communities, it is crucial for such bridge replacements to adopt "Smart Structures", such as maintenance-free structures. Therefore, this research was being conducted on precast PC (prestressed concrete) decks using carbon fiber reinforced polymer (CFRP), which are corrosion-resistant and can reduce maintenance costs. The Result showed that thin-walled PC decks with CFRP also had an same effective anchorage length for conventional standard PC steel strand wire. And, based on numerical analysis and loading tests, it was confirmed that the bending load carrying capacity of PC decks can be evaluated using the current design method.

Keywords: carbon fiber; CFRP; PC deck; short span bridge; maintenance free; finite element method.

https://doi.org/10.2749/manchester.2024.0336
Distributed by structurae

Inspection and complete rehabilitation of the Langebro Bridge in Copenhagen with focus on sustainable solutions

Ulrik Sloth Andersen
COWI A/S, Kongens Lyngby, Denmark

Rasmus Johan Finnerup Johansen
COWI A/S, Esbjerg, Denmark

Mette Kristensen
COWI A/S, Kongens Lyngby, Denmark

Contact: usa@cowi.com

Abstract

Langebro is an iconic bridge across the harbour in central Copenhagen, Denmark. The bridge connects central Copenhagen with the island of Amager.

The bridge consists of different spans, including a steel bascule span and two arch spans over the harbour. Viaduct spans on each side allow road traffic underneath the bridge. The bridge was completed in 1954. The bridge has a total length of 385 meters, a width of 33 meters and carries six road traffic lanes, along with cycle lanes and pedestrian footways. The bridge is a landmark and is protected (cultural heritage).

A complete rehabilitation including strengthening of the entire bridge is currently in progress.

Keywords: Rehabilitation; load capacity assessment; strengthening; concrete repair, brickwork rehabilitation; provision of additional concrete cover; condition assessment; sustainable solutions.

1 Introduction

Over the past decades, most countries have experienced an increase in traffic in terms of volume and weight. In addition, the general condition of many bridges has deteriorated and environmental conditions, including, e.g., the usage of de-icing salts, has caused corrosion of reinforcement and spalling of cover concrete.

For Langebro Bridge a complete rehabilitation is currently in progress. The works were initiated in 2021 and are expected to be completed in 2025.

2 Layout of the bridge

2.1 Details for the Langebro Bridge

Langebro Bridge is a complex structure where some of the areas below the approach spans are utilized for parking and office space, etc. The approach spans are constructed from a beam-slab RC-structure supported on RC columns and walls. The area below the approach spans on the Copenhagen (West) side covers an area of around 4,500 m² and was originally utilized as a parking area. The area below the approach spans on the

https://doi.org/10.2749/manchester.2024.0345
Distributed by structurae

Strengthening of a Curved and Skew Supported Prestressed Hollow Box Girder

Maria Kierzek, Vasco Amaral, Kristian Schellenberg

Equi Bridges AG, Chur, Switzerland

Contact: maria.kierzek@equibridges.ch

Abstract

Two equivalent motorway flyover ramps built in 1963, curved in view and with skewed abutments must be rehabilitated. The superstructures need to be strengthened due to deficiencies in shear capacity.

The post-tensioned concrete box section girder is supported by four bearings, all of which are of a different type. One of the bearings serves as a tension bearing, in form of a vertical, not inspectable post-tensioned cable. A monolithic connection of the superstructure with the abutment has been elaborated to provide a low maintenance alternative force path for the case of a potential loss of the tension in the vertical tendon. In addition, the proposed connection provides for the required seismic resistance.

The strengthening for shear force is executed by doubling the outer post-tensioned web.

Keywords: rehabilitation, strengthening, upgrade, post tensioned hollow box.

1 Introduction

The flyover ramps were built in 1963 as part of a motorway project. All the bridges along the route were erected on full scaffolding. The curved hollow box superstructure in concrete has been post-tensioned in stages. The curved in plan flyovers with skewed ends carry one lane of traffic and an emergency lane, each, to and from the motorway, respectively.

A condition and structural assessment showed that both structures have deficiencies in the shear capacity of the post-tensioned webs and in the torsion capacity of the bottom slab of the hollow box section.

The independent checking of the structural evaluation and the design of the strengthening measures was completed in 2023. The structure was modelled in SOFiSTiK with shell elements to evaluate the structural behaviour capturing the particularities of the curved hollow box section and the skewed supports, including the torsional response to the actions.

2 Original design

When the structure was designed in 1962, a simplified beam model was used, Figure 1.

https://doi.org/10.2749/manchester.2024.0354
Distributed by structurae

Microcracks assessment during unloading for structural elements reuse

Sushree Sunayana, Lisbeth M. Ottosen

DTU Sustain, Technical University of Denmark, Kongens Lyngby

Contact:limo@dtu.dk,

sussu@dtu.dk

Abstract

Larger scale concrete production to satisfy rapid infrastructural development leads to significant resource exploitation. One of the important ways to achieve sustainability in concrete construction is by optimizing the use of resources. To address this challenge, reusing structural concrete elements emerges as a viable alternative. During the process of selective demolition, structural concrete elements are unloaded. To assess their quality for reuse, a non-destructive testing technique is required. This study investigates the propagation of surface cracking during loading and unloading states using a digital image correlation (DIC) technique. Standard concrete prism specimens were subjected to compression loading at different stress levels before reaching the peak stress and subsequently unloaded. A novel method was developed to analyze the microcracks during unloading by digitally reproducing the DIC data. Quantification of surface cracking in the unloaded state can provide insights into the previous stress state experienced by the concrete elements and potential areas for reuse.

Keywords: Digital image correlation, unloading, compression, reuse, strain fields

1 Introduction

The exponential growth of concrete infrastructures is alarming in the context of sustainability. There is an urgent need to establish a balance between the rising demand for concrete infrastructures and the necessity to minimize CO2 production and resource consumption to achieve sustainability in concrete construction. In this context, recycling of construction demolition wastes such as coarse aggregates, fine aggregates or cementitious materials from recycled concrete powder have been explored by many previous studies (1-2). However, this total demolition of structures and their recycling process is more energy intensive with heavier equipment and less focus on quality materials for reuse (3). The performance of concrete produced using these recycled wastes depends on many factors like the parent concrete source, crushing method, quality and quantity of adhered mortar content affecting the higher water absorption of recycled materials, and formation of two interfacial transition zones due to the attached mortar layer which leads to more weakness at microstructure of concrete (1). On the other hand, the selective demolition process focuses more on the extraction of materials or components with a greater potential for reuse and avoids the large quantity of waste generation, sorting, and

https://doi.org/10.2749/manchester.2024.0361
Distributed by structurae

Damage characterisation using Sentinel-1 images: Case study of bridges in Ukraine

Nadiia Kopiika, Jelena Ninic, Stergios-Aristoteles Mitoulis

University of Birmingham, UK

Contact: n.kopiika@bham.ac.uk

Abstract

Bridges are vital infrastructure assets, ensuring the economic activity during the adverse times of conflict. Notwithstanding, there is insignificant research regarding their damage characterization with the use of remote approaches for post-conflict recovery. Monitoring and remote sensing is a promising technology for identification of damages caused by war-induced hazards, including artillery fire, explosions and shelling, and hence facilitate accurate and rapid evaluations of capacity and functionality loss, providing valuable information for reliable risk assessments at emergency and normal circumstances. The geospatial analysis, based on Interferometric SAR (InSAR) products of coherence, calculated between SAR images recorded at different dates could serve as a mean to characterize the level of damage, as demonstrated in this research. The main findings of study include the use fully open-access and remote data for assessment of critical infrastructure damages.

Keywords: bridges; damage; targeted human-induced hazard; explosion; Interferometric SAR (InSAR) products; coherence; recovery; remote monitoring; transport network; functionality.

1 Introduction

Due to vital importance of bridges in linking regions, enabling transportation and fostering economic progress [1] they often become the most targeted assets in war-torn regions. In such circumstances mass bridge destruction is often even more complicated due to limited access to them, resulting in inability of rapid assessment, decision-making and post-conflict recovery. On-site inspection and testing, which are typical approach for damage detection and retrofit decision-making, are increasingly time- and resource consuming, as well as difficult in accessibility, thus this survey method cannot be implemented effectively [2]. Remote sensing can serve as a substitute for identifying structural damage in aftermath or during the conflict due to ability to detect alterations across extensive areas and its quick revisitation as well as high potential to reduce the necessity for on-site surveys, which is the issue for conflict-affected areas that may be challenging to access [3]. This capability gap is of specific importance for ensuring of resilience and sustainability of infrastructural systems, revealing the necessity of research on remote assessment approaches. Recent years, modern remote techniques, including Earth Observation (EO) and geospatial approaches and especially Synthetic-Aperture Radar (SAR) images have gained remarkable popularity for effective management of large portfolios of structures in post disaster regions [4][5][6]. In particular, the one of the most effective approaches is associated with the use of Coherent Change Detection (CCD), by comparing alterations in the landscape before and after

https://doi.org/10.2749/manchester.2024.0367
Distributed by structurae

Structural assessment of corbels and half-joints in existing bridges

Rob Vergoossen, Evert van Vugt

Royal HaskoningDHV, Rotterdam, the Netherlands

Martijn de Boer

Royal HaskoningDHV, Amsterdam, the Netherlands

Contact: rob.vergoossen@rhdhv.com

Abstract

In new bridges the use of half-joints and corbels is not recommended from a durability viewpoint. However, in existing bridges they are frequently present. The design and detailing rules for concrete have changed over the last decades. A dilatation joint is always present above a half-joint or corbel. During service-life this joint deteriorates and almost always starts to leak and water with de-icing salts penetrate to the structure underneath. This initiates a large risk on corrosion of the reinforcement steel. However, this steel in this construction detail is crucial for the bearing capacity of the structure itself. What many structural engineers don't know is that the actual detailing of the reinforcement within the half-joint or corbel in relation to the position of the loads determines the stress in the reinforcement a7nd thus the capacity. In addition to this engineering effect, standards and insights have also developed over time. On the bases of some examples of existing corbels and half-joints the different ways to calculate such a structure are described in the paper. The well-known strut-and-tie model as well as the shear-cut-method from the Dutch CUR 40 are compared to non-linear finite element models. It is concluded that (as usual) the devil is in the detail.

Keywords: Structural Assessment, concrete corbel, concrete half-joint, detailing, shear.

1 Introduction

With his patent [1] in 1866 Heinrich Gerber became the inventor of the Gerber beam. In his patent he emphasises the advantage of a statical determined structure: the settlement of supports and the temperature influences do not result in internal forces. At that time easy calculation by hand was also an advantage. As reinforced concrete was only barely invented, it was not used for buildings let alone bridges. So, the first applications of Gerber beams in bridge design were made from steel. With the introduction of prefabrication and prestressed concrete after the Second World War, the concrete Gerber beam became popular in bridge design. As the construction depth can't be altered at the location of the hinges, the total depth is divided into two halves. Therefore, concrete Gerber beams are known as half-joints or dapped-end beams. From a structural point of view a half-joint is quite like a corbel or saddle.

Up till the seventies calculations were mainly done by hand. Traffic was low and de-icing salts were hardly used, so there wasn't much deterioration at the joints. Although the bending moment at the half joint is zero, the shear force is maximal.

https://doi.org/10.2749/manchester.2024.0376
Distributed by structurae

Evaluation on a load-carrying capacity of the stiffened plates subjected to biaxial forces considering the local buckling of the longitudinal ribs

Kousuke Yasuda, Takashi Yamaguchi

Osaka Metropolitan University, Osaka, Japan

Seiji Osakabe

CTI Engineering Co. LTD, OSAKA, Japan

Contact:sh23581b@st.omu.ac.jp, yamaguti-t@omu.ac.jp,

Abstract

This study analyzed load-carrying capacity of stiffened plates under one and two-directional forces with variations in the rib arrangement and the ratio of applied vertical to horizontal stress. The analysis was based on the Metropolitan Expressway Company's standard drawings for Steel Deck Structures. In the case that subjected to uniform compression along the bridge axis, reducing the number of longitudinal ribs from 8 to 6 increased the width-to-thickness ratio parameter from 0.54 to 0.70, with little impact on the obtained load-carrying capacity. On the other hand, the case under uniform compression perpendicular to the bridge axis, reducing ribs resulted in decrease of load-carrying capacity. In the case that subjected to biaxial forces, the load-carrying capacity curves depend on the width-to-thickness ratio parameters of each direction, and it demonstrated the difference buckling resistance of the ribs.

Keywords: Stiffened plates, load-carrying capacity, rib arrangement, biaxial forces

1 Introduction

The steel deck plates are stiffened with both longitudinal and lateral ribs. The required relative stiffness between the deck and the longitudinal rib is specified In Japanese specifications for highway bridges（JSHB) [1] to prevent local buckling of the panels surrounded by longitudinal and lateral ribs. Since they have many ribs more than that determined by the required relative stiffness in JSHB, considering the fatigue durability and cracks of the pavement, it is considered safe for local buckling of the panels between ribs. It might be possible to reduce the number of longitudinal ribs based on load-carrying capacity.

In addition, as the length of the bridge become longer, structural verification of stiffened plates subjected to biaxial forces should be required, such as thebridges categorized as follows:

(1) Box girder bridges consisting of steel decks as the upper flange plates and slender floor beams, where the deck plates are subjected to not only the longitudinal in-plane stress due to the longitudinal bending but also the

Load Transfer Mechanism of Single-sided frictional joints with high strength countersunk head bolts

Misato Konishi, Takashi Yamaguchi, Gen Hayashi

Osaka Metropolitan University, Osaka, Japan

Masayori Yoshimi

NIPPON STEEL BOLTEN CORPORATION, Osaka, Japan

Contact: xiaoximeili@gmail.com, yamaguti-t@omu.ac.jp, hayashi-g@omu.ac.jp

Abstract

This study analyzes the load transfer mechanism in single-sided frictional joints, with high-strength countersunk head bolts. Numerical analysis on coupon-type joints explores the bearing force on the counterbore, the friction force ratio to bearing force, and the slip resistance difference between countersunk head bolts and conventional bolts. The findings revealed that high-strength countersunk head bolted single-sided frictional joints employ a bearing force on the counterbore part by a bolt tightening. Since the stress occurs in the thickness direction of the main plate/the splice plate in the case of high-strength countersunk bolts, yielding of the main plate/the splice plate is limited and the reduction of the bolt axial force is not significant. Consequently, a single-sided frictional joint with high-strength countersunk bolts demonstrated higher slip strength.

Keywords: high strength countersunk head bolt, single-sided friction joints, slip coefficient, splice plate arrangement, countersinking bolt hole

1 Introduction

A countersunk head high-strength bolt, simply referred to as a countersunk bolt, features a smooth bolt head, as shown in Figure 1. This design, when applied to frictional joints for bridge deck plates, eliminates bolt head protrusion, thereby ensuring uniform base asphalt thickness [1]. The objective of this study is to develop countersunk bolted single-sided friction joints, simply referred to as CBJ, and counterbore processing in the main plates to achieve a completely flat steel deck surface [2], as shown in Figure 2.

In a previous study [1], slip tests were performed on both single- and double-sided frictional joints using 90° countersunk bolts. It was observed that the axially parallel part of the counterbore, marked by the red circle in Figure 3, undergoes plastic deformation. This leads to a lower axial force than that in a high-strength hexagon bolt (referred to as a hexagon bolt) when the tensile load is applied. In single-sided frictional joints, the slip coefficient decreased by approximately 6%, and in double-sided joints, it decreased by approximately 10% with countersunk bolts compared to hexagon bolts.

To suppress the plasticity of the axially parallel part, the bolt head opening angle was adjusted to 92° [3],

https://doi.org/10.2749/manchester.2024.0393

Influence of CO_2 Emission Pricing on the Degree of Reuse in Building Projects

Lars Magnus Johnsen, Sigurd Lundberg Olsen, Sverre Magnus Haakonsen

Norwegian University of Science and Technology, Trondheim, Norway

Contact: lars.m.johnsen@ntnu.no

Abstract

By 2030, CO_2 emissions must be drastically decreased to meet the goals of the Paris Agreement. As a result, the modern construction sector urgently needs to transition to a circular economy. This paper investigates how pricing of CO_2 emissions at different levels impacts the viability of reuse in building projects. A recently developed design tool is used in two case studies to find appropriate reclaimed steel elements for a truss structure at Old Trafford, Manchester. Utilising optimisation algorithms, the design tool automatically proposes substitutions of elements in a designed building with reusable elements. The conducted case studies demonstrate that an increased CO_2 emission price encourages a higher utilisation of reusable elements, even considering the substantial driving distance involved in acquiring them. The results indicate that increasing the CO_2 emission price in the future will motivate the reuse of old materials in the building projects of tomorrow.

Keywords: Reuse; Digital design tool; Circular economy; CO_2 emission pricing.

1 Introduction

In the Paris Agreement, the United Nations made a commitment to limiting global warming to well below 2°C and ideally below 1.5°C by the end of this century [1]. To accomplish this goal, emissions must decrease by 45% by 2030 [2] and reach net zero before 2050 [3]. This impacts the building and construction sector, which uses about 50% of extracted resources worldwide [4]. The sector is responsible for 37% of global CO_2 emissions [5] and accounts for over 33% of the waste in the European Union [6].

The primary cause of the high CO_2 emissions in the construction sector is the linear economy, which discards resources and building materials after use [7]. Consequently, the construction industry must quickly shift towards a circular economy to reduce CO_2 emissions [8].

One method to price the CO_2 emissions in the construction sector is to use the carbon price benchmarks from The Organisation for Economic Co-operation and Development (OECD). The first benchmark defined by the OECD of EUR 30 per tonne CO_2 [9] is a historic low-end and minimum price level to start triggering meaningful efforts. The second benchmark, which is described as a low-end 2030 and a mid-range 2020 benchmark, is EUR 60 per tonne of CO_2. This price is also in line with a 2060 scenario of gradual decarbonization [10]. The third benchmark, which is set at EUR 120 per tonne of CO_2, is a central estimate of the carbon costs in 2030. To investigate how the price of CO_2 emissions affects the use of reusable building elements, this paper aims to answer the following research question:

How is the price of CO_2 emissions affecting the reuse of building elements?

First, the digital design tool used in this paper is described. Then, two case studies are defined to investigate how the price of CO_2 emissions is affecting the reuse of building elements. Lastly, the results of the case studies are presented and discussed.

https://doi.org/10.2749/manchester.2024.0402
Distributed by structurae

Effect of Topology Optimization Parameters on Additively Manufactured Space Frame Nodes

Luke Farrugia, Jeanette Muñoz Abela

University of Malta, Msida, Malta

Contact: luke.w.farrugia.15@um.edu.mt

Abstract

Topology optimization of a double layer grid space frame node was examined, considering load combinations and various optimization parameters including minimum member sizes and mass reduction constraints. Minimum member size constraints up to 15mm improved stiffness by creating slender secondary supports, enhancing the primary load path. Post-processing techniques involving smoothing and rationalization reduced maximum stresses by 47%. Compared to conventionally designed nodes, the optimized nodes showed remarkable structural performance, with stress levels reduced by up to 88%. Nodes that were optimized to the load combination performed significantly better than nodes optimized to single load cases. The study also explored physical prototyping feasibility.

Keywords: topology optimization; additive manufacturing; space frame; structural optimization; parametric design.

1 Introduction

The integration of additive manufacturing (AM) into the fields of architecture and structural engineering has the potential to create spatial structures that are no longer restricted by standardization. By coupling topology optimization (TO) with AM, structural engineers can design and fabricate bespoke nodes with optimized structural performance and reduced fabrication lead times.

To date, a number of continuing studies that designed and fabricated intricate geometries for structural nodes in bespoke space frames, gridshells [1,2] and tensegrity structures [3] are available. In the case of space frames, the structural performance of the topology optimized nodes was not compared to that of a node defined parametrically or conventionally. Furthermore, there is limited information on the performance of optimized joints against multiple load cases, where research to date focused on single load case topology optimization.

Consequently, this research paper considers optimizing space frame roof nodes to multiple load cases and compares the structural performance of the optimized nodes against a spectrum of load cases. Additionally, the effect of the various optimization parameters present in the Solid Isotropic Material with Penalization method (SIMP) was also investigated. The behaviour of a parametrically defined node using mesh subdivision was also assessed, where the results obtained using numerical analysis techniques were compared to the results of the topology optimized nodes as well as those designed conventionally. The suitability of AM in fabricating the optimized nodes was also assessed.

https://doi.org/10.2749/manchester.2024.0409
Distributed by structurae

Development of cold-bonded lightweight concrete aggregates using biowaste

Daia Zwicky, Julien Ston

Institute of Construction and Environmental Technologies iTEC*, School of Engineering and Architecture Fribourg* HEIA-FR*, University of Applied Sciences and Arts Western Switzerland* HES-SO

Contact: daia.zwicky@hefr.ch

Abstract

The use of lightweight concrete could overcome some of the disadvantages of normal-weight concrete. However, the fabrication of lightweight aggregates is energy intensive and considerably draws on non-renewable resources. The positive consequences from lighter weight on supporting structural components' dimensions are frequently outrun by the increase in carbon footprint of up to 65% stemming from the lightweight aggregates. On this background, fabrication of lightweight aggregates in a low-energy cold-bonding pelletizing process, using bio-based waste and by-products, and alternative binders in combination with or instead of cement was explored. Presented results cover reflections for recipe mix design, observations made in the pelletizing and hardening process, results obtained for density, strength, thermal properties, and carbon footprint of this alternative way to produce lightweight aggregates for concrete.

Keywords: lightweight aggregates; pelletizing; biowaste; alternative binders; structural properties; thermal properties; carbon footprint.

1 Introduction

Concrete is the second most used material by mankind (after water), due to its many advantages: it has a simple recipe (basically aggregates, cement, and water), is cheaply and widely available, and is easily handled as it is pourable, possibly self-compacting, and self-hardening. Furthermore, concrete provides good acoustic insulation, fire protection and thermal storage capacity.

However, its intensive and widespread use heavily draws on non-renewable natural resources. More importantly, cement production is responsible for vast amounts of greenhouse gas emissions. In building construction, minimum dimensions of components are often dictated by execution while the concrete strength is hardly governing. And its high density may require additional material volume in supporting structures.

The use of lightweight concrete (LWC) could overcome some of these disadvantages. But the fabrication of lightweight aggregates (LWA), such as expanded glass or clay, is very energy intensive and draws on non-renewable resources, too (sand, in particular). The possible reduction of material quantity and of the associated carbon footprint, due to reduced density of LWC, is outrun by the added carbon footprint from LWA (up to 65%).

On this background, fabrication of LWA in a low-energy, cold-bonding pelletizing process from sawdust (an ample waste from timber production), calcium-rich wood ashes (an abundant waste from district heating in Switzerland), and alternative binders such as hydraulic lime and metakaolin in combination with or instead of cement is explored. This paper reports on challenges encountered and observed performances in this initial step towards an alternative way to produce LWA for concrete.

https://doi.org/10.2749/manchester.2024.0419
Distributed by structurae

Properties of Cementitious Materials with Reclaimed Cement

Alyssa Yvette Sunga, Shahriar Abubakri*, Gilson Lomboy, Islam Mantawy

Center for Research and Education in Advanced Transportation Engineering Systems, and Department of Civil and Environmental Engineering, Rowan University, 201 Mullica Hill Road, Glassboro, NJ, USA

Contact: abubakri@rowan.edu

Abstract

This paper introduces an eco-friendly approach to developing cementitious materials using reclaimed cement obtained from demolished structures or disaster debris as a partial replacement for virgin cement, with a focus on the properties of the resulting cement paste. This innovative practice aims to reduce the demand for new cement in the building and construction industry, thereby contributing to a more sustainable and carbon-neutral built environment. Specimens with varying proportions of reclaimed cement, ranging from 0 to 20%, were prepared and analyzed for both fresh and hardened properties. The findings reveal that cement paste containing up to 20% reclaimed cement shows comparable performance to control specimens made solely with ordinary Portland cement (OPC), indicating their potential suitability for various built environment applications.

Keywords: reclaimed cement; compressive strength; heat of hydration; sustainability; cement

1 Introduction

The rapid development of the construction industry increases the demand for different types of concrete. Concrete is composed of a few primary materials, with cement serving as the crucial binder that holds these components together. Cement, when mixed with water, forms a paste that binds the other materials together and hardens over time, which contributes to the physical properties of hardened concrete.

Cement is produced by following multiple energy-intensive processes which include extreme heating of its materials [1]. This heating process releases a significant amount of carbon dioxide (CO_2) into the atmosphere, thus posing detrimental effects to the environment. More than 500,000 tons of harmful emissions per year come from the cement industry, making it the third largest source of air pollution [2]. A typical concrete mix has only 10-15% cement by mass, yet 90% of its greenhouse gas emissions come from cement [3]. The study of alternative cementitious materials has been emerging. Since the use of concrete cannot be eliminated to minimize environmental impacts.

Multiple studies have investigated alternatives or additives to cement [4]– [7]. Supplementary cementitious materials (SCMs) have been widely used in concrete as partial replacements to cement because most SCMs are by-products of industrial processes making them more cost-effective, and because of their significant contribution to the physical properties of concrete [8]. Commonly used SCMs include fly ash, slag, and silica fume [9]. However, the growing demand for SCMs such as fly ash and slag is expected to outstrip supply by 50%, while the availability of slag cement is diminishing due to reduced blast furnace operations [10].

https://doi.org/10.2749/manchester.2024.0428
Distributed by structurae

Lateral stiffness design and optimization for over-track residential towers in metro depots

Fang Xu
Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Xin Zhao*, Shuang Wu
Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Contact: 22zx@tjad.cn

Abstract

For over-track residential towers in metro depots, distinctive layer heights and structural systems arise due to reasons including architectural function and process. This results in the formation of a stiffness transformation at the base of the structure. In order to meet the stiffness ratio requirements, neglecting the use of optimization design methods may lead to large dimensions of components and high utilization of materials. This paper firstly summarizes the lateral stiffness optimization design methods for over-track residential towers in metro depots. Then a practical engineering case is given to illustrate how to use this method in practical engineering. The case study demonstrates that changing the structural system of the over-track, layer height correction and column bracing can make it easier to meet the stiffness ratio requirements at the base, thus improving architectural function and saving cost.

Keywords: Over-track in metro depots, Residential tower, Lateral stiffness, Optimization, Structural system, Layer height correction, Column haunching

1 Introduction

All With the advancement of urbanization in China, rail transit has gradually become the primary way of urban public transportation. At present, more than 43 cities in China have been approved for rail transit construction planning, with a total mileage of more than 8600 km [1]. Under the background of increasingly developed urban rail transit and increasing land resources occupied by rail transit depots, the rational development of the upper cover project of rail transit depots can make full use of urban land resources, optimize urban space construction, and improve social and economic benefits. For the development and construction of the over-track residential tower projects in metro depots, there is an obvious stiffness mutation at the bottom of the structure due to the architectural functions and processes of the layer under slab, platform layer and slab layer [2]. According to the project experience, the stiffness ratios of the slab layer to the platform layer and the layer under slab to the slab layer are the controlling condition for the stiffness design of the over-track structure. The limit value of the stiffness ratio of the over-track structure of the rail transit is stipulated in the Shanghai code of China. The limit value of the stiffness ratio of the layer under slab

Bracklinn Falls Footbridge: efficient modular design

David Knight
Cake Engineering, London, UK

Keith Brownlie, James Marks
BEAM Architects, Dorset, UK

Contact: david@cakeindustries.co.uk

Abstract

The construction and access constraints of the Bracklinn Falls site drove the development of a new modular system and governed the structural and aesthetic design for the new footbridge. The resulting structure consists of perforated panels, formed from single sheets of weathering steel folded into a z-shape. These panels were bolted to cross frames and assembled to create a half through beam that spans 21.4m. The structure was assembled bay-by-bay and push launched along a set of temporary rails, before being jacked onto the permanent bearings.

By using a folding process, the modular system minimised welding and hence fabrication time and energy use. This paper looks at how the multiple constraints of a particular project enabled the design team to deliver a footbridge with an exemplary embodied carbon rating [1] as well as achieving economic, robustness, durability and aesthetic goals.

Keywords: Design; Fabrication; Collaboration; Sustainability.

1 Introduction

Generally, the advantages of modular bridge construction are speed of installation; construction quality (due to offsite fabrication); and overall capital cost. It is not often associated with a focus on sustainability and durability. This project approaches these advantages from the other direction and is modular by necessity. Taking as a starting point a complex site, this paper describes the design process and key design decisions. The modular nature of the final scheme [Figure 1] is shown to be a necessary outcome of the site constraints, and shows another avenue for repeatable processes that could be used as a bridge product.

2 Site

Bracklinn Falls is situated in a gorge surrounded by ancient woodland within the Loch Lomond and the Trossachs National Park. The park authority required a replacement footbridge to cross the gorge and to provide views of the falls. However, access for construction plant and materials was extremely difficult, with the sole access via a steep and sharp cornered path.

https://doi.org/10.2749/manchester.2024.0443
Distributed by structurae

Life-cycle analysis of the Colne Valley Viaduct and assessment of optimised solutions

Mathis Kominiarz*

Rendel LTD, London, UK

Ingérop, Rueil-Malmaison, France

Zeina Al-Nabulsi, PhD

Rendel LTD, Birmingham, England

***Contact:** mathis.kominiarz@gmail.com

Abstract

The Colne Valley Viaduct (CVV), a 3.4km precast post-tensioned segmental viaduct with 57 spans is set to become the UK's longest railway viaduct. This study aims to carry out a life cycle assessment (LCA) of the CVV. The carbon analysis will focus on the 462m long constant depth deck section of the viaduct, and this will be compared against alternative materials and deck types. The LCA calculations will concentrate on product modules (A1 to A3), the construction process (A4 and A5), the replacement (B4) as per the global warming potential (GWP) indicator in kgCO_2e. Calculations will be based on activity data from the CVV Bill of Quantities, selected carbon emission factors (i.e. for electricity or fuel) and generic Environmental Product Declarations for materials purchased. This study intends to highlight any bridge structural components with high carbon emissions, that will need to be tackled in future projects to reach the 2030 and 2050 ambitious UK carbon targets.

Keywords: Bridge design, Life cycle assessment, Carbon emission factors, Optimisation, Concrete, Steel.

1 Introduction

The built environment sector is a major actor in global warming, accounting for at least 37% of global greenhouse gas emissions [1]. With urbanisation intensifying to meet the needs of a growing world population, these emissions are set to increase. To address the major environmental and social challenges of the 21st century, all stakeholders in the construction industry need to ensure that future projects minimise their impact on the environment.

A wide range of solutions based on frugal construction, or the use of bio-sourced materials are available, such as earth concrete or construction with timber. However, these solutions are becoming rarer in the civil engineering sector, particularly for bridges as their limited strength make them more suited to the building industry. Through the example of the Colne Valley Viaduct's (CVV) construction, the aim of this paper is to analyse how the structural design office can play a key role in reducing the environmental impact of the structures they design.

https://doi.org/10.2749/manchester.2024.0451
Distributed by structurae

A low carbon bridge over the River Thames, London, UK

Davood Liaghat, Koon Lok (Stephen) Nip, Antigoni Chatzidaki

Buro Happold, London, United Kingdom

Contact: antigoni.chatzidaki@burohappold.com

From a study in collaboration with:

Tom Osborne, Enea Latxague

Knight Architects, London, United Kingdom

Abstract

The construction industry must make a concerted effort to reduce its carbon footprint. This initiative for carbon reduction should supplement the social and economic benefits that infrastructure projects offer. A proposition project was initiated to design a pedestrian and cycle bridge over the River Thames in London with a carbon target of 250 $kgCO_2e/m^2$, whilst not compromising the functionality of the bridge. To this end, the Nine Elms to Pimlico site, in London, was chosen as our challenge. The project has shown that a low carbon bridge over the river is feasible, although achieving an upfront carbon of less than 250 $kgCO_2e/m^2$ proved to be too ambitious for this bridge with current design constraints. The need for unconventional materials, technologies and design processes has been identified. A reduction of 75% was achieved by redesigning the superstructure, to reach the targeted carbon further work is needed on the substructure and foundations.

Keywords: low carbon; bridge design; superstructure; long-span bridge; timber arch.

1 Introduction

Whether it is for replacement and improving resilience of existing bridges, or construction of new bridges to facilitate mobility and enhance people's lives, the demand for bridge design in the coming years is evident. In addressing the pressing Climate Emergency, the design of new bridges must prioritise greater material efficiency, functional effectiveness, and environmental harmony.

1.1 Setting a target

The carbon footprint associated with the construction of a bridge, or any civil engineering project, can be divided into different stages and modules, ranging from raw material supply to final recycle and recovery.

A proposed rating system for bridges, Structural Carbon Rating Scheme for Bridges (SCORBS), assigns ratings from 'A++' to 'G' based on the structural normalised upfront carbon for modules A1-A5, or 'Cradle to Practical Completion', as defined in *BS EN 17472:2022*, see Figure 1 [1].

This paper's objective is to demonstrate that a carbon focused design can be achieved without comprising quality but upon the assumption that the early decision for the necessity of a new bridge has already been made.

The key carbon metric used is normalised carbon, measured in kilograms of carbon equivalent per area ($kgCO_2e/m^2$). The carbon assessments

https://doi.org/10.2749/manchester.2024.0460
Distributed by structurae

The Challenges of Designing a Low Carbon Bridge

Tom Osborne, Enea Latxague

Knight Architects, London, United Kingdom

Contact:t.osborne@knightarchitects.co.uk

From a study in collaboration with:

Davood Liaghat, Koon Lok (Stephen) Nip, Antigoni Chatzidaki

Buro Happold, London, United Kingdom

Abstract

Despite our industry declaring that the climate emergency is upon us, and that immediate, targeted action to reduce the carbon associated with our infrastructure is necessary, our industry's design and procurement processes remain largely unchanged from 'pre-declare' levels. Earlier this year, a team comprised of Buro Happold, Knight Architects, Graham and Gleeds undertook a study to understand the challenges of designing a low-carbon bridge. Two key themes emerged: the technical challenge of removing embodied carbon from the bridge, and the associated consequences of doing so. A parallel paper has been written [1], to highlight the technical challenges, whilst this paper sets out the professional, social and economic themes explored. The "Nine Elms to Pimlico" crossing of The Thames was our testbed. Our technical aim was to achieve normalised carbon of 250 kgCO_2e/m^2. Our professional aim was to do so whilst maintaining a safe, inclusive, and contextual design.

Keywords: low carbon; net-zero; bridge design; climate emergency

Thame Valley Viaduct: carbon efficient DfMA viaduct for HS2

Fernando Madrazo-Aguirre

COWI, London, UK

Contact: femz@cowi.com

Abstract

Located outside Aylesbury (UK), Thame Valley Viaduct is one of the highest-profile viaducts in the entire HS2 route and the longest structure in the C2-C3 section with a total length of 880m. COWI worked closely with the client, architect, contractor and the supply chain to deliver an elegant and efficient structural design.

The design follows Design for Manufacture and Assembly (DfMA) principles to increase the proportion of prefabrication to reduce construction times, reduce the amount of work on site, increase quality of construction and reduce construction risks. In addition, the final design reduces the embodied C02 by 60% relative to the reference design. Thame Valley Viaduct has been showcased by HS2 as an example of design excellence.

This paper aims at showing the design of this viaduct, while explaining what DfMA principles have been introduced and the challenges involved.

Keywords: DfMA; high-speed railway; precast; post-tensioning; modular construction.

1 Introduction

High Speed 2 (HS2) is Great Britain's new high-speed railway. Phase 1 of HS2, once operational, it will connect the cities of London and Birmingham—UK's two largest cities—by bullet trains that will provide zero-carbon journeys. Phase 2, which would connect Birmingham with cities further North, is currently on hold.

The project comprises 230 km of track, four new stations, two depots, over 50 km of tunnels and 130 bridges. The railway is planned to be open between 2029 and 2033.

HS2 Ltd is the company responsible for developing and promoting HS2 and is funded by grant-in-aid from the government. It is an executive non-departmental public body sponsored by the Department for Transport from the UK Government. HS2 Ltd has awarded different contracts covering the procurement of the civil infrastructure, train stations, track installation and rolling stock, among others. The main civil engineering works were divided into four main contracts, and Thame Valley Viaduct is located in one of them: C2-C3 in the Central area, which runs from the North Portal of the Chiltern Tunnels to the South Portal of Long Itchington Wood Green Tunnel.

The C2-C3 contract was awarded as a Design-and-Build project to the EKFB Joint Venture (JV), comprising Eiffage Genie Civil, Kier Infrastructure and Overseas Limited, Ferrovial Agroman and BAM Nuttall—initially Carillion was part of the JV until it went bankrupt and Ferrovial and BAM joined the team. EKFB awarded ASC JV (Arcadis, Setec and COWI) the design work, and ASC has worked with

https://doi.org/10.2749/manchester.2024.0478
Distributed by structurae

Investigation into the cause of cracks and the opportunity to refurbish steel Vierendeel railway bridges

Philippe Van Bogaert, Hans De Backer

Civil Engineering Department, Ghent University, Belgium

Bart De Pauw

TUCRAIL Ltd, Brussels, Belgium and Civil Engineering Department, Ghent University, Belgium

Contact:philippe.vanbogaert@ugent.be

Abstract

The oldest of a set of 3 steel Vierendeel bridges, carrying railway tracks across the canal from Mechelen to Leuven, shows various cracks, mainly in the vertical members. Material testing demonstrates that the early age steel characteristics show a large variation for strength, yield point, impact notch energy and chemical composition. A thorough investigation into both the ULS and the fatigue resistance does not imply these to be the cause of the cracks. Comparing the location of the cracks and those of the dynamiting and subsequent repair of the steel structure, reveals that the brittleness of the material must be the cause of the damage.

Keywords: Vierendeel bridge, historic structure, material testing, brittleness, fatigue of riveted structure, dynamiting.

1 Introduction

In Belgium, during last century, longer and medium span steel railway bridges were frequently designed utilizing the Vierendeel system. In the town of Mechelen, three railway lines cross the canal to Leuven by three bridges of that specific kind, offering a singular illustration of this type of application. In 2021–2022, two of these bridges—which were built in 1958 and had suffered severe deterioration—underwent renovations that included the installation of a new rail fastening system. Constructed between 1933 and 1935, the third bridge connects Brussels and Antwerp directly by rail. This bridge's tracks were the nation's first to be electrified. The bridge suffered severe damage during World War II. At the height of the first and seventh bays, it fractured in half. German engineers restored the bridge in July 1940. A fourth bridge, which spans the canal and carries the new bypass line, was constructed next to the oldest one in 2017 and allows for faster connections. This bridge's design, which is a beam construction with varying heights and both ends clamped in the RC abutments, reverses the idea of an arch structure and contrasts with the old bridges.

In 2020, the oldest bridge was found to have several cracks. Additionally, the cross sectional area of various secondary parts of the bridge, such as the rail supporting the longitudinal beams and crossbeams, looked to have significantly decreased, and the anti-corrosion protection appeared to be inadequate. Because of this and the

https://doi.org/10.2749/manchester.2024.0486
Distributed by structurae

A Case Study on the Structural Assessment of an Existing Through Arch Truss Bridge

Dillon Betts, Aaron Ferguson, Jorge Pérez Armiño
COWI North America, Halifax, NS, Canada

Will Crocker
Nova Scotia Department of Public Works, Halifax, NS, Canada

Contact: dibe@cowi.com

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 over navigable waters. 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, the presence of tack welds throughout the structure, cracked floorbeams and wind-induced vibrations. As a part of this study, a series of detailed and focused bridge inspections, including structural health monitoring (SHM), were performed to inform the structural analysis. To assess the structure, a finite element (FE) model was created and calibrated using SHM data and the inspection findings. Additionally, a wind buffeting analysis was performed to refine the wind loading for the assessment. Based on the results of the analysis and investigations, a rehabilitation plan was developed to ensure that the bridge could remain in service for an additional 15 years.

Keywords: arch truss; finite element analysis; wind buffeting; assessment; rehabilitation.

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. Construction of the approximately 750m long through-arch truss bridge started in 1960 and it opened to traffic in 1961. The bridge has a total of eight spans: three approach spans, two splay spans, two main side spans and one main centre span. The bridge is shown in *Figure 1*.

The structure has undergone various maintenance and rehabilitations since 1990, including a deck replacement, recoating, and various truss reinforcements. At over 60 years in service, the bridge is reaching the end of its design life. It has several structural and operational deficiencies, including a previously failed truss diagonal, cracking of floorbeams, and restricted maintenance access due to the narrow width of the deck.

To provide the Owner (the Province of Nova Scotia) with a rehabilitation plan for this structure, an extensive inspection program and finite element (FE) analysis were performed. Providing the client with a deep understanding of the current condition and performance of the bridge allows them to make informed decisions to support a sustainable

https://doi.org/10.2749/manchester.2024.0493
Distributed by structurae

River Lea Crossing Refurbishment & Strengthening: A case study for refurbishment of an historic bridge

Michael Duvall, Andrew Hodgkinson
Hewson Consulting Engineers Ltd, Guildford, UK

Contact: michael.duvall@hewson-consulting.com

Abstract

The River Lea Crossing was completed in 1934 and remains in service today, carrying the A13 in East London over a tributary to the River Thames. The crossing comprises a single two-pinned arch span of approximately 61m. The bridge is constructed of steel and is supported on huge mass concrete abutments. Due to the expectations that it was nearing the end of its service life the was planned to be replaced by 2030. An extensive programme of surveys, inspection, monitoring and assessment of the superstructure and substructure, going beyond the normal requirements of current inspection and assessment standards, demonstrated that the bridge could be retained and refurbished to considerably extend its serviceable life.

This paper presents a case study of the project providing an example for future bridge rehabilitation schemes, which will inevitably become more prevalent as the industry learns to make better use of existing assets and build less in response to the Climate Emergency.

Keywords: bridges; inspection; assessment; refurbishment; rehabilitation; steel; arch; historic bridges

1 Project Introduction

The River Lea Crossing, Figure 1, was constructed as part of the Royal Docks Approaches Improvement in East London. Completed and opened to traffic in 1934 [1], the bridge is still in use today as part of the strategic road network carrying the A13. The bridge is currently operated and maintained by Road Management Services (A13) plc. (RMS) through the 30-year A13 Thames Gateway Design, Build, Finance and Operate (DBFO) contract with Transport for London (TfL). At the end of the contract in 2030 the bridge will be handed back to TfL.

The DBFO contract required replacement of the bridge superstructure prior to hand back on the basis that it would have been in service for almost 100 years and was therefore expected to be near the end of its serviceable life. However, regular inspections of the bridge during the DBFO contract indicated that while in need of a major maintenance intervention, the bridge was in good condition for its age. A load assessment undertaken in 2011 found the live load capacity to be HA + 30 units of HB loading in accordance with the Design Manual for Roads and Bridges (DMRB) [2], which was surprising given the significant increase in vehicle loads since it was originally designed.

In 2019 RMS commissioned a feasibility study to develop both a replacement and a refurbishment scheme and evaluate the options. The refurbishment scheme needed to be equivalent to a replacement scheme and provide a design life of 120 years from 2030. The schemes were evaluated in terms of technical feasibility, traffic impact,

https://doi.org/10.2749/manchester.2024.0500
Distributed by structurae

Hidden defects risk assessment at the Humber Bridge

John Collins, Peter Campbell

Roughan & O'Donovan, Leeds, UK

James Barnes

Humber Bridge Board, Hessle, UK

Contact: john.collins@rod.group

Abstract

The Humber Bridge opened in 1981. It is a suspension bridge carrying the A15 dual carriageway. Its 1410 m main span is the longest in the UK. It is owned and operated by the Humber Bridge Board. Following unplanned works to bearings arising from a hidden defect in 2020, Roughan & O'Donovan was commissioned in 2021 to undertake a hidden defects study following the guidance of CIRIA C764. Potential hidden defects for component groups and their possible causes were identified. The criticality and vulnerability of each hidden defect was assessed. A risk ranking table was then used to rank each hidden defect. Resulting mitigation measures included instigating a programme of non-destructive testing to welds, periodic survey of fixed points on the towers and anchorages and expansion joint works. Such a systematic, risk based approach is felt particularly applicable to the management of aging transportation infrastructure under high traffic and environmental demands.

Keywords: bridges; defects; Humber Bridge; suspension bridge; steel; bridge management.

1 Introduction

1.1 The Humber Bridge

The Humber Bridge is an iconic landmark crossing the Humber Estuary, connecting Yorkshire and Lincolnshire in the UK (Figure 1). Opened by Queen Elizabeth II in 1981 it was the world's longest single span suspension bridge until 1997 and remains the longest in the UK at 1410 m. It has asymmetrical side spans of 280 m and 530 m (Figure 2). A Grade I listed structure, as designated by Historic England, the bridge plays a vital role in helping the Humber region reach its potential. It is owned, operated and maintained by the Humber Bridge Board (HBB), who collect tolls to finance the crossing. The bridge carries the A15 trunk road, north and south, utilising four lanes with two additional walkways and passes over a main line railway, the A63 trunk road and two other minor roads. On average there are 33,000 crossings per day. Between June 2022 and June 2023 an estimated 120,864 pedestrians and 74,563 cyclists used the walkways.

Figure 1. The Humber Bridge, viewed from Hessle.

Composite Effects Between Steel Girder and Orthotropic Steel Deck Connected by Shear Force Transferring Members During Deck Replacement Work

Sayuri KITAICHI, Masakazu TAKENO
Nippon Steel Corporation, Tokyo, JAPAN

Mitsuru SHIRATORI, Kazusa MORIKAWA
Yokogawa NS Engineering Corp., Tokyo, JAPAN

Takashi YAMAGUCHI
Osaka Metropolitan University, Osaka, JAPAN

Shunichi NAKAMURA
Tokai University, Tokyo, JAPAN

Contact: kitaichi.9fp.sayuri@jp.nipponsteel.com

Abstract

To shorten the construction period, a novel deck replacement method, which does not need the removal of the entire existing reinforced concrete deck above the girder flanges, has been developed and applied to actual deck replacement work. This method is characterized by a load transfer between the girder and the deck using shear force transferring members (SFTMs). To verify this composite effect by installing SFTMs in accordance with the construction stage, field measurement and FEM analysis have been carried out. The obtained results indicate that the neutral axis in the cross section of the girder moves upward as the construction progress. If the index is defined as 100% for the fully composite state and 0% for a non-composite state, its value for the obtained state is approximately 70%, which indicates that SFTMs have sufficient functionality to enable the interaction between the girder and orthotropic steel deck effective.

Keywords: Composite steel girder; Orthotropic steel deck; Deck replacement; Field measurement.

1 Introduction

1.1 Objectives

As the deterioration of reinforced concrete (RC) decks of steel highway bridges due to heavy traffic has become apparent, deck replacement works have been implemented earnestly in Japan. These construction works are usually carried out while regulating traffic. In order to minimize the inconvenience to traffic, enabling construction in narrow spaces and shortening the construction period is desirable. To satisfy the requirements of RC deck renovation of existing composite steel girder bridges, a novel deck replacement technology employing an orthotropic steel deck

https://doi.org/10.2749/manchester.2024.0518
Distributed by structurae

Numerical Study on Square Large Sectional Concrete-Filled Steel Tubular Columns with Separating Cross Steel Plate

Wencong Li

Toyo University, Kawagoe, Japan

Contact: li051@toyo.jp

Abstract

To meet the demand of structural performance of the tomorrow's supertall buildings, square large sectional concrete-filled steel tubular columns with separating cross steel plate were proposed. In this research, numerical studies on the square large sectional concrete-filled steel tubular columns with separating cross steel plate under lateral force in two different directions are carried out to investigate the effect of loading direction on the inelastic behavior of this kind of column. Numerical results show that there is no significant difference in the initial flexural stiffnesses of the proposed square large sectional concrete-filled steel tubular columns with separating cross steel plate in two different loading directions, but there is a certain degree of difference in their flexural strengths.

Keywords: Mega CFT column; separating cross steel plate; different loading direction; numerical study; supertall building.

1 Introduction

In order to satisfied structural demand of supertall building with increase of the structural height, concrete-filled steel tubular column (abbreviated as CFT column hereinafter) with separating cross steel plate shown in Figure 1 was proposed [1]. For this kind of multi-cell CFT column, if the lateral force loading direction is different, the seismic performance may also be different. In order to apply this kind of multi-cell CFT column to the tomorrow's supertall buildings, it is necessary to clarify the seismic performance of the multi-cell CFT column under lateral force in different directions in consideration of uncertainty in the direction of earthquake ground motion.

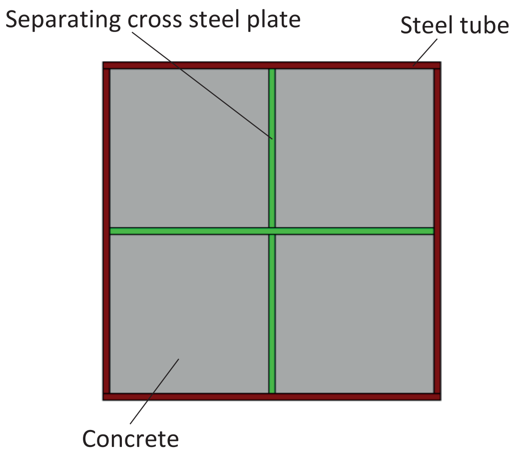

Figure 1. Cross section of concrete-filled steel tubular column with separating cross steel plate

In this research, numerical studies on the square large sectional CFT columns with separating cross steel plate under lateral force in two different directions are carried out to investigate the effect of loading direction on the inelastic behavior of the multi-cell CFT column using the finite-element analysis platform of OpenSees [2].

https://doi.org/10.2749/manchester.2024.0527
Distributed by structurae

Variable stiffness and damping components for semi-active vibration control and inflatable rigidization

Qinyu Wang
Key Laboratory of Civil Engineering Safety and Durability of China Education Ministry, Department of Civil Engineering, Tsinghua University, Beijing 100084, China

Gennaro Senatore
ILEK – Institute for Lightweight Structures and Conceptual Design, University of Stuttgart, Pfaffenwaldring 7 70569 Stuttgart, Germany

Kaspar Jansen
Department of Design Engineering, TU Delft, 2628 CE Delft, NL

Arjan Habraken, Patrick Teuffel
Chair of Innovative Structural Design (ISD), Department of Built Environment, TU Eindhoven, Eindhoven, the Netherlands

Contact: qwang2@mail.tsinghua.edu.cn

Abstract
The paper explores the potential applications of adaptive components based on shape memory polymer (SMP) composites in vibration control of plate/shell structures and rigidization of inflatable structures. These components achieve stiffness and damping variation by thermally actuating SMP between its glassy and rubbery states. In CASE A, steel-SMP sandwich plates of a truss bridge are actuated to glass transition temperature (Tg), where material damping reaches the peak to mitigate dynamic responses. CASE B proposes a simple and reversible rigidization method for inflatable structures, creating high compaction ratio and design flexibility. Converting the SMP layer between its glassy and rubbery states, inflatable structures achieve multiple functions during transportation, construction, and service life. SMP-based adaptive components enhance structural performance and mitigate dynamic effects in demanding environments for various structures.

Keywords: adaptive components; shape memory polymer (SMP); variable stiffness and damping; vibration control; plate/shell structures; inflatable structures; physical rigidization; construction in extreme environments

1 Introduction

1.1 Vibration control

Structural control strategies optimize performance in adaptive structures under changing loading conditions, categorized as passive, active, semi-active, and hybrid [1]. Passive systems, e.g. base isolation, require no control power but have limited capabilities. Active control effectively reduces structure responses, especially in seismic- [2] and wind-excited [3] buildings, but can be unstable due to high power density and control uncertainties. Semi-active control systems, like magnetorheological dampers, perform better than passive systems and offer reliability and energy efficiency over fully active systems. Hybrid control combines passive, semi-active, and active

https://doi.org/10.2749/manchester.2024.0534
Distributed by structurae

Extradosed Bridge Part of the Third Ring Road of Mecca – Conceptual Design

Fernando Sima, Mike Schlaich

schlaich bergermann partner, Berlin, Germany

Maher Youakim, Essam Ayoub, Karim Hany

Euro Consult for Engineering Consultancy, Cairo, Egypt

Mourad Bakhoum

ACE (Moharram – Bakhoum), Cairo, Egypt

Contact: essam.ayoub@euroconsult.com

Abstract

The aim of this paper is to present the conceptual design process of the proposed Extradosed Bridge, as part of the Third Ring Road of Mecca project, near the Jamarat site in KSA. The proposed bridge is conceived as an Extradosed Bridge with an open cross section with two main longitudinal girders in post tensioned concrete and spans of 85-145-90 m. It is the result of a conscious and rigorous conceptual design process, that took into consideration the special context and boundary conditions, in some cases, quite unusual for a road bridge. The resulting slender, durable, and elegant bridge fits in the context, providing an iconic, yet subtle reference to this important site.

Keywords: Extradosed Bridge, Skewed Bridge, Post-tensioned Concrete, Stay Cables, Vibrations, Constructability.

1 Introduction

A new bridge is foreseen as part of the Third Ring of Mecca project in Saudi Arabia, currently under design and construction, that serves as the new crossing over the Jamarat area, west of the holy site for Muslims, as part the development of the whole Hajj area. At first sight a conventional highway bridge, it is in a very special location that significantly conditioned the design: millions of pilgrims will make use of the bridge or pass under it during the Hajj every year in their pilgrimage to the holy Jamarat site.

As bridge designers, it is rare to have the chance to design a road bridge located in such prominent location. Therefore, the conceptual design of the bridge required careful considerations, taking into account the special context and the singular boundary conditions.

This paper describes the conceptual design process of this bridge which is presently out for tender and which the client wants to open to traffic by 2027. Numerous solutions were studied in the process, and finally two parallel extradosed

https://doi.org/10.2749/manchester.2024.0543
Distributed by structurae

Cody Dock Rolling Bridge: infrastructure and place

Robert Nilsson, Alfred Jacquemot, Giulio Gianni, Tim Lucas
Price & Myers, London, UK

Thomas Randall-Page
London, UK

David Knight
Cake Industries, London, UK

Contact: r.nilsson@pricemyers.com

Abstract
The Cody Dock Rolling bridge is a new steel bridge over a dock entrance near the River Lea in London. Spanning seven metres between existing dock walls, it allows the passage of vessels into the dock by rolling along a track such that the deck turns upside down and is lifted clear of the navigation envelope. The bridge is carefully counterweighted so that the centre of gravity is approximately level, allowing the 13.2-ton bridge to roll using only a hand cranked winch. Despite the simplicity of this movement, the design process and fabrication revealed complex and unique engineering challenges arising from combining an adaptive design of a moving bridge with high environmental aspirations and a limited budget.

Keywords: Footbridge, moving bridge, durability and longevity, low-maintenance, weight and material efficiency, human-powered, replaceable components, low-impact, Victorian simplicity, local team.

Figure 1. View of the bridge in motion from the south-west bank. Photo credit: Jim Stephenson

https://doi.org/10.2749/manchester.2024.0551
Distributed by structurae

Design of Whitegates to Athlone Castle Pedestrian, Cycle Bridge

Pankaj Kumar Das, Mark Kilcullen, Matthew Ryan, Rachel Harney

Roughan & O'Donovan Ltd, Arena House, Arena Road, Sandyford, Dublin, D18 V8P6

Contact: pankaj.kumardas@rod.ie

Abstract

The modern and sleek design of a new pedestrian, cycle bridge across the River Shannon is a vital link in the EuroVelo Route 2 Galway to Dublin Cycleway. The scheme was configured to act as a landmark structure, central to the proposed national cycle network, and a beacon for eco-tourism and patrons of active travel. It sought to overcome the severe space restrictions along riverbanks to construct the bridge and approaches over and within the Shannon Special Area of Conservation. The design aspired to deliver high quality finishes appropriate to a landmark structure in a thriving urban centre. The design needed to overcome severe geometric constraints to accommodate river navigation to land on the roof of the award winning Luan Gallery and altering the gallery to accommodate the bridge abutment in a visually seamless fashion. The scheme required the construction of the western approach ramps and boardwalk while maintaining the existing mature treeline along the river.

Keywords: cycle, river, bridge, orthotropic, steel, analysis, constrained, vibration, pier.

1 Introduction

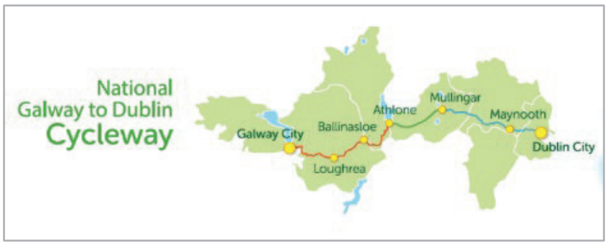

Figure 1.1: EuroVelo Route 2

In 2012, ROD-AECOM was appointed by Westmeath County Council to develop EuroVelo Route 2, the Dublin to Galway Cycleway. It represents a principal component of the National Cycle Network, and is key to Active Travel transition in Ireland. A critical element of the cycle route required a landmark bridge crossing of the River Shannon in Athlone town, the ancient centre of Ireland.

ROD-AECOM worked in partnership with Seán Harrington Architects to deliver the design of this unique structure. This paper briefly describes the option selection process for the scheme and presents, in more detail, the design development and construction of the bridge. A key objective was to provide sustainable transport options for both cycling and walking along a safe and secure route which is separated from vehicular traffic. Furthermore, schemes which serve to enhance connectivity for sustainable tourism, promoting good health and wellbeing at a local level, fully align with Ireland's Sustainable Development Goals (SDGs).

2 Options Selection

Nine alternative crossing locations and configurations were considered in choosing an appropriate bridging point along with six route options through the town to the river. The route and crossing options are shown in Figure 1.2.

https://doi.org/10.2749/manchester.2024.0560
Distributed by structurae

Two-dimensional transient thermal analysis of drilled-pile wall exposed to extreme temperatures and discussion on frost mitigation methods.

Santeri Tammi M.Sc., Summer Shahzad Ph.D.

Ramboll Finland Oy, Espoo, Finland

Eero Särkkä M.Sc., Mikko Hyyrynen M.Sc.

Ramboll Finland Oy, Tampere, Finland

Contact: summer.shahzad@ramboll.fi

Abstract

This paper analyzes earth-retaining walls made of drilled or bored large-diameter steel piles filled with concrete subject to Nordic temperature loads, especially focusing on Finnish temperature conditions and their effects and mitigation methods. Two-dimensional numerical analysis is carried out with Finite Element Method (FEM) software Comsol Multiphysics 6.1. The result's order of magnitude is validated by a literature review and by a one-dimensional analytical model. The paper aims to understand the frost depths with and without thermal insulation and to find their optimal locations. Results show that the thermal insulation layers might not give the intended benefits if the thermal bridges are not mitigated carefully. Moreover, it is evident from analysis that the horizontal part of the insulation covering the top of the ground plays an important role in decreasing the frost depth. The important findings will help designers reduce material waste, save public money in big infrastructure projects, and preserve the environment.

Keywords: frost depth; cold bridges, frost heave; thermal insulation; extreme temperature loads; retaining wall; bored-pile wall; sustainability; non transient thermal analysis; heat transfer; numerical analysis.

1 Introduction

Temperature loads on structures have a significant impact on their structural behaviour and performance. These loads arise from the expansion and contraction of materials due to temperature variations, leading to thermal stresses and deformations. Understanding the effects of temperature loads is crucial for the design and analysis of these structures to ensure their stability, structural integrity, longevity, durability, and watertightness.

One of the causes of temperature loads include frost heave, which leads to additional loads on the structure. Because these loads are difficult to estimate due to the complexity of the problem, so usually mitigation methods are used to prevent the frost heave phenomena and therefore the knowledge of frost depths becomes indispensable.

The frost depth in the ground can be estimated using literature-based measurement results or by solving analytical equations in simple cases only. However, in a case of a retaining wall the approach is not applicable due to the complexity of the geometry. In addition to the horizontal boundary (surface of the ground) there's also a vertical boundary from which heat transfer occurs. Thus, the problem should be viewed at least in two dimensions. In addition to the increased dimensions, there's a possibility that the retaining wall forms a thermal bridge, which has a detrimental effect on frost depth.

https://doi.org/10.2749/manchester.2024.0573
Distributed by structurae

A New Method for Calculating the Shear Stiffness of RC Beams with Web Diagonal Cracks

Wei Dou

Anhui Transport Consulting & Design Institute Co., Ltd., Hefei, Anhui, China

Transportation Energy Conservation and Environmental Protection Technology Transportation Research & Development Center, Hefei, Anhui, China

Shengbin Wang

Anhui Transport Consulting & Design Institute Co., Ltd., Hefei, Anhui, China

Yongxue Jin*

Tongji University, Shanghai, China

Dong Xu

Tongji University, Shanghai, China

Contact: 1910330@tongji.edu.cn

Abstract

Investigation shows that long span concrete box girder bridges often suffer from cracking and deflection diseases simultaneously. A considerable number of the cracks are diagonal web cracks, which reflects the reduction of the shear stiffness of the structure. However, the current specifications only consider the adverse effects caused by flexural cracks and ignore the shear deflection. In addition, some scholars have found that the horizontal reinforcement of the web also limits the development of diagonal cracks. This paper carried out shear tests on I-shaped beams with different forms of reinforcement in the web. Then, a new calculation method is proposed to calculate the shear stiffness after diagonal cracking, which takes into account the influence of the vertical and horizontal reinforcement at the same time.

Keywords: shear stiffness; diagonal crack; truss model; horizontal reinforcement; stirrup.

1 Introduction

On one hand, experimental research on the shear load capacity of RC beams has been relatively mature while few experiments have been carried out on the shear deformation. On the other hand, current specifications only provide calculation methods that consider structural degradation stiffness due to flexural cracks. Mainstream calculation methods include the stiffness analytical

Predicting Fractures in Reinforcing Steel Bars: A Low Cycle Fatigue CNN Approach

Islam M. Mantawy, Naga Ravuri

Civil and Environmental Engineering Department, Rowan University, Glassboro, New Jersey, 08028

Contact: mantway@rowan.edu

Abstract

Resilience is enhanced by machine-learning-based structural health monitoring (ML-SHM). ML-SHM minimizes delays in recovery after events, offering continuous monitoring for improved resourcefulness. This paper discusses the use of convolution neural networks (CNNs) for SHM with time-series data from seismic events. Current ML approaches overlook the temporal nature of the data. The proposed ML-SHM approach involves converting time-series data into images using the Markov Transition Field (MTF), obtained from strain data collected during shake table tests, and utilizing these encoded images in training and testing CNN models. CNN models achieved impressive accuracy in training (100%) and testing (96.7%) using only 3 layers. By stacking eleven earthquake excitation representations through MTF images, particularly for low-cycle fatigue, this method shows promise in revolutionizing fracture estimation from strain data.

Keywords: Resilience; Structural Health Monitoring; Convolutional Neural Network; Machine Learning; Low-cycle fatigue

1 Introduction

Structural Health Monitoring (SHM) is vital for asset management, ensuring safety and functionality. Traditional methods are resource-intensive, relying on laborious sensor-based data collection. Advances in machine learning and computer vision offer efficient options for SHM, enhancing effectiveness and streamlining processes [1-6]. The use of convolutional neural networks (CNNs) to analyze visual data from cameras or sensors adds advantages to SHM toolkits. CNNs have shown great potential in detecting and characterizing structural damage, which could improve the efficiency and accuracy of SHM techniques [1,2,4,5].

Several researchers have advanced machine learning and deep learning techniques in civil engineering applications. Mantawy and Mantawy used acceleration and displacement time-series data to develop a convolutional neural network model for the structural health monitoring of the rocking bridge specimen by encoding the time series into images [3], in which the present paper is advancing this technique to utilize strain data for accumulated damage detection.

As evident in the abovementioned references, researchers can utilize machine learning and CNN techniques for vibration-based damage detection using acceleration and displacement time series data either by (1) extracting meaningful features from the time series data [2], (2) converting time series data (mainly acceleration) into 2D matrix, or (3) encoding time series data into images [3]. However, strain time-series data presents complex challenges for machine learning techniques due to the accumulation effects due to low-cycle fatigue, e.g., damage in reinforcing bar does not only depend on the current strain time series but also the history of strain experienced by the reinforcing bars throughout the life of the structures.

https://doi.org/10.2749/manchester.2024.0587
Distributed by structurae

Ultimate Shear Strength of Welded Stainless and Carbon Steel Girders

Kentaro Kato, Hironori Ishii, Yoichi Yuki

Yokogawa bridge Holdings Corp., Chiba, Japan

Takeshi Miyashita

Nagaoka University of Technology, Nagaoka, Japan

Kimitoshi Nishimura

Narasaki Seisakusyo Co., Ltd., Muroran, Japan

Contact:k.kato@ybhd.co.jp

Abstract

Stainless steel is a high-performance alloy with superior corrosion resistance compared to carbon steel. By applying stainless steel to corroded areas of a steel bridge, durability can be substantially improved. Our objective is to create a steel bridge that integrates hybrid structural components, which are composed of a combination of welded stainless steel and carbon steel, used to reinforce steel girder ends or their lower sections. Specifically, I-girder ends mainly subject to shear loads are our primary focus for corroded sections. This study examines the ultimate shear strength of welded steel girders comprised of stainless and carbon steel through load tests and numerical analysis. As a result, the ultimate strength of a hybrid girder can be assessed using a design equation for a homogeneous girder made of carbon steel by the Basler equation or an ultimate shear strength curve for stainless steel plates proposed in previous research in Japan.

Keywords: Stainless steel; welded steel girder; hybrid structural member; I-girder ends; load test; finite element analysis; ultimate shear strength.

1 Introduction

The durability of steel bridges poses a significant problem due to heavy corrosion throughout their lifecycle. Deterioration of steel girder ends, or their lower part is caused by water leakage from damaged drainage ditches and airborne salt. This study considers improving this corrosion problem by using high-performance steel. Stainless steel is a high-performance alloy with superior corrosion resistance compared to carbon steel. By applying stainless steel to corroded areas of a steel bridge, durability can be substantially improved. Substitutions of stainless steel for corroded sections are expected to be a cost-effective solution, despite a higher material cost of stainless steel than carbon steel.

Our objective is to create a steel bridge that integrates hybrid structural components, which are composed of a combination of welded stainless steel and carbon steel, used to reinforce steel

https://doi.org/10.2749/manchester.2024.0596
Distributed by structurae

Streamlining a Transitional Shelter Design: A DfMA-driven Approach for Efficient Design and Assembly

Cheryl Lyne C. Roxas, Rhem Leoric C. Dela Cruz, John Paul Q. de Pedro, Breman M. Tamani Jonathan R. Dungca, Bernardo A. Lejano, Jason Maximino C. Ongpeng

De La Salle University, Manila, Philippines

Contact: cheryl.capiz@dlsu.edu.ph

Abstract

The rapid and effective provision of transitional shelters is of paramount importance in disaster response and humanitarian aid efforts. This study focuses on the development of an innovative, structurally sound, and economical transitional shelter design in the Philippines using the Design for Manufacturing and Assembly (DfMA) concept. Though several existing shelter designs were already introduced in the country, these designs raised concerns about their adequacies to withstand hazards and constructability. This paper then explored DFMA principles and developed a framework as applied in a cold-formed steel-based shelter design to ensure ease in the assembly of the components, simplifying the construction, and at the same time achieving structural stability. The findings of this study significantly enhance the Philippines' disaster response by improving the existing shelters in terms of cost-efficiency, ease of construction, and structural stability.

Keywords: transitional shelters; design for manufacturing and assembly; cold-formed steel, light gauge steel

1 Introduction

Transitional shelters are post-disaster shelters built to facilitate the transition of the affected population by natural disasters to a more durable shelter [1]. These shelters are essential in the recovery program of the government and humanitarian organizations after a calamity as they grant safety and discretion, safeguard from climate, and promotion of good health to the victims of natural disasters [1], [2]. Due to its geographical location, the Philippines is a disaster-prone country constantly hampered by typhoons and earthquakes. In 2022, five tropical cyclones made landfall causing massive damage to 2.3 million houses and displacing 8.39 million of the population [3]. With these frequent occurrences of natural disasters, the provision of shelters for the victims is a crucial factor in their recovery, leading to the development of shelter design guidelines. According to the International Federation of Red Cross (IFRC), transitional shelters must be designed to minimize the risk of the occupants against natural hazards and reusable for other purposes or recyclable for reconstruction [4]. These shelters could also take several mechanisms of construction, which could vary from prefabricated structures, flat-packed structures, or a combination of different salvaged and donated materials constructed by the residence owner [5]. In the case of the Philippines, two transitional shelter designs have been published by IFRC and these were constructed through traditional methods using conventional materials such as

https://doi.org/10.2749/manchester.2024.0604
Distributed by structurae

Assessing the carbon footprint of bridges and a strategy to deliver carbon reductions

Philip Chalk, Joe Stevenson

Mott MacDonald, London, UK

Contact: philip.chalk@mottmac.com, joe.stevenson@mottmac.com

Abstract

As actions to tackle the impacts of the climate emergency start to gain traction across the industry and beyond, reduction of carbon in bridges should be front of mind for bridge engineers. Understanding the impacts of our design and construction work is essential to make meaningful reductions to the carbon footprint of our structures. The whole life carbon of a bridge is known to significantly differ from that of a building structure. A gap in this knowledge was identified across the industry throughout the design, construction and operation life cycle stages. This paper reports on the journey that was undertaken by Mott MacDonald and how this, along with the learning from other consultants helped shape industry-wide guidance via the Net Zero Bridges Group. This work enables whole-life carbon reductions in bridges to be integral to all our projects throughout all lifecycle stages.

Keywords: Bridges; carbon footprint; carbon assessment; decarbonisation; sustainability; net zero

1 Introduction

The need to decarbonise our infrastructure is well understood by this point. This compels the bridge engineer to reduce the overall carbon footprint of the structure, even if each bridge may only be a small percentage of a country's total infrastructure carbon emissions.

Often engineers are reluctant to admit that they can significantly influence the carbon footprint of what they design or build. The argument typically includes a narrow scope constrained by limited funding and the fact that engineers will consider their designs to be already structurally efficient. This latter aspect is partly driven by reducing costs and construction time, but also from an engineer's pride for their work.

There are many things we as bridge and structural engineers can do to influence the carbon footprint and other sustainability aspects of the assets we design. The key is to engage with the topic, undertake your own carbon assessments to understand the process and its limitations, identify carbon hotspots and think how you can reduce these throughout your design whilst still fulfilling the client's requirements. In fact, it is often prudent to challenge the brief if a clear easy win from a carbon reduction or sustainability perspective can be gained.

2 Carbon Assessments

2.1 What is a Carbon Assessment and Why Are They Important?

A whole-life carbon assessment (WLCA) is a method of estimating the total amount of carbon emissions that are produced by a built asset throughout its entire lifecycle. [1]

Forecasting and tracking carbon throughout a design is important to inform design decisions. The choices that can impact carbon emissions most are made at the start of a project. At the concept stage, changing the bridge location, bridge form, materials, span arrangement or construction

https://doi.org/10.2749/manchester.2024.0613
Distributed by structurae

As bridge engineers, are we designing efficient structures?

Gareth T Davies

Cass Hayward LLP, Chepstow, Wales, UK

Contact:gareth.davies@casshayward.com

Abstract

As bridge engineers we should be designing efficient structures, minimising waste and by default minimising carbon emission, but are we?

The paper will look at how design codes define actions and resistances. For actions in particular, some examples of onerous loading requirements will be discussed and how as engineers – particularly in the current climate of reducing carbon emissions – we should be able to challenge some of these requirements.

Some illustrative examples of plate girder bridges will be considered to demonstrate how different interpretation of the design codes can lead to different arrangements of plate thicknesses, stiffeners and weld configurations and will explore the impact these may have on fabrication and construction, cost and embodied carbon.

Keywords: bridges; steelwork; concrete; net zero; carbon; design codes, estimate.

1 Introduction

As bridge engineers we should be designing efficient structures, minimising waste and by default minimising carbon emission, but are we?

At Cass Hayward we have been designing and undertaking independent design checking of bridges – predominately in the UK - for over 40 years and have seen a variety of schemes over this time period.

Historically what we would have considered as efficient was a design which gave our Contractor clients the most competitive solution in a Design and Build tender, but is this how efficient bridge designs should be measured?

This leads to the title of the paper – What is an efficient bridge design?

Different roles (Clients, Developers, Asset Managers, Contractors, Designers) may consider this question and come up with a range of answers see Figure 1.

This paper will explore the question by considering if our Codes of Practice for loadings are becoming too onerous or conservative; and looking at a simple bridge design with varying properties to measure some of the key metrics noted above.

2 Are our Codes of Practice too onerous?

2.1 Role of Independent Design Checker

For Highway and Rail Design in the UK, the role of the independent checker is defined in the appropriate Engineering Assurance documents [1] & [2] and is predominately a check that the designer has provided a structure which is strong enough to carry the loads over the road/ railway / river etc. and is compliant with standards.

However, the scope of the checker is not to advise on elements which are "over designed" but to confirm "if it works". Examples of such scenarios are noted in Table 1.

https://doi.org/10.2749/manchester.2024.0622
Distributed by structurae

A Broadened Approach to the Environmental Assessment in Bridge Design

Vazul Boros, Michael Aleksa, Paul Rosenkranz, Sonia Zajac, Veronika Prändl-Zika

Austrian Institute of Technology, Vienna, Austria

Contact: vazul.boros@ait.ac.at

Abstract

The construction industry must cut its carbon footprint significantly and therefore needs to widen its performance indicators like safety, reliability, availability, and economy by environmental aspects. There are numerous challenges to an objective comparison of bridge design alternatives based on environmental considerations. In addition to the considerable uncertainties in the Global Warming Potential of construction materials the question of setting adequate boundaries for the environmental assessment must be addressed. The aim of the present case study of a typical overpass above a motorway is to illustrate the importance of the interaction between the structural design choices, such as the placement of an intermediate support, and their consequences for traffic. An objective environmental evaluation of bridge design choices must consider both aspects. The importance of such a broadened approach shall be highlighted in the present study.

Keywords: bridges; environmental assessment; global warming potential; uncertainties; traffic simulation; life cycle analysis.

1 Introduction

The Austrian Institute of Technology (AIT) strives to be a leading research and technology organisation at the highest international level for infrastructures, with the vision to successfully address the grand challenges and transformations and thus drive the transformation towards a sustainable and future-proof world. The construction industry is responsible for approximately 50-60% of the global resource consumption and with a share of 53 % it is also the main source of worldwide greenhouse gas emissions, with 12 % contributed by infrastructural constructions such as bridges [1]. Therefore, it is one of the central goals of AIT's Unit for Transportation Infrastructure Technologies to guide the construction industry towards a design and planning process, which incorporates in addition to traditional performance indicators such as safety, reliability, availability, and economy also the hitherto not always duly considered environmental aspects.

Despite the fact, that the standardization of Environmental Product Declarations (EPDs) in the EN 15804 [2] contributed significantly to more objective assessment procedures for environmental impact, still significant challenges remain to be solved. In a previous study, focusing on the Global Warming Potential (GWP) of the main construction materials used in bridge design, we already observed, that the differences between EPDs can be significant [3]. Choosing one single value to represent the environmental impact of a material may therefore be misleading, especially since due to the procurement procedures typically

Reuse of cast-in-place concrete slabs in new structures

Lukas Felber, Matthias Dietz, Ingo Müllers
Schüßler-Plan GmbH, Düsseldorf, Germany

Markus Nöldgen
Technische Hochschule Köln - University of Applied Sciences, Cologne, Germany

Contact: lfelber@schuessler-plan.de

Abstract

This paper presents the approach of reusing existing concrete slabs in new constructions as a method to vastly reduce the environmental footprint of building structures. The general method including structural challenges are described concerning the reused slabs and their needed substructure. A life-cycle-assessment is conducted, stating that the reusage of concrete slab elements is potentially climate- and resource-neutral. The LCA-comparison between a conventional layout design and a design implementing reused concrete slabs shows a reduction of 27% and 32% of carbon and material footprint, respectively.

Keywords: urban mining; reuse; life-cycle-assessment; circular economy; global warming potential; total material requirement

1 Introduction

As the recycling of cement is technically not feasible today, the CO_2- and resource-intensive production of cement from raw materials precedes the manufacturing of any sort of concrete. The piecewise reuse of complete components therefore presents a unique possibility for an almost climate- and resource-neutral supply of structural concrete elements, as almost only energy resources are needed during the manufacturing process. In contrast to the conventional demolition, this urban mining approach demands a selective dismantling of building structures, followed by extracting and potentially repairing the reclaimed concrete elements. Due to the relative structural simplicity and the abundance in concrete structures, the reuse of cast-in-place concrete slabs seems feasible and would have significant ecological benefits. To implement these often 50-year-old elements into new structures, the reused concrete slabs need to satisfy the ultimate limit state (ULS) criteria of today's industry standards and frameworks. Additionally, a substructure of newly produced elements needs to be designed, allowing for an easy reinstallation of the slabs. This paper presents a method for implementing reused cast-in-place concrete slabs in new structural design. Besides identifying significant factors concerning the properties and the ultimate limit state of reused slabs, the necessary substructure of conventionally produced elements will be described based on a generic layout design. A life-cycle-assessment (LCA) will be conducted using the software GaBi to identify the environmental benefits of reusing concrete slabs in new structures.

https://doi.org/10.2749/manchester.2024.0639
Distributed by structurae

Sustainable concrete for the Uithoornlijn Project

Michael Menting & Roy Van de bilt

DuraVermeer Infra Landelijke projecten, Hoofddorp Nederland

Contact; MichaelMenting@hotmail.com

Figure 1. Uithoornlijn after construction

Abstract

The Uithoornlijn project involves the construction of a concrete pavement for buses with tram tracks, with a focus on achieving low CO2 emissions during construction. The largest share of emissions comes from cement production for the concrete. Through smart reduction in cement usage and the incorporation of various substitutions, the CO2 emissions have been reduced to approximately 1,400 tons.

The sustainable concrete mix requires attention to the slow strength development, especially in cold conditions. Insulating the concrete after placement helps retain heat and stimulate strength development. Sufficient time is allowed between pouring and loading the structure, and a maturity-strength relationship is established to manage this process. Risk management measures, such as adding additional dilations, are implemented to prevent damage from frost-thaw cycles and dilatation issues.

Using sustainable concrete mix yields substantial sustainability benefits and contributes to environmental goals. The project focuses on an optimized mix to reduce CO2 emissions without compromising the construction quality. With a well-thought-out plan and risk management, the construction can be successfully executed, making a positive impact on the environment and enhancing the project's sustainability ambition.

Keywords: Infrastructure, sustainability, alternative binders, construction, lightrail, urban, public transport, concrete, technology.

https://doi.org/10.2749/manchester.2024.0647

System reliability accounting for corrosion-induced degradation over time

Simone Celati, Agnese Natali, Walter Salvatore

University of Pisa, Pisa, IT.

Sebastian Thöns

Lund University, Lund, SE.

Contact: simone.celati@phd.unipi.it

Abstract

The remaining lifetime of concrete structures subjected to chloride-induced corrosion has been studied in many papers. However, few studies so far consider explicitly experiences from case studies, jointly several corrosion mechanisms and a system perspective. This paper introduces a methodology to evaluate the time-dependent system reliability for concrete bridges subjected to reinforcement corrosion. Here, both chloride and carbonation induced corrosion is jointly considered building upon the thermodynamic conditions for corrosion. The corrosion propagation is modelled with a structural system reliability analysis where different structural system models for repair and replacement consequences are developed. The developed approaches and models are applied to a bridge case study and the service life extension is quantified.

Keywords: Reinforced concrete bridges; over-time reliability; chloride-induced corrosion; system modelling.

1 Introduction

Concrete bridges are essential components of transportation networks, providing fundamental links for the movement of people and goods. The consequences of their collapse are always high and include both direct costs, related to structural rebuilding and human lives lost, as well as indirect costs such as disruptions in the transportation of essential raw materials and inconveniences for the general population. Despite their relevance, a significant proportion of bridge structures in Italy, as well as in numerous other countries worldwide, exhibit varying degrees of deterioration, primarily attributed to their age together with the lack of consistent maintenance over time and are close to the end of their designated lifetime [1,2]. However, efforts should be devoted in prolonging their service life for sustainability and economic efficiency. In this approach, level 1 verifications, involving the partial factor method, are proved to be inadequate due to the inherent limitations of such a generalized assessment approach, but given their easy-to-be-applied procedure, they can be adopted as an initial step aided at the identification of the less secure elements within a structure. Instead, Level 3 methods, encompassing full probabilistic calculations, appear to be more adequate to achieve a more accurate structural safety evaluation. This approach leads to the computation of the reliability index and, generally, allows the incorporation of supplementary information such as inspection outcomes, material tests, monitoring data, and more. Furthermore, it accommodates the integration of degradation models and the explicit consideration of the time variable. Many authors [3–5] have explored the reliability assessment of reinforced concrete structures facing corrosion degradation. Typically, these studies separately focus on degradation due to chlorides or carbonation. In the case of chloride-induced corrosion, they examine the diffusion process of chlorides as the sole trigger for corrosion, determining the time it takes for corrosion to initiate. This information is then used to predict the development of corrosion and the

https://doi.org/10.2749/manchester.2024.0655
Distributed by structurae

Bristol Temple Meads Railway Station roof refurbishment project

Peter Chong CEng FIStructE MICE FGS, Stephen Wren CEng MICE, Gabor Galyasz MAPM, Duncan Woolsmith CEng MIStructE MICE, Omar Hindi GMICE

Stantec, Reading, UK

Contact: gabor.galyasz@stantec.com

Abstract

This paper focuses on the Bristol Temple Meads station roof refurbishment project, which involves metalwork repairs, painting and re-glazing of the main shed and canopies in this Historic England Grade I Listed Building. The project is presented from a designer's point of view.

The paper focuses on lessons learnt by the design team that could be applied to similar future refurbishment projects.

Keywords: roof refurbishment, historic building, heritage, repairs, structural assessment, defects, analysis, tie bars, forge weld, Non-destructive testing (NDT).

1 Introduction

The Bristol Temple Quarter project will transform over 130 hectares of brownfield land over the next 25 years into a series of thriving, well-connected mixed-use communities.

The regeneration builds on the UN's Sustainable Development Goals to put low-carbon, climate-friendly homes, jobs, and opportunities at the heart of the city, alongside new green spaces.[1]

The Bristol Rail Regeneration Programme is closely linked to the above project. This programme includes projects that are closely related to the Bristol Temple Meads (BTM) station: refurbishing the station roof, improving reliability and efficiency of the station's electrical system, constructing new station entrances, and improving passenger facilities. [2] Network Rail (NR) has also upgraded the track and signalling at Bristol East Junction.

A refurbished BTM will build on its role as the region's largest transport hub. Work will preserve the heritage of this historic station while creating a gateway to Bristol and the West of England fit for the 21st century. [1]

This paper describes how the designers addressed various challenges on the Bristol Temple Meads station roof refurbishment (BTMRR) project. These include how their analysis reduced the capital carbon of the refurbishment, how the design team addressed the potential presence of latent defects in critical structural components of the arched roof, and how the collaborative approach of designer, contractor, client project team and client asset manager contributed to an efficient design process.

2 Project introduction

Bristol Temple Meads station is a Grade I listed structure owned by NR. Main areas of the station are on Figure 1. The last refurbishment was in the early 1990's.

The BTMRR project involves metallic and woodwork repairs, painting and the complete re-

https://doi.org/10.2749/manchester.2024.0664
Distributed by structurae

Assessment of Strength and Stiffness Properties of Wood in Existing Structures

Lilita Ozola, Martins Petersons

Latvia University of Life Sciences and Technologies, Jelgava, LATVIA

Contact: Lilita.ozola@lbtu.lv, lit1oak@inbox.lv

Abstract

In this study specimens cut from intermediate timber floor beams that have been in service for more than 120 years were tested. The objective of this paper is to determine the strength characteristics and stiffness modulus of old wood and examine relationships between different properties. Experimental tests for determining the mechanical properties in bending have been carried out in short-term static loading. Also shear strength and compression strength perpendicular to the fiber direction was determined by tests. It is concluded that the modulus of elasticity of wood during long-term service under load decreases faster than the strength properties. When evaluating the relationship between wood strength and stiffness properties, a weak correlation was found between bending strength and modulus of elasticity. As well as other properties (density, moisture content etc.) didn't show any remarkable correlation significance.

Keywords: strength of old wood; bending strength/ modulus of rupture; modulus of elasticity; compression strength perpendicular to grain, shear strength.

1 Introduction

Adequate selection of the characteristics of the mechanical properties of wood is always a highly responsible task for an engineer performing a technical survey of historical wooden building structures with the aim of assessing their suitability for future use. Experimental destructive methods give the most reliable results, however they are expensive and time-consuming. Moreover, often it is complicated to get sufficient number of specimens from existing structures.

Nowadays some non-destructive methods are developed for assessment of mechanical properties of timber. For example, resistographic method when density of timber is measured basing on power consumption in electronic drilling device. Using density measurements strength of wood may be determined by known correlation equations strength versus density. For old wood it is doubtful suggestion as correlation between wood properties may be moderate or weak.

In many cases it is expected to extend service life of structures due to its importance from an architectural point of view. Then question arises, how much is residual strength of old wood? Are the relationships defined for new wood still valid in existing structures after long-term use under load?

The aim of this work is to examine the physical and mechanical properties (density, bending strength, modulus of elasticity, shear and compression perpendicular to fiber direction), as well as to prove the relationships between some properties for old wood that has actually served in structures of building much more longer than the intended time, nevertheless not degraded by decay or insects .

https://doi.org/10.2749/manchester.2024.0673
Distributed by structurae

Shear reinforcement of Steel I-beams using CFRP composites

Sean Zahra, Jeanette Muñoz Abela

University of Malta

Contact: sean.zahra.17@um.edu.mt

Abstract

This paper presents an investigation on the shear strengthening of steel I-beams with carbon fiber-reinforced polymer (CFRP) materials, particularly using SikaWrap® - 600, and its bonding with steel surfaces using epoxy Sikardur® - 300. Six CFRP installation configurations were tested on a 6" x 3" recycled S235 I-beam (1.3 m) under four-point bending. Configurations consisted of bonding CFRP wrap to the web only, to the web and radii of the beam, and wrapped all around the beam in both a vertical and diagonal orientation.

Vertical and diagonal orientation configurations increase the shear area of the web of the steel section by 140 mm^2 and 170 mm^2, respectively. It was shown that 1.2 mm CFRP strengthening material has the potential for enhancing shear strength at yield by a minimum of 21.42% (for configuration 1) and up to a maximum of 37.5% (for configuration 4). This upper limit enhancement would be equivalent to welding a 2.8 mm S275 steel plate using EN 1993-1-1:2006 guidelines.

Keywords: CFRP Shear Strengthening; Retrofitting; Load-Carrying Capacity; Bond Behaviour, Failure Mechanisms.

1 Introduction

Typically, within any relatively modern building or structure, I-beams will be used as the structural steel. However, if further reinforcement within an existing structure is required, be it due to material fatigue or additional loading requirements, additional steel plates may be welded to the beam to enhance strength and stiffness. This not only presents practical installation difficulties but also can induce tensile residual stresses which may weaken the fatigue performance of the section [1].

Shear failure typically occurs when the shear force exceeds the shear capacity of the beam. The aim of this study is to explore the possibilities offered by the application of externally bonded carbon fibre reinforced polymer composites (CFRP) as an alternative means of strengthening I-beams in shear. This approach may be preferable when shear strengthening is required within locations where welding which produces heat, sparks, and gases is prohibited or not advisable due to safety risks. However, CFRP comes with its own drawbacks, such as cost implication and time required to achieve full strength which may also be an issue. Despite this, the use of CFRP composites for shear strengthening I-beams may have additional benefits given that CFRP materials are lightweight, corrosion-resistant, and have excellent durability. These properties make them attractive for retrofitting existing structures without significantly increasing the overall weight or compromising the long-term performance of the reinforced elements [2].

The study aims to contribute to the body of knowledge regarding alternative methods for structural reinforcement and provide insights into

Seismic Evaluation and Rehabilitation of Steel Structures in the United States

Roberto T. Leon
Virginia Tech, Blacksburg, VA, USA

Jay Harris
National Institute of Standards and Technology, Gaithersburg, MD, USA

Conrad Paulson
Wyss, Janney & Elstner, Pasadena, CA, USA

Contact: rleon@vt.edu

Abstract

The USA has a very significant stock of existing steel buildings that were built before modern design provisions were incorporated into design codes for seismic and hurricane actions. Until about 10 years ago, evaluation and retrofit of structures were based on two documents: (1) *ASCE 31 Seismic Evaluation of Existing Buildings*, and (2) *ASCE 41 Seismic Rehabilitation of Existing Buildings*. Over the past decade, efforts have been made to (1) unify the evaluation and retrofit processes into a single document, with the ASCE 41 edition from 2017 mostly completing this task; and, (2) separating loading requirements, to be kept within a new ASCE 41, and material-specific evaluation/retrofit provisions, to be developed for different construction materials by professional associations. As a result, AISC has recently published *ANSI/AISC 342-22 Seismic Provisions for Evaluation and Retrofit of Existing Structural Steel Buildings* to supplement the 2023 edition of ASCE 41. This document applies to metal buildings, particularly steel ones but includes composite, cast iron, and wrought iron elements. To aid in this task, a new edition of the *AISC Design Guide 15: Assessment and Repair of Structural Steel in Existing Buildings* will be published soon. The paper and presentation will first give some context for the development of the *Provisions*, and then discuss significant changes, including, to name a few: (1) updates to the condition assessment process and its testing requirement; (2) conditions under which default material properties can be used; (3) factors for expected material yield/ultimate strength for different eras; (4) definitions of simplified force-deformation curves for force- and deformation-controlled elements; and (5) performance-based design parameters.

Keywords: Existing structures, rehabilitation, seismic design, steel structures, steel-concrete composite structure

https://doi.org/10.2749/manchester.2024.0690
Distributed by structurae

Create Space For An Extra Intermediate Floor By Jacking

Marco Rubeo, Michael Mollentze, Daniel Harkin

Freyssinet Ltd, Telford, UK

Contact: marco.rubeo@freyssinet.co.uk

Abstract

An intermediate floor has been added to an existing 10 storied office reinforced concrete building in a busy city centre by jacking up the last two top floors by 3.6m. This solution was proposed as an alternative to the demolition of the roof and the building bottom up of the new floors which has allowed to significantly reduce the environmental impact of the project. Perimetral restraints have been installed to guide the structure during jacking and provide stability against wind loads. Jacking has been carried out with primary jacks installed in the axis of all building columns and secondary jacks installed on steel clamps working in friction and prestressed against the columns. Relative vertical movements between the columns have been controlled by a combined use of a synchro-pump and a laser-based monitoring system following the progress of the lifting.

Keywords: additional floor, jacking, environmental impact, clamps, friction, laser monitoring system.

1 Introduction

An intermediate floor has been added to an existing 10 storied office reinforced concrete building in a busy city centre by jacking up the last two top floors by 3.6m.

This solution was proposed by Freyssinet as an alternative to the demolition of the roof and the building bottom up of the new floors which has allowed to significantly reduce the environmental impact of the project.

As preliminary operations, the last two floors (n.9-10) have been laterally restrained by six radial restraints anchored on floor n.8 and then disconnected from the lift shafts. Two radial restraints anchored to the lift shafts have been then added along the disconnected edge.

Jacking has been carried out with primary jacks installed in the axis of all building columns. Steel clamps working in friction and prestressed against the column by PT bars have been installed below and above the column portion to be cut and removed for allowing the installation of the primary jack. Secondary jacks have been installed between the two levels of clamps for unloading the column before cutting.

The lifting has been carried out by a sequence of jack extensions and contractions intercalated with steel support insertions and bracing installation. Relative vertical movements between the columns had to be maintained below the limit of 2mm and this was achieved by a combined use of a synchro-pump and a laser-based monitoring system following the progress of the lifting.

During the vertical movement, a system of radial jacks sliding against the lateral restraints ensured that all restraints remained engaged (even in storm condition) to maximise the horizontal stiffness of the restraint system.

https://doi.org/10.2749/manchester.2024.0698
Distributed by structurae

Reconstruction of a Ukrainian road bridge by use of 3D printed minimass beams

Andy Coward

Net Zero Projects Limited, London, UK

Torben Forsberg

FORSBERGS, Copenhagen, Denmark

Contact: andyc@minimass.net, tof@forsbergs.dk,

Abstract

Minimass is an open "truss-type" concrete and steel beam which creates stiffness and strength through axial compression and tension. The new technique of 3d concrete printing unlocks the potential of this design by allowing the fabrication of these beams at a fraction of the cost of traditional means: no formwork, minimal steel reinforcement, low carbon. The rural bridge in Ukraine is located in Kherson Oblast. The original span was destroyed during the war. The new bridge deck is designed with prefabricated minimass beams, lattice slab concrete panels between the beams and a cast in-situ top slab. The combined use of printed and in-situ concrete leaves various technical issues to be studied, for example the construction joints shall be designed to ensure 100 years' service life. The minimass beam structure is estimated to reduce the material quantities and embodied carbon by 40% in this case.

Keywords: minimass™ beam, printed concrete, external posttensioning, composite truss

1 Introduction

Road and rail bridges in Ukraine have suffered damage and destruction throughout the period of fighting in the country, as they are a key element of transport logistics. According to the State Agency for Reconstruction and Development of Infrastructure in Ukraine [1], 346 bridges have been destroyed (up to the end of June 2023). 41 bridges were re-built during 2022 and it is expected that 40 locations will be re-built during 2023. In addition, the Reconstruction Agency has implemented temporary crossings at a further 85 of these locations. One of these temporary crossing locations was identified by the State Agency for Roads as being a suitable location for the construction of a new type of bridge, to act as a pilot which demonstrates the practical application of 3D printed concrete for infrastructure.

The State Agency for Roads has engaged with a local non-profit organisation called Team 4 UA, who have started to introduce 3D printing for concrete to the Ukrainian market. Net Zero Projects (NZP), working with COBOD International and Rambøll, has developed a design for a new bridge, using the principles of minimass beams, described herein.

The bridge is located just north of the village of Starosillya, Figure 1, at km 54+397 of the road T-22-07 / T-04-03 / Vysokopillia – Velyka Oleksandrivka – Beryslav, in the Kherson Oblast.

https://doi.org/10.2749/manchester.2024.0706
Distributed by structurae

Fast, interactive digital design tools to inform decision making in bridge design

Helen Fairclough, Matthew Gilbert
University of Sheffield, Sheffield, UK

Tom Pritchard
LimitState Ltd., Sheffield, UK

Ian Firth, Daniel Green*
COWI, London office, London, UK
** DG current address: Expedition Engineering, London, UK*

Contact: helen.fairclough@sheffield.ac.uk

Abstract

In light of the climate crisis, it is important to be able to evaluate both embodied and operational carbon quickly and accurately to ensure the best overall decisions are made. This contribution will focus on the use of digital design tools to guide the former, by rapidly identifying the unavoidable embodied carbon associated with the construction of bridges. Practical design tools are introduced in web-app form (LayOpt:BRIDGE) and as a plugin to the Rhino/Grasshopper parametric modelling ecosystem (Peregrine), each giving results in just a few seconds. The speed of these methods facilitates exploration of different sites or materials. The results provide an absolute lower bound on the embodied carbon required, allowing evaluation of the extent to which it is theoretically possible for a given development to be advantageous. Additionally, the benchmark results obtained can be used both qualitatively and quantitatively to inform proposed designs.

Keywords: Optimization; Bridge design; Embodied Carbon.

1 Introduction

The embodied carbon associated with the construction of bridges and other structures is a particularly hard-to-decarbonise aspect of achieving net-zero in the built environment. In the UK, it has been suggested that reductions of 20% in material usage are required through improvements in structural design efficiency [1], such as using optimized structural forms.

The highest potential for influencing the embodied carbon of a project is at the earliest stages of design, where there is most freedom. As decisions become fixed, the possible level of influence decreases, as illustrated in Figure 1. Thus, it is prudent to focus attention on tools that can be used before an initial concept has been fixed.

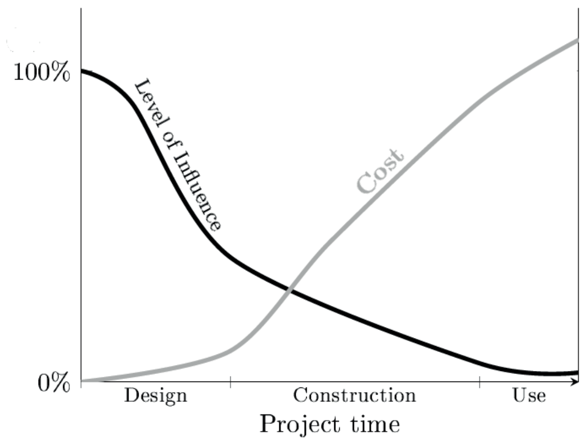

Figure 1 - Changes in the potential level of influence and project costs over time (after [2])

https://doi.org/10.2749/manchester.2024.0715
Distributed by structurae

Application of Carbon Fibre Reinforced Polymer Cable in Extradosed Bridge

Li Dong, Peng Feng

Department of Civil Engineering, Tsinghua University, Beijing, China

Yu Wang

School of Civil Engineering, Chongqing Jiaotong University, Chongqing, China

Contact: fengpeng@tsinghua.edu.cn

Abstract

The extradosed bridge is defined as the structure between the girder and cable-stayed bridges. Carbon fibre reinforced polymer (CFRP) cables are favoured over steel cables due to their lower weight, higher strength, and reduced thermal expansion ratio, rendering them suitable for shorter tower structures. A comparative design study involving the replacement of steel cables and concrete girders with CFRP cables and steel girders in a 220m span extradosed bridge reveals that the cables bear most of the vertical loads. Proper implementation of CFRP cables reduces nonlinear effects and main girder stresses, increases deflection and vibration period, and mitigates the adverse impact of temperature load. This study offers a novel application of CFRP cables in an extradosed cable-stayed bridge, providing economic and environmental benefits, expedited construction, and enhanced structural performance.

Keywords: CFRP cable; extradosed bridge; structural performance; cost; carbon emission.

1 Introduction

Due to constraints in material properties and construction ability, bridges often utilize cables to enhance their spanning capacity[1][2]. Extradosed bridges, serving as a structural system intermediate to continuous girder bridges and cable-stayed bridges, are designed to provide higher levels of external prestressing than continuous girder bridges, along with pylons of lower height compared to typical cable-stayed bridges. Extradosed bridges leverage the benefits of variable-height continuous girders, and cable supports to extend concrete bridge spans to over 200 meters.

The lower height of the pylons in a structural system akin to a cable-stayed bridge leads to increased axial pressure on the main girders[3]. This requires more material to be used in the main girders to withstand it, resulting in a further increase in deadweight. Moreover, the larger nonlinear effect of longer cables with smaller horizontal angles also reduces the efficiency of force transmission. Concrete girders are typically constructed using cantilever casting, a method that demands longer construction time and entails higher risks. The consolidation of pylons and girders commonly employed in extradosed cable-stayed bridges enhances structural stiffness and mitigates construction challenges. However, it

https://doi.org/10.2749/manchester.2024.0724
Distributed by structurae

The client's point of view on the realisation of a geopolymer concrete bridge with recycled concrete aggregates

C.B.M. (Kees) Blom

Engineering department city of Rotterdam, Delft university of technology, The Netherlands

W.D. (William) Schutte, A.P. (Albert) Allaart, J.L.M. (Joep) van Leeuwen

Engineering department city of Rotterdam, The Netherlands

Contact: cbm.blom@rotterdam.nl

Abstract

The city of Rotterdam in the Netherlands has been involved in the North West European Interreg URBCON program. This program includes the development of geopolymer concrete based on the client demands and the application in demonstration projects. Rotterdam acts as client willing to tender for a geopolymer concrete bridge including recycled concrete aggregates. A major difficulty is that the newly developed material has no track record, there is no tendering and building experience and the existing framework (i.e. EC2) is not formally applicable.

This paper shows the interesting observations and the learnings from the client's point of view, based on being part of the URBCON program and the actual design, tendering process and realisation of the geopolymer concrete bridge.

Keywords: geopolymer, concrete, bridge, decks, client, upscaling, tests, tendering, contract, contractor, supplier.

1 Introduction

The city of Rotterdam is a local governmental organization. A major task is to develop and maintain infrastructures (e.g. transportation, sewers, water barriers) and buildings which involve concrete. The tasks should obey political ambitions, including the reduction of CO2e (equivalent) exhausts and usage of raw material resources.

The Interreg project URBCON (2019 – 2023) serves the goal to reduce CO2 (equivalents) production and limiting usage of raw material resources in the process to create concrete. Rotterdam participates in this project to include the role of clients.

On the one hand there is the development of concrete types without (or limited use of) Ordinary Portland Cements (OPC) by use of Alkali Activated Materials (Geopolymer Concrete, GPC) and the use of a considerable amount of secondary (mined) raw materials like sands and aggregates. On the other hand, the society is willing to use these new types of concrete. Clients evidently play an important role as launching customer and acceptance of these developments.

Research projects on new concrete developments have several scales, from molecular, nano, micro to macro levels. From the client's perspective projects involve design, funding, verification, tendering, procurement, permits, project management, construction, usage, maintenance, etc.

https://doi.org/10.2749/manchester.2024.0730
Distributed by structurae

Topology-Optimization-Based Additive Construction for Sustainability

Islam M. Mantawy, Jenna Migliorino, Anthony Mackin, Aly Ahmed, Zaid Hanoun, Tia Donovan, Michael Dustal, Austin Felixbrod, Robert Ruhl, David Sibor, Tyler Tran, Austin Werner, Mike Brown, Ryan de la Cuesta, Tyler Ortzman, and Paul Riter

Rowan University, Glassboro, NJ, USA

Contact: mantawy@rowan.edu

Abstract

For decades, concrete structures have been constructed using cementitious materials using conventional methods through formworks (either cast-in-place or precast). Concrete with sufficient slump is needed to fill up the formwork. This approach results in significant material wastage (placing materials in locations where stresses are low or very low) and increases carbon footprint. Additive construction provides unique opportunities to build form-free structural elements with complex geometry, enabling topology and structural optimization. This paper presents (1) an introduction to topologically optimized compression-only (C-only) structures; (2) the development of concrete mixes for additive construction; (3) an explanation of the additive construction process and equipment used to develop 3D-printed C-only structures; and (4) preliminary results of the 3D-printed C-only structures.

Keywords: Additive Construction; Topology Optimization; Lower Embodied Carbon; Cementitious Materials

1 Introduction

Topology optimization is a method of optimizing geometries using algorithmic models to optimize material usage and layout within a user-defined space for a given set of loads, conditions, and constraints [1]. Topology Optimization maximizes design performance and efficiency by removing redundant material from areas that do not carry significant loads. Topology optimization is used for weight reduction and design challenge solutions for problems like reducing resonance and thermal stresses. The use of topology optimization magnifies the performance of structures and minimizes the amount of material used. Topology-optimized beams are known to perform better than traditional low-weight beam designs. Common topology optimization methods include homogenization [2], evolutionary structural optimizations (ESO) [3], sequential element rejections and admissions (SERA) [4], and solid isotropic materials with penalization (SIMP) [5]. Structural elements designed using these topology optimization methods are commonly constructed using conventional construction techniques (cast-in-place as opposed to additive construction) which limit their use in construction due to complex forming. Additive construction used as a form-free method of application, provides unique opportunities for topologically optimized structures and forms.

Unlike conventional construction, equipment for additive construction is technologically advanced to allow for accurate and precise deposition of 3D-printed concrete in continuous filaments and layers with the desired dimensions and rheology. Automated systems for additive construction include precise concrete mixers capable of proportionally mixing concrete ingredients promptly. The developed 3D-printed mixtures are

https://doi.org/10.2749/manchester.2024.0738
Distributed by structurae

Pile type selection and design of permanent-temporary synthesis structures for underground urban complexes in soft soil foundation site

Jianlan Chen, **Shuang Wu**

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Xin Zhao *

Structural Engineering Department, Tongji University, Shanghai, China

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Contact: 22zx@tjad.cn

Abstract

With the continuous acceleration of urbanization, the development of underground space is becoming more and more widespread. In response to the high cost of underground engineering in soft soil foundation complexes, engineering designers have proposed a design concept of combining the temporary support system for excavations during the construction phase with the permanent and temporary main structural system during the use phase. This paper introduces the composition of the permanent and temporary combination system of the pile foundation engineering of the soft soil foundation complex and the selection and design method of the permanent and temporary combination pile foundation, determines the joint design criteria of the temporary column pile and the permanent engineering pile of the foundation pit, and carries out the joint selection, joint layout and pile body design of the pile foundation. Taking the X102 plot complex project of Shanghai West Railway Station as an example, this paper summarizes the permanent and temporary combination of pile foundation, which can be used as a reference for similar projects. Engineering practice has proved that the permanent-temporary combination of pile foundation in underground engineering of soft soil foundation complex can greatly reduce the engineering cost and meet the social demand of energy saving and carbon reduction.

Keywords: soft soil foundation site； pile type selection ； excavation column pile ； pile foundation layout ； permanent-temporary synthesis

1 Introduction

In the process of underground space development of urban complex projects, soft soil foundation cities are facing the challenges of deep foundation and deep foundation pit design and construction technology. In order to shorten the construction period, reduce the project cost and protect the surrounding environment, the reverse construction method is often used in underground engineering [2,3,9], that is, the horizontal support of the foundation pit in the construction stage is combined with the horizontal floor of the main structure in the use stage, and the vertical support

Additive Manufacturing Techniques for Repairable Braced Frames

Hamdy Farhoud, Islam M. Mantawy

Rowan University, Glassboro, NJ, USA

Contact: mantawy@rowan.edu

Abstract

Special concentrically braced frames (SCBFs) have been used in lateral load-resisting systems over the last decades. SCBFs are designed to provide significant inelastic deformation capacity primarily through tensile yielding and compression buckling. Even though SCBFs satisfy design requirements for life safety, they sustain high levels of damage which results in economic losses due to the need for replacement. This paper proposes a new concept that focuses on concentrating the damage due to tensile yielding and inelastic buckling in a segment of the brace (fuse) while protecting the rest of the brace. This concept enables repairability after high-level seismic excitation by replacing the damaged fuse. The replaceable/recycled fuses are additively manufactured to achieve desired ductility through optimised geometry. The paper includes a description of numerical results from a small-scale specimen tested under cyclic protocol load.

Keywords: concentric braced frames; seismic; repair; deconstruction; additive manufacturing.

1 Introduction

Special concentrically braced frames (SCBFs) represent a distinctive category within the broader class of concentrically braced frames (CBF). These frames are designed as a seismic force-resisting system, specifically engineered to counteract lateral forces induced by seismic events (earthquakes). SCBFs meet both the serviceability and strength limit states. In severe events of earthquakes, SCBFs dissipate seismic energy through yielding in tension, in-elastic buckling in compression, and fracture from low-cycle fatigue, as shown in Figure 1. Moreover, the damage is irreparable, leading to the building's instability and a longer downtime after major seismic events [1].

Researchers over the last few decades have developed devices and structural systems to minimize damage or even fully protect structures during extreme seismic events. Such technologies include seismic isolation [2], passive and semi-active damping devices [3], rocking/self-centring

Figure 1. Inelastic brace buckling failure [1]

Data-driven corrosion risk assessment for structures using ISO 9223

Anders W. B. Skilbred, Sergiu Paereli and Andreas Krapp
Jotun AS, Hystadveien 167, Sandefjord, Norway

Bruna Frydman
Arup, Axeltorv 2K, Copenhagen, Denmark

Graham Gedge
Arup, Blythe Gate, Solihull, UK

Contact: anders.skilbred@jotun.com

Abstract

The new reality of a changing climate influences how infrastructure is designed and built. The materials used for construction are significant contributors to greenhouse gas emissions and need to change to minimise both first use and life cycle impact.

The appropriate choice of materials to enhance initial durability and reduce maintenance throughout an asset's life requires a change in the approach to assessment of risk and mitigation of corrosion.

This paper presents a methodology for a data-driven corrosion risk assessment. The method is built on open-source environmental data, and utilizes the quantitative methods described in ISO 9223. The paper discusses validation of the estimated corrosion risk for a wide range of locations using existing on-site measurements and presents two cases where the methodology has been put to use.

Keywords: Atmospheric corrosion, ISO 9223, open-source global data, corrosion risk, sustainability

1 Introduction

As climate changes, it is more important than ever to build more sustainable and resilient structures for future generations that remain serviceable for many decades. Further, as all structures will inherently have an environmental footprint it is also just as important to build any new structure in the most sustainable way possible. Reducing the environmental footprint during construction means, in simple terms, using less material without sacrificing the function or the service life of the structure. For structural steel, degradation due to corrosion is a durability limiting factor that requires prevention.

Corrosion has a tremendous cost to society. Several studies report that an estimated total cost of corrosion could be more than 6.2 % of the global Gross Domestic Product (GDP) including indirect cost [1, 2]. So, reducing the impact of corrosion by building more resilient structures, at the same time reducing the need for periodic maintenance will

https://doi.org/10.2749/manchester.2024.0762
Distributed by structurae

Preliminary tests for application of carbon nanotubes and *Bacillus sphaericus* bacteria in self-healing cement mortars

Eryk Goldmann, Marcin Górski, Barbara Klemczak

Department of Structural Engineering, Faculty of Civil Engineering, Silesian University of Technology, Gliwice, Poland

Aleksandra Ziembińska-Buczyńska

Department of Environmental Biotechnology, Faculty of Environmental Engineering, Silesian University of Technology, Gliwice, Poland

Contact: eryk.goldmann@polsl.pl

Abstract

Self-healing in concrete is a popular and developing topic, which utilizes both biotic and abiotic mechanisms to close micro-cracks. Nano additives such as carbon nanotubes (CNT) improve the cement material's resistance to cracks but could also influence the survivability of microorganisms in concrete. A combination of CNT and calcium carbonate precipitating bacteria might lead to both improvement of concrete's durability and provide self-healing properties, while increasing the survivability of the microorganisms in the environment of the cement-based material. The presented research focuses on preliminary tests of the influence of the *Bacillus sphaericus* bacteria and low addition of CNT on the cement mortar's strength and survivability of microorganisms in the environment of cement matrix. Strength tests and biotic control were performed to provide data to modify the mix for further tests concerning mechanical properties and survival of microorganisms.

Keywords: cement mortars; self-healing; carbon nanotubes; *Bacillus sphaericus*; cementitious composite.

1 Introduction

Concrete is the most popular construction material in the world and the questions of its durability, deterioration and sustainability are important considerations for advanced, modern materials. One of the important and developing strategies for increasing the durability of concrete structures is the usage of self-healing materials which utilize various techniques to counteract cracks and minor damage that can occur during the life cycle of a concrete structure. Damage of the concrete matrix is unavoidable on the micro level due to mechanical and non-mechanical factors including thermal effects, shrinkage and corrosion. These cracks, even if their influence on bearing capacity might not be substantial, reduce the durability of concrete by allowing the ingress of various corrosive media, reducing its longevity. Self-healing materials approach this problem by providing intrinsic or autogenous mechanisms that counteract micro-cracks appearing during the life cycle of a structure.

https://doi.org/10.2749/manchester.2024.0769
Distributed by structurae

Methodology of a predictive tool for corrosion prediction and risk-based maintenance in reinforced concrete structures.

Paulo Claude, Patrick Rougeau, Jonathan Mai-Nhu
CERIB, Epernon, France

Frédéric Duprat, Thomas De Larrard
LMDC, Toulouse, France

Louis Marracci, Pascal Guedon
Arcadis, Paris, France

Contact: P.CLAUDE@cerib.com

Abstract

This paper contributes to the understanding and prediction of the corrosion condition of steel in reinforced concrete structures while proposing solutions to reduce both financial and ecological costs associated with their maintenance. It presents a comprehensive tool and methodology for predicting maintenance and repair in maritime structures and bridges that are exposed to carbonation and chloride ingress. The tool incorporates various resources, including numerical and analytic models, as well as an experimental results database based on existing literature. This database facilitates the conversion of composition parameters into input parameters for the durability models. The application of this tool is demonstrated on a maritime structure in this paper. Deterministic and probabilistic predictions using the Monte Carlo method are utilized to determine the optimal time for inspection and maintenance operations.

Keywords: Reinforced concrete; Corrosion; Carbonation; Chloride ions ingress; Modelling; Experimental results database; Probabilistic approach.

1 Introduction

The maintenance and repair of civil engineering and maritime reinforced concrete structures pose significant challenges for project owners. One of the main causes of failure in these structures is the corrosion of steel reinforcements [1]. This corrosion process is typically divided into two stages: initiation and propagation [2]. The concrete that surrounds the steel reinforcement has a high pH value, typically above 13 for traditional concrete [3]. This alkaline environment ensures that the steel remains in a passivated state, which protects it from corrosion (pH > 9, Pourbaix diagram [4]). The initiation phase of corrosion occurs when aggressive species penetrate the concrete and alter its cementitious matrix. These substances can cause depassivation of the steel when they reach the vicinity of the reinforcement, leading to the propagation of corrosion.

Chloride ion penetration and carbonation are the two main factors responsible for the initiation of

https://doi.org/10.2749/manchester.2024.0775
Distributed by structurae

Selection and Design of Integrated Coating Systems for Structural Components of All Steel Residential Towers

Shuang Wu, Xin Zhao, Yuzhou Hou, Fang Xu,
Tongji Architectural Design (Group) Co.,Ltd , Shanghai,China

Yi Huang
China Overseas land & Investment LTD, Shanghai,China

Contact: wushuang@tjad.cn

Abstract

The all-steel structure has the advantages of small size and small number of vertical components, and the all-steel structure can realize more spacious apartment types and flexible building space. The steel structure members of the all-steel residential tower need to the use of paint or other methods to meet the requirements of safety, durability and aesthetics. In the aspect of safety, the fire-resistant time of steel structure members is improved by fire-resistant coating. Based on the engineering background of the all-steel residential tower, this paper discusses several reasonable and feasible alternatives of the integrated coating system for steel structure members, and further expounds the selection of the coating scheme and the main design points. At the end of the paper, a 100m and a 150m all-steel residential tower are taken as examples to introduce how to apply the integrated thinking to the selection and design of the coating system, indicating that the integrated coating design can better meet the safety, durability and aesthetic requirements of the all-steel residential tower structural system.

Keywords: All-steel residential tower, integrated painting design, steel structure fire protection design, steel structure anti-corrosion design, steel structure appearance design

1 Introduction

The all-steel structure has the advantages of small size and small number of vertical components, and the all-steel structure can realize more spacious apartment types and flexible building space. The steel structure members of the all-steel residential tower need to the use of paint or other methods to meet the requirements of safety, durability and aesthetics. In the aspect of safety, the fire-resistant time of steel structure members is improved by fire-resistant coating. Durability through anti-corrosion coating to resist the corrosion of steel plates, especially outdoor, underground and wet parts; Aesthetically, the coating system needs to meet the smallest possible thickness, a flat dense surface and a tight fit with steel structure members. At present, the current fire protection design code of the construction industry, steel structure design code for fire protection and anti-corrosion single-function coating has given more clear technical requirements, in addition to the appearance of exposed steel structure

https://doi.org/10.2749/manchester.2024.0783
Distributed by structurae

Electric Curing of Conductive Concrete for Cold Weather

Alyssa Yvette Sunga, Shahriar Abubakri*, Gilson Lomboy, Islam Mantawy

Rowan University, New Jersey, USA

Danielle Kennedy, Benjamin Watts

U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, New Hampshire, USA

Contact: abubakri@rowan.edu

Abstract

This paper presents electric curing of concrete as an effective thermal application method, facilitating the continuous construction of concrete structures during cold weather. Concrete specimens were cast and cured at -15°C for 48 hours, followed by air curing at 20°C. Voltage was applied to the specimens at an early stage to maintain their temperature above the freezing point for the initial 48 hours after mixing while stored at -15°C. The compressive strength of specimens was measured at a 7-day age. Results show that electric curing can linearly increase the temperature of conductive concrete. Additionally, it is demonstrated that a temperature controller can be used to maintain the concrete temperature at a desired level (target temperature) throughout the curing period. The study concludes that electric curing effectively prevents frost damage in conductive concrete, even at temperatures as low as -15°C.

Keywords: Conductive concrete, frost damage, electric curing, cold weather concrete

1 Introduction

Concrete is cured by maintaining specific moisture and temperature conditions to develop the desired mechanical and durability properties [1]. One key factor in this process is the ambient conditions. The weather greatly affects the curing process; the preferred temperature is between 10°C to 30°C [2]. In addition, curing slows down and nearly stops when the temperature is below 0°C. Cold weather condition is defined when the average daily temperature for more than three consecutive days drops below 5°C, according to the American Concrete Institute (ACI) [3]. For cold regions, concrete curing requires extra caution since it is prone to frost damage. If water in the fresh concrete mixture freezes prior to the development of adequate strength, cracks form and lead to long-term mechanical and durability issues. Using cold-weather admixtures, external heating, or insulated blankets are common measures to prevent frost damage. It is also important to monitor the concrete at an early age to check for deformations or any signs of freezing [4]. One way to prevent frost damage to fresh concrete is to accelerate curing or maintain the temperature of concrete above 5°C through thermal applications until concrete achieves sufficient strength.

Electrical resistivity of concrete ranges between 10^5 (for wet concrete) to 10^{12} ohm-mm for dry concrete. This led to dry concrete to act as an insulator [5]. Innovations have led to the development of electrically conductive concrete (ECC) where conductive materials are added so a continuous current flow network is formed [6]. Some common applications of ECC include de-icing

EXTRACTION STRENGTH OF COMPACT COLUMN-PILE JOINTS

Tokuo Shimozono, Keisuke Watanabe, Kei Haraguchi, Takuya Yoshida

East Japan Railway company, Tokyo, Japan

Contact: shimozono@jreast.co.jp

Abstract

Japanese metropolitan railway stations experience high user traffic and demand efficient, space-saving construction methods. In particular, providing foundations for large platform sheds is costly and requires a long construction period. Our team has been researching ways to economize with more compact and efficient column-pile joints with double steel pipes, without using foundation footing. We have focused on enhancing tensile strength by assessing the bearing strength of column-pile joints with anchorage mechanisms that involve anchor and fixing plates. The key purpose is to clarify the degree of resistance when the angle exceeds 45 degrees. The aim of our experiments using eleven different specimens was to establish an evaluation formula for tensile strength and find a correlation between load capacity and the angle between plates.

Keywords: Column-pile joint; Steel pile; Anchor plate; Push-out test, Fixing plate, Mortar injection

1 Introduction

Construction at Japanese railway stations is conducted at night, allowing passengers and trains to use facilities in the daytime, when fresh concrete from construction is allowed to dry. Construction involving the provision of foundations for large platform sheds is particularly costly and requires a long construction period. Therefore, it is essential to find a way to economize on the size of column-pile joints.

The authors have conducted research on joint structures using double steel pipes, eliminating the need for foundation footings [1]. In this study, our purpose was to clarify the degree of tensile strength by assessing the bearing strength of column-pile joints with anchorage mechanisms that involve anchor and fixing plates.

As shown in Figure 1, the steel pipe is filled with non-shrinking mortar, and extraction force is transmitted through the mortar between the anchor plate and the fixing plate located at the top of the steel pipe. Since the strength formula for cases in which the fixing plate is installed inside a steel pipe and the angle between the outer edge of the fixing plate and the inner edge of the reinforcing plate exceeds 45 degrees has not been established, its strength is determined by a punch-out test.

This paper also considers the results of punch-out tests and proposes a method for evaluating maximum tensile strength.

2 Test plan

2.1 Test specimens

A list of test specimens is presented in Table 1. The authors fabricated specimens to simulate the pile-head section of steel pipe piles. Specimen No. 1 (267-06-P) was designated as the standard. The embedded portion of the anchor plate was lengthened for specimens No. 2 (267-12-P) and No. 3 (267-18-P), . For test Specimen No. 4 (267-18-D), the reinforcing steel plate was round with a diameter of 9 mm, assuming that a round steel plate would be welded in place on site of the

https://doi.org/10.2749/manchester.2024.0798
Distributed by structurae

Strain distributions for shotcrete failure in hard rock tunnels

August Jansson, Carlos Gil Berrocal, Ignasi Fernandez
Chalmers University of Technology, Göteborg, Sweden

Rasmus Rempling
Chalmers University of Technology, Göteborg Sweden
NCC, Göteborg, Sweden

Contact: august.jansson@chalmers.se

Abstract

Shotcrete linings are a commonly used support system in hard rock tunnel construction, providing flexibility and minimizing construction time. Understanding the strain behaviour of shotcrete under different loading scenarios and interface conditions is vital for optimizing tunnel support design and ensuring long-term structural integrity. In this study, distributed optical fibre sensors were installed in laboratory prepared specimens, in which the lining was subjected to two distinct loading scenarios: a rock load and a distributed load. The specimens in the study consisted of two concrete layers where the substrate slab was either hydro-demolished or ground prior to casting a top fiber reinforce concrete layer. Key findings from the experiments reveal that specimens with rougher substrate surfaces exhibit higher post-failure ductility compared to those with ground surfaces, suggesting superior performance after peak loading.

Keywords: Shotcrete; Distributed optical fibre sensors; Structural health monitoring; Experiments.

1 Introduction

In hard rock tunnels, sprayed fibre reinforced concrete, or shotcrete, in combination with rock bolts, is the most commonly used lining system. The rock bolts anchor large loose blocks to underlaying rock, whereas the shotcrete carries smaller blocks and loose rock material between the rock bolts. As the shotcrete is sprayed directly on the rock, a bond is formed between the materials and loads on the lining are carried in composite action.

Experiments on shotcrete linings have been carried out previously [1, 2], however, the focus was put on the interaction between lining and rock bolts and characterization of load carrying capacities. Furthermore, previous test setups only considered loads in one direction, not enabling redistribution of forces.

In analytical design of shotcrete linings, as proposed by Barret and McCreath [3], two cases are considered where the bond is either intact or not. If the bond is intact, the load is considered as rigid and transferred as shear forces in the lining to the rock bolts. In the other case, without bond between lining and rock, the load is considered as distributed and the lining acts as a slab in bending, supported by the rock bolts. By considering the interface as unbonded between the materials, the model is conservative, and the probability of overdesigning is high. By investigating the failure process of a shotcrete lining subjected to block loads and distributed loads from rock mass, a

https://doi.org/10.2749/manchester.2024.0806
Distributed by structurae

An Anti-corrosion Method for Concrete Slab with Cathodic Protection

Eri Suzue, Taku Tsujimoto

Honshu Shikoku Bridge Expressway Company Limited, Kobe, JPN

Keiichi Eguchi,

Honshi-Expressway Bridge Engineering Company Limited, Kobe, JPN

Contact: eri-kinouchi@jb-honshi.co.jp

Abstract

Ohnaruto Bridge is a suspension bridge with a total length of 1,629m and has served for 38 years since opening in 1985. In 2001, flaking prevention work and surface coatings as salt damage countermeasures were carried out. Also, cross-sectional restorations were applied to deteriorated sections of the concrete slab. However, after 10 years of the repair work, in 2011, same deteriorations were observed again. Field investigations revealed that the main cause of the deterioration was macro-cell corrosion at the boundary between the repaired and unrepaired sections of the cross-sectional restoration. Impressed current cathodic protection method was adopted as a result of the verification to avoid the re-degradation and to save life cycle cost. This paper reports field investigations of the cause of the re-degradation, a study on cathodic protection, installation work of the adopted protection method, and its maintenance.

Keywords: Reinforced concrete, Macro-cell corrosion, Salt damage countermeasure, Cathodic protection, Life cycle cost, Impressed current system

1 Introduction

Ohnaruto Bridge (Figure 1) is a suspension bridge with a total length of 1,629m and served for 38 years since opening in 1985. The bridge is crossing Naruto strait where corrosion environment is harsh. In 1996, deteriorations due to the chloride attack such as spalling and corrosion were observed at the concrete slab on the 1A anchorage of Ohnaruto Bridge (Figure 2 (a), Figure 3). In 2001, cross-sectional restoration, surface coatings and spalling prevention were applied to the deck [1]. As the cross-sectional restoration, after chipping off the deteriorated concrete and removing the rust from reinforcing bars, anti-corrosion treatment and primer were applied to reinforcing bars, and refilled with polymer-modified mortar. However, same deteriorations were observed again about 10 years after the repair work (Figure 2 (b,c)).

https://doi.org/10.2749/manchester.2024.0814
Distributed by structurae

Enhancing Root-Deck Crack Detection in Orthotropic Steel Decks through Numerical Investigation of Eddy Current Techniques

Praphaphankul Nitipong, Akutsu Ayako, Eiichi Sasaki

Department of Civil Engineering, Tokyo Institute of Technology, Tokyo, Japan

Contact: praphaphankul.n.aa@m.titech.ac.jp

Abstract

Orthotropic steel decks in long-span steel bridges are susceptible to fatigue cracking, especially subsurface root-deck cracks. These cracks, hard to detect visually, can cause significant damage if unnoticed. Therefore, the early detection of these subsurface cracks is crucial in preventing further deterioration and ensuring the long-term sustainability of the bridge. In this study, a novel approach for the detection of subsurface cracks in orthotropic steel decks, utilizing new signal processing techniques based on eddy current technology (ECT), as well as optimizing the configuration of the ECT probes, is proposed. Through numerical analysis, response signals obtained from subsurface crack detection using ECT in frequency domains are extracted and analyzed with the proposed method to develop advanced feature extraction techniques that enhance sensitivity and improve the depth of subsurface crack detection. Additionally, various coil-based eddy current probes are examined to identify the most suitable probe configuration that offers robust performance in detecting subsurface cracks. The findings from this study contribute to the advancement of more effective strategies for subsurface crack detection in orthotropic steel decks by integrating advanced eddy current techniques, feature extraction methods, and optimized hardware configurations.

Keywords: Eddy current, root-deck crack, orthotropic steel deck, bridge maintenance

1 Introduction

The challenge of detecting root-deck cracks in orthotropic steel decks (OSDs) requires extra attention [1]. Traditional visual inspections often failure to detect these cracks due to factors like limited visibility, small initial size, complex geometry, and the presence of coatings [2], as shown in Figure 1. These undetected cracks can lead to rapid structural decline and even catastrophic failures [3]. To prevent severe bridge damage, it's essential to use advanced non-destructive evaluation methods for early, accurate, and reliable detection of these damages.

Eddy current technique (ECT), a promising technique in electromagnetic non-destructive evaluation and testing (NDE&T), is highly effective for detecting internal and subsurface damage in electrically conductive materials. ECT's strengths lie in its ability to identify subsurface cracks, handle surface irregularities, and provide fast data collection along with detailed defect characterization [4, 5]. Additionally, ECT is cost-effective and minimizes the need for extensive preparation, such as surface treatment before and after inspection, making it an ideal choice for examining orthotropic deck bridges. The frequency used in ECT significantly affects the results. Lower frequencies are better for subsurface damage while higher frequencies are suitable for surface damage [6]. Therefore, low-frequency ECT is commonly used for subsurface damage assessment. However, at low frequencies, both the spatial resolution and sensitivity of the detection coil and sensor are reduced due to the skin effect.

Therefore, the Swept Frequency Eddy-Current Technique (SFECT) is a promising variation of ECT that is particularly effective in identifying subsurface damage. SFECT stands out for its ability to detect defects across a variety of materials and flaw geometries. This adaptability is attributed to its use of multiple frequencies, allowing the

https://doi.org/10.2749/manchester.2024.0822
Distributed by structurae

Patch Plate Strengthening of Steel Box Member by Frictional High-Strength Bolts/Studs

Hina Ishiguro, Takashi Yamaguchi

Osaka Metropolitan University, Osaka, JAPAN

Manabu Okumura, Keito Suzuki, Yuta Yamamoto

FaB-Tec Japan Corporation, JAPAN

Contact: sh23616a@st.omu.ac.jp

Abstract

An analytical study was conducted to examine the differences in design and reinforcement effectiveness in patch plate reinforcement using high-strength bolts and studs. High-strength stud bolts, which were recently developed in Japan, allow for one-sided installation. From the obtained analytical results, it was found that the yield load of the high-strength stud bolt was 13% higher than that of the high-strength bolt because of the absence of cross-sectional defects in the main plate, and the rate of increase in slip load twice as large. In addition, it was shown that the thickness of the patch plate could be reduced by 11 mm, and the ratio of the load transmitted to the patch plate was also higher. It has been concluded that the usage of high-strength studs reinforcement is desired from the viewpoint of mechanical rationality and economical aspects.

Keywords: High-strength bolt/ stud bolt; Patch plate; Reinforcement; Load transfer

1 Introduction

In Japan, patch plate reinforcement of steel members has been adopted in recent years to improve the seismic resistance of steel structures and increase their load-bearing capacity. The reinforcement patch plates are connected to the structures through high strength bolted friction joints generally. HTB is in accordance with the Japanese Industrial Standards (JIS B 1186) which is based on International Organization for Standardization (ISO). When using high-strength bolted reinforcement in closed section members of arch and truss bridges, handholes are required and high-strength stud bolts has been proposed to ease their installation.

The cross-sectional view of the patch plate reinforcement using high-strength stud is shown in Figure 1. High-strength stud bolts have been developed in recent years and have not yet been standardized. Studs are attached to existing members by welding, so that no bolt holes are drilled in the main plate. As a result, it can be installed from the external side of the cross-section. On the other hand, high-strength bolts require bolt hole drilling and hand-holes. Since the cross-sectional area of the existing member will be reduced, its bearing capacity is reduced and the patch plate thickness is increased [1].

However, few studies have focused on high-strength stud reinforcement, and so far, detailed comparisons between high-strength stud

https://doi.org/10.2749/manchester.2024.0831
Distributed by structurae

Effect of Column Studs on Column-Pile Joints in Buildings without Underground Beams

Keisuke Watanabe

East Japan Railway Company, Tokyo, JAPAN

Contact: ke-watanabe@jreast.co.jp

Abstract

Column-pile joints without underground beams are becoming a de-facto standard for foundation structures of over-track buildings. In the current design guideline, steel column-pile joints are constructed by embedding the steel column at the top of a cast-in-place concrete pile, and the joint is reinforced by an outer steel pipe. If the joint is to retain seismic performance of the joint with a thinner steel pipe, it will need more reinforcement in the form of studs along the sides of the column and reinforcing bars. Loading tests were conducted with specimens to evaluate performance of the column-pile joint. Specimens with thinner steel pipes and without column studs show smaller strength. However, specimens with column studs and reinforcing bars show greater strength than specimens with thicker steel pipes. From the findings of the experiments above, column-pile joints with thinner outer steel pipes and column studs would seem to be most effective.

Keywords: column-pile joint, over-track building, column studs, loading tests

1 Introduction

In Japan's metropolitan centers, larger station buildings are needed to accommodate the many railway users. However, there is rarely enough land available to construct new station buildings since land in these areas is already developed. On the other hand, space above station platforms or railway tracks has rarely been used until recently. As railway companies give top priority to consistency in daily operations, trains are never stopped even when constructing a building over tracks, adding greatly to construction costs.

Underground beams are generally necessary for architectural structures. It is necessary to support tracks with temporary structures when constructing beams under a railway track, thus construction of underground beams is quite expensive. Therefore, in order to utilize over-track

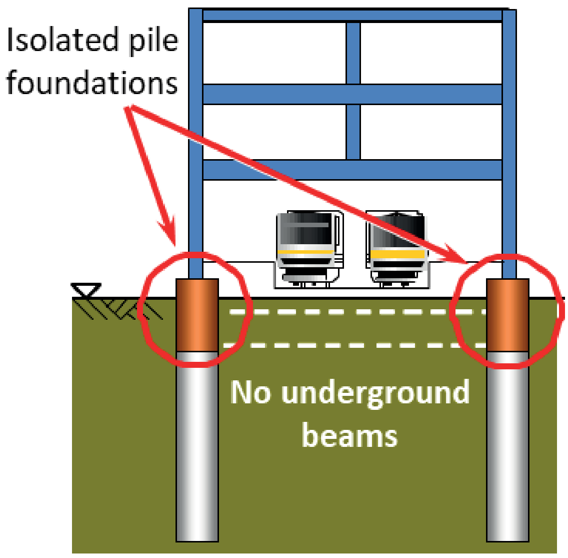

Figure 1. Image of over-track building pile

https://doi.org/10.2749/manchester.2024.0840
Distributed by structurae

Experimental study on the bond-slip relationship between concrete and deformed rebar embedded in grouted corrugated duct

Xu Wang, Zhao Liu, Jiacheng Zheng

School of Civil Engineering, Southeast University, Nanjing, China

Contact: mr.liuzhao@seu.edu.cn

Abstract

The grouted corrugated duct (GCD) connection has appeared as an attractive option for joints between precast bridge pier segments due to its large construction tolerance and low cost. However, the bond-slip relationship between the embedded rebar and the mortar has not been clearly established, which underscores the need for experimental investigation. To this end, 24 pull-out experimental tests were conducted with/without GCD in this study. The results showed that GCD specimens had higher bond strength and plumper bond-slip curve than the specimens without GCD connection. Then, an analytical model based on thick-walled cylinder theory was proposed to determine the bond-slip constitutive curve of GCD connection. Finally, a modified cohesive model was developed at the interface between rebar and dummy rebar in finite element model. The proposed bond-slip model, finite element analysis and tested data match well with each other.

Keywords: Grouted corrugated duct connection; pull-out test; bond-slip; thick-walled cylinder theory; finite element model; cohesive.

1 Introduction

Over the past few decades, the concept of accelerated bridge construction (ABC) has gained global acceptance. The ABC technique may not only mitigate traffic and environmental disruptions but also lead to reduced life-cycle costs, expedited construction timelines, and enhanced construction quality [1]. In practice, the dependable static behavior of joints is a design crux to the prefabricated bridge elements and systems. The precast component interface is discontinuous, constituting structural weak zones [2]. Given the increasing popularity of the grouted corrugated duct (GCD) connection in numerous bridge projects owing to its significant construction tolerance and cost-effectiveness, the mechanical characteristics of these joints primarily rely on the bond anchorage properties of the rebars [3]. Although various specifications have provided the bond-slip relationship of rebar, the rebar is embedded in normal concrete (ENC) directly. The corrugated duct will change the bond mechanism of rebar, but the relative research is still lacking. Meanwhile, compared to ENC connection, GCD connection has the following characteristics:

(1) The diameter of rebar in GCD connection is larger. The diameters of rebar for most researches on bond-slip were mostly ranged from 8 mm to 25 mm [4]. However, the diameters of rebar in GCD connection were always large and ranged from 25 mm to 42 mm [5]. The reason is that the GCD connection is usually employed in merge structures, large-diameter rebar is selected to provide adequate bond anchorage effect.

(2) GCD connection has stronger confinement. The bond stress of deformed rebar embedded directly in concrete is comprised of chemical adhesion, friction and mechanical interaction [6]. For GCD connection, the extra mechanical interaction is provided by duct and it will lead to higher confinement level than the rebar directly embedded in normal concrete.

(3) The materials in GCD is discontinuous. It could be found that the GCD connection is comprised of mortar, duct and normal concrete. As the bond stress is generated, the mechanics is transmitted

https://doi.org/10.2749/manchester.2024.0848
Distributed by structurae

Sustainability as a key design factor from the structure conception stage

Ignacio Navarro, Alejandro Ramos, Jose Maria Lorenzo, Jose Luis Sanchez

TYPSA, Spain

Contact: ijnavarro@typsa.es ; jmlorenzo@typsa.es

Abstract

Sustainability shall be integrated in the structural design from the early conception of the design, focusing on the impact on carbon footprint. A holistic approach to sustainability and its influence on structural evaluation is key to identify the main factors impacting on carbon footprint. Emphasizing the importance of considering sustainability early in the design process, it connects sustainability with the structure's conception. The case study of the HS2 project's Victoria Road Crossover Box is presented. Initially a standard rectangular box, the final structure evolved into a secant multi-shaft design with 5 bubbles, akin to a Caterpillar's shape. The shift challenged the traditional approach, enhancing efficiency, sustainability and structural behaviour.

The impact of the structural efficiency into the sustainability approach is discussed on this paper and relevant conclusion are stated on the key design factors governing the sustainability approach.

Keywords: sustainability; carbon-footprint; high-speed railway; HS2; caterpillar; early design engagement.

1 Introduction

It is out of any doubt that the sustainable future to which our society is committed is driving the construction sector to face a deep paradigm shift. The conventional way of engineering, struggling to optimise the designs to reach highly cost-effective infrastructures as the only key factor, is almost obsolete nowadays. Today, other aspects, such as the environment and the global value for the society, need to be considered to overcome the challenges of this century. The Sustainable Development Goals in 2015, and the European Green Deal, have changed the paradigm in the construction sector to promote sustainable design and practices.

The European Union has created the frame to encourage engineering sector to reassess not just economic viability but also alignment with the sustainable criteria, influencing the likelihood of funding for 'green' projects. As a result, it's driving a transformative change in the construction sector, promoting innovation and steering away from conventional, less eco-friendly methods towards more socially responsible practices. Local regional governments and private clients have also raised the commitment to achieve climatic goals, aiming to obtain a certain level of scoring in private certification systems, such as ENVISION or BREEAM [1].

Extensive research has been conducted on sustainability matters during the past recent years investigating how to enhance the performance to overcome the aforementioned design pressures.

https://doi.org/10.2749/manchester.2024.0855
Distributed by structurae

Deep reinforcement learning algorithm based optimization method for the multiple storey braced steel frame structure under global stiffness constraints

Ming Chen, Xin Zhao*, BingJie Du

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Contact: 22cm@tjad.cn

Abstract

In the process of multiple storey braced steel frame structure design in the real world, after the completion of structural topology design, it is necessary to calculate the cross-section size of the member. The cross-section of the member not only affects the index of the member itself, but also changes the global stiffness of the structure, thus affecting the global index of the structure. The adjustment of the cross-section of the member needs to consider the influence of its own index and the global indices. Designers need a lot of repeated calculations to optimize member cross-section. This paper studies the use of artificial intelligence to replace manual cross-section optimization. The training method of the agent adopts the PPO algorithm in reinforcement learning, and created a structural generator which randomly generates various structural schemes of the plane layout to interact with the agent, so that the agent can accumulate optimization experience and improve optimization ability in continuous trial and error. The training goal of the agent is to complete the adjustment of the cross-section with the least volume of material and the least of computation that satisfy constraints. Compared with manual optimization, agent optimization saves more than 95 % of time.

Keywords: Global Stiffness Constraints, Member cross-section, Reinforcement Learning, Deep Learning

1 Introduction

The design process of multiple storey braced steel frame structure in the real world is generally divided into two stages. In the first stage, designers need to complete structural topology design, including beam and column layout, arrangement of brace. The second stage is to select the cross-section of the members based on the existing structural topology, which needs to meet the global constraints of the structure and the constraints at the member level. Constraints can be divided into driven constraints[1], control driven constraints are crucial for structural optimization, in this study only considers the storey drift, member constraints generally includes stress ratio, stability, deformation, etc. When select member cross-section in the second stage, both of these constraints need to be met simultaneously.

The modification of member cross-sectional dimensions not only affects its own indices, but also affects the global indices of the structure. When designing structures in real life, the

https://doi.org/10.2749/manchester.2024.0864
Distributed by structurae

Experimental study and finite element analysis on seismic behavior of flat vertical-diaphragm stiffened concrete-filled SHS column joints

Jianan Chen, Xin Zhao

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Danlin Feng, Wei Wang

Tongji University, Shanghai, China

Yang Wang, Yi Huang

China Overseas Property Group Co., Ltd., Shenzhen, China

Contact: 22zx@tjad.cn

Abstract

There are great advantages in adopting steel structure for tall residential buildings. In order to study the mechanical properties of the flat vertical-diaphragm stiffened concrete-filled SHS column joints, such as stiffness, bearing capacity, failure mode, and deformation capacity, full-scale tests and finite element analysis are conducted based on the actual case in China. Results of cyclic tests are listed in this paper. Proper design suggestions and a scientific foundation are provided to the application of this kind of joints accordingly. The test results show that the failure mode of specimen FCFST-S-H is ductile failure due to connection loss and the failure mode of specimen FCFST-C-H is observed as connection failure. In both sets of cyclic loading tests, the joint has good energy dissipation capacity. The finite element analysis results are consistent with the test results.

Keywords: vertical-diaphragm stiffened joints; full-scale test; finite element analysis; seismic performance; cyclic testing results.

1 Introduction

CFST columns, also known as concrete-filled steel tube or concrete-filled square hollow sections, are being increasingly popular as structural elements. Filling the steel section with concrete results in increased strength and ductility without increasing the section size. (1) The objective technological innovation has many potential benefits in construction. Consequently, various domestic and foreign scholars have conducted numerous experimental and theoretical studies. This has led to a growing emphasis on the application of CFST column-steel beam connection in research.

Dehghani and Aslani (2) provided a comprehensive review and statistical analysis on the available experimental fatigue data of CFTS joints and while also exploring research gaps in this field. Tort and Hajjar (3) carried out a computational study to investigate the nonlinear response of composite

https://doi.org/10.2749/manchester.2024.0871
Distributed by structurae

Advancements in Shear Resistance Prediction for Concrete Beams: A New Shear Model

Ke Hu

Anhui Transportation Holding Group Co., Ltd., Hefei, China

Xiangyong Duanmu, Dong Xu

Tongji university, Shanghai, China

Contact:duanmu@tongji.edu.cn

Abstract

The shear resistance of concrete beams has been a challenge. This study introduces an innovative shear model based on the critical crack model. By incorporating the concept of a local compression zone, the shear contribution from the upper edge of the concrete is effectively enhanced. An expression for the shear capacity of a concrete beam is derived by assuming an inclination angle for a critical crack. The optimal crack inclination angle is determined through an analysis of extreme values. To assess the reliability of the proposed methodology, the widely recognized ACI-DAfStb database was used. Comparative analyses were conducted between the calculation results obtained by the new model and those derived from the Strut-and-Tie model for deep beams and the truss model for slender beams. The positive results of these comparisons affirm the efficacy of the developed approach in enhancing the accuracy of shear behavior predictions in concrete beams.

Keywords: shear resistance; concrete beams; critical crack; ACI-DAfStb;

1 Introduction

The challenge of addressing shear resistance in reinforced concrete girders has been a persistent concern in the realm of bridge design [1-3]. When subjected to the combined effects of bending moment and shear force, concrete girders undergo the development of diagonal principal tensile and principal compressive stresses. The occurrence of critical cracks ensues when the principal tensile stress is larger than the material's tensile ultimate strength. The formation of diagonal cracks induces force redistribution, leading the structure into intricate nonlinearities.

In the early 1900s, truss models emerged as conceptual tools for analyzing and designing reinforced concrete beams. The earliest truss models assumed a parallel chord truss with compression diagonals inclined at 45 degrees with respect to the longitudinal axis of the beam, neglecting the contribution of concrete in tension [4]. Subsequently, the Strut-and-Tie Model (STM) for deep beams and the truss model for slender beams were developed based on these foundational approaches [5]. Both methods are written into the relevant codes in various countries and have become the main design methods nowadays.

Experimental observations have revealed that critical cracks occur in concrete beams experiencing shear damage. This paper adopts the assumption of a single main crack, allowing for the

https://doi.org/10.2749/manchester.2024.0879
Distributed by structurae

Overturning of Freestanding Cylindrical Structures under Pulse-like Ground Motions

Xun Zhou, Jianzhong Li

Tongji University, Shanghai, China

Contact: lijianzh@tongji.edu.cn

Abstract

This paper focuses on predicting the seismic overturning of freestanding cylindrical structures. Idealized cylinders of different sizes and slenderness are excited by synthetic pulse-like ground motions. A total of 245000 results are summarized in the form of the overturning spectrum. The obtained spectrum, however, shows large motion-to-motion variability. To reduce the variability, the support vector machine (SVM) algorithm is employed subsequently. Three geometry-related parameters of cylinders and twenty-five intensity measures characterizing ground motions are selected as candidate features. Using the minimum Redundancy Maximum Relevance (mRMR) algorithm and forward stepwise feature selection method, the optimal SVM model is determined by which model makes the least false-negative misclassification cases, that is, wrongly predicting actual overturning as non-overturning.

Keywords: freestanding cylinder; overturning spectrum; pulse-like ground motion; support vector machine.

1 Introduction

Past earthquakes have shown the great seismic performance of freestanding structures, such as classical columns [1] and storage tanks [2]. During earthquakes, these structures uplift and rock at the base, limiting the inertia forces imposed on themselves. Nowadays, rocking is widely recognized as a seismic isolation technique and has been exploited in designing new structures. However, it has been reported by accumulated studies that freestanding structures are vulnerable to overturning, especially when subjected to pulse-like ground motions [3].

Since Housner [4] first published the seminal work on the dynamics of a freestanding rigid block, the overturning behaviour of rocking blocks subjected to earthquake waves [5] has been systematically investigated. Nevertheless, it should be noted that these studies investigate the overturning in two dimensions (2D). Recently, several studies have shown that for freestanding structures, the three-dimensional (3D) effect on their seismic overturning is significant[6]. This effect is more pronounced for irregular non-structural components, such as museum artifacts [7] and unanchored equipment [8]. Vassiliou [6] analytically investigated the overturning behaviour of 3D cylinders subjected to an ensemble of ground motions with identical statistics properties. Later, the overturning behaviour was emphasized on a 3D podium, a slab supported by four rocking columns [9]. The results show large motion-to-motion variability of the obtained overturning spectra. Compared with the aforementioned 2D overturning, the 3D overturning of freestanding structures is more sensitive to the parameters that define it and, thus, more difficult to predict.

https://doi.org/10.2749/manchester.2024.0887
Distributed by structurae

Evaluation of Resilience in Displacement Restrain Brace with initial story stiffness and Buckling Restrained Brace

Akine Otani

Tokyo Denki University, Tokyo, Japan, Graduate Student

Takeshi Asakawa, Haruki Yokoyama

Tokyo Denki University, Tokyo, Japan

Contact: 23fma13@ms.dendai.ac.jp

Abstract

Setting prestress disc springs at the end of the PC steel bar of DRB (Displacement Restrain PC steel bar Brace) can provide "initial story stiffness" to the brace before the story displacement reaches the "initial story displacement". This system with disc springs is called DRBS. We evaluated its resilience using time history response analysis under a large-scale earthquake by 10 story-mass system model. In addition, we were shown that the result of summarizing the results of story deformation angles, residual deformations, floor response accelerations, and floor response velocities. Then, the influence in non-structural elements was described as horizontal displacement by the relationship between floor response accelerations and floor response velocities.

Keywords: displacement restrain PC steel bar brace; disc spring; mass system model; time history response analysis; story deformation angle; residual deformation; floor response acceleration; floor response velocity; non-structural element; horizontal displacement

1 Introduction

Japan is an earthquake-prone country. And Japanese building structures are designed using response control analysis with braces systems. The DRB (Displacement Restrain PC steel bar Brace) is one of these bracing systems. The DRB is based on the conventional brace using the PC steel bar and has a predefined stat gap at the end of the bar brace. When the relative story displacement reaches that state which we call "initial story displacement", the bracing system functions to control the displacement [1]. Moreover, setting prestress disc springs at the end of the PC steel bar of DRB can provide "initial story stiffness" to the brace before the story displacement reaches the "initial story displacement". This bracing system is called DRBS. After the story displacement reaches the "initial story displacement", both the DRB and DRBS fully demonstrate the stiffness of the PC steel bar brace [2].

This paper reports the resilience of structures which braced with DRB or DRBS and BRB (Buckling Restrained Brace). Previous research has already shown that the story deformation angles of the building using the DRBS are less than those of the DRB [3]. It means that the "initial story stiffness" reduced structural damage and improved resilience performance compared to using DRB. On the other hand, one of the issues is the lack of consideration for non-structural elements. This is because the structural target performance is

https://doi.org/10.2749/manchester.2024.0896
Distributed by structurae

Heating and Thermal Conductivity Effect Inside High Damping Rubber Bearing at Low Temperature

Shen Jie, Igarashi Akira

Kyoto University, Kyoto, Japan

Dang Ji

Saitama University, Saitama, Japan

Hamada Yuki, Himeno Takehiko

Kawakin Core-Tech Co., Ltd., Saitama, Japan

Contact: shen.jie.34z@st.kyoto-u.ac.jp

Abstract

The temperature dependence and heating effect during cyclic loading of high damping rubber (HDR) make the seismic design of HDR bearings included isolated bridge quite complicated, particularly at low ambient temperature. To elaborate the hysteretic behaviour of HDR bearings, past researchers considered the temperature dependant effect, the thermo-mechanical coupling. However due to the newest pseudo dynamic and real time hybrid loading tests, it seems need to further consideration about thermal conductivity inside the laminated rubber layers and the redistribution of deformation due to the difference of the inner temperature. The heating effect and thermal conduction are investigated in this research to illustrate the heat transfer mechanism within the bearings. A new numerical model involving the temperature dependence of the stress-strain relationship of the rubber was incorporated to simulate how the heating and thermal conductivity effects works together inside each layer of the bearings. The numerical model is validated by the tests of quasi-static cyclic loading and real-time hybrid simulation at −20°C, 0°C and 23°C.

Keywords: high damping rubber bearing; hysteretic model; heat transfer; heating effect; thermal coupling; low temperature.

1 Introduction

Rubber bearings have been widely employed as highly effective isolation devices worldwide for buildings, bridges and other structures [1,2]. The high damping rubber (HDR) bearing is regarded as the promising cost-effective device for application due to its effective and stable isolation properties. However, the HDR bearing shows significant temperature sensitivity, exhibiting not only the temperature dependence leading to higher stiffness at low ambient temperature, but also the heating effect due to the energy dissipation. These factors complicate the time evolution of the device

https://doi.org/10.2749/manchester.2024.0904
Distributed by structurae

Vibration design and dynamic testing for long-cantilevel composite floors equipped with vibration rods in office tower

Yutong Xu, Xin Zhao

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Yang Wang, Jianyun Pan

China Overseas Holdings Limited., Shenzhen, China

Jun Chen

Tongji University, Shanghai, China

Contact: 22zx@tjad.cn

Abstract

Given the growing requirements for architectural space, large-span and long-cantilever floor structures have become prevalent in urban complexes. Large-span and long-cantilever floor structures have low fundamental vibration frequency due to weak vertical stiffness, and generate greater vertical vibration induced by human activity. Human comfort of the floor vibration becomes a determining factor of structural design. To effectively improve the comfort of floor vibration, it is necessary to adopt efficient vibration reduction measures that do not affect architectural functions and have relatively limited costs. This paper mainly discusses the principle of vibration design for long-cantilever floors with vibration rods, as well as the design points in engineering applications. Taking the example of the Lingchao Building located in Shenzhen, China, the paper presents a theoretical analysis and sensitivity study of vibration rods during the design phase of long-cantilever floor structures. Additionally, it describes dynamic testing of floor vibration comfort during the construction phase, providing empirical evidence to validate the effectiveness of the vibration rods in vibration mitigation.

Keywords: vibration rods; dynamic testing; long-cantilever floors; human comfort of the floor vibration; vibration analysis induced by human activity.

1 Introduction

Given the growing requirements for architectural space, large-span and long-cantilever floor structures have become prevalent in urban complexes. Large-span and long-cantilever floor structures have low fundamental vibration frequency due to weak vertical stiffness, and generate greater vertical vibration induced by human activity. Beyond a certain threshold, these vibrations can induce discomfort and psychological distress among occupants. (1) Therefore, in the

Fabrication's role in a world in emergency: reducing environmental impact by collaboration

David Knight, Thomas Dutton, Dewi Uridge, Keefer Erickson

Cake Industries, London, UK

Contact: david@cakeindustries.co.uk

Abstract

The influence that engineers and designers have on improving the sustainability outcomes of construction projects is well documented, but less focus has been given to those further down the supply chain. Whilst the biggest impact on out-turn embodied carbon can be made at the conceptual and project definition stage, it should not be ignored that there is room for improvements throughout the project cycle. Projects are often passed to fabricators as a completed package: fully detailed with no room for influence and improvement by those making the object.

This paper will examine the benefits that can be extracted by the inclusion of makers and fabricators within the design process, and how that closer collaboration can assist in improving the project against a series of performance and sustainability markers.

Keywords: Design; Fabrication; Collaboration; Sustainability.

1 Introduction

While collaborative approaches to design and construction have improved since the processes described in the major reports by Latham (1994) [1] and Egan (1999) [2], the immediacy of the climate emergency requires redoubled efforts across the industry.

Efforts to reduce the overall embodied carbon usage within a project have become mainstream over the last five years [3,4] for the primary design team. However, extending this through to the rest of the supply chain is not a subject that has been significantly explored. Some fabricators and suppliers are engaged in the behaviours that are necessary to address our influence on the climate emergency and would value the opportunity to offer additional improvements to an engaged design team.

This paper reflects the experience of a small fabricator focused on complex and intricate work. Different drivers may apply to larger or more production-oriented fabricators. By looking at recent examples the paper aims to highlight areas of improvement that could be made and also misconceptions that might occur in the early embodied carbon calculation process. It is expected that the general principles that can be drawn from these examples can be extrapolated to larger projects.

2 Cost does not equal carbon

The vast majority of fabrication contracts are let to the lowest cost tenderer. Whilst some consideration is made to baseline quality requirements, the consideration of carbon has never (in our experience) been a criterion for selecting a fabricator. Alternative, fabricator

https://doi.org/10.2749/manchester.2024.0922
Distributed by structurae

Analysing Embodied Carbon for Rural Trail Bridges in East Africa

Nicola Turrini, Faustin Bajeneza

Bridges to Prosperity

Miriam Graham, Lucy Cryer, Charlotte Murphy

Arup

Contact: nicolaturrini@bridgestoprosperity.org, charlotte.murphy@arup.com

Abstract

Bridges to Prosperity (B2P) spent the last two decades designing and building trail bridges to better lives in rural communities and fight poverty caused by rural isolation, with a current focus in East Africa. Accurate carbon factors are crucial for understanding the carbon impact of a structure and influencing the supply chain to reduce emissions. This paper outlines the methodology used to calculate carbon factors tailored to B2P's supply chain. Analysis of B2P A1-5 embodied carbon data, calculated using these factors, is presented to show the relationship between trail bridge span and embodied carbon. The paper also discusses how B2P can use this data to make informed decisions to reduce their bridge's carbon impact. This research contributes to the organization's goal of promoting sustainable and environmentally conscious infrastructure development in East Africa.

Keywords: trail bridges; rural infrastructure; carbon factors; embodied carbon; carbon assessment

1 Introduction

When rivers swell in rural communities, walks to school, the doctor, work, or the market become life-threatening without safe and reliable transportation infrastructure. Bridges to Prosperity (B2P) envisions a world where poverty caused by rural isolation no longer exists. B2P works closely with governments and communities to build trail bridges in isolated communities globally, constructing or supporting over 480 trail bridges, serving >1.7 million people, in 21 countries.

Utilising refined standardised bridge designs and a construction process optimised for remote environments with manual processes has facilitated cost reductions. The cost of a B2P-designed trail bridge is lower than other traditional infrastructure. B2P aims to source materials locally, and those that aren't locally available they then look to repurpose material where possible, including steel pipe and cable from large construction sites and ports. This contributes to a lower embodied carbon. When combined with a cost-share approach, it is feasible for budget-constrained governments to invest in their own rural infrastructure programs. Several studies have shown trail bridges have a high ROI, returning at least 6x the cost in increased economic activity [1]. Additionally, communities with new trail bridges saw a 75% increase in farm profits, a 60% increase in women entering the workforce, a 36% increase in employment income, and a 30% increase in overall household income.

Carbon assessments had not previously been conducted for B2P bridges. This year B2P have collaborated with Arup to upskill B2P staff on embodied carbon calculations and increase understanding of embodied carbon. This article presents the initial outcomes of the work and discusses how B2P can use this data to drive further improvement.

Load Bearing Behavior of 3D Printed Prestressed Segmental Concrete Girders

Marc-Patrick Pfleger, Elisabeth Radl, Osman Esebali, Markus Vill

FH Campus Wien, University of Applied Sciences, Vienna, Austria

Contact: marc-patrick.pfleger@fh-campuswien.ac.at

Abstract

This research discusses the load-bearing behavior of prefabricated girder segments produced by a concrete 3D printing technology. The segments are joined together with grout and are prestressed to form load bearing bending members. Various hollow segments are printed individually where intended cold joints were created. Before continuing the printing process, different joint reinforcements were installed at the cold joints to improve the shear force transmission between the segments. The focus of this research was to observe the segment joints as well as the reinforced cold joints within a segment when high shear stresses are applied. The specimens were observed in a 3-point bending test. The deflection, cracking and failure behavior is evaluated and described in detail based on each specimen's test results and compared to the numerical and analytical results.

Keywords: Concrete 3D printing, bending members, prestressing, segmental girder, bending test.

1 Introduction

Additive manufacturing technologies, often known as 3D printing, are already being used in various industries and are helping to open up completely new production possibilities. This manufacturing method enables cost- and material-efficient production of e.g. prototypes, individualized one-offs or small series without having to provide or produce molds, formwork or other special tools. 3D printing is already used very successfully in industrial processes (mechanical engineering, toolmaking etc.) outside the construction industry. This makes it possible to economically produce parts and components with deviations from common standards or geometries [1]. Currently, there are also numerous international R&D and pilot projects dealing with the use of 3D printing in structural concrete engineering [2], [3]. The developments, some of which are running in parallel, have resulted in numerous approaches to solutions, which can be fundamentally differentiated into technologies for the prefabrication of components or systems for construction site production. Common research goals of the individual projects can often be found in the basic concept of a particular technology:

- reduction of manual labor,
- increase in material efficiency,
- waste avoidance or
- improvement of customizability.

Especially, the fact that the production of concrete - primarily the production of the contained cement - results in a high proportion of climate-impacting gas emissions makes targeted material use desirable. According to studies, this accounts for at least 8% of global CO_2 emissions [4]. Nevertheless, the demand for concrete has been increasing exponentially for several decades due to its cost-effectiveness and broad applicability. If any ecological aspects are included in the considerations, concrete should be used more

https://doi.org/10.2749/manchester.2024.0938
Distributed by structurae

Super-Low-Carbon Footbridge Design

Ben Curry, Callum Fleming
COWI, London, UK

Ben Addy, Ezra Groskin
Moxon Architects, UK

Contact: bncy@cowi.com

Abstract

Through the lens of embodied carbon, this paper compares two recent projects by a single team, for the same client, with similar physical constraints. One has been built, the second is in detailed design stage, and the cumulative lessons for future projects are considered.

Keywords: Footbridges; embodied carbon.

1 Introduction

Moxon Architects and COWI have a track record of successful bridge collaborations. This paper discusses two recent footbridge projects with a particular emphasis on the embodied carbon, and how lessons learnt from the first project informed the second design. Ideas for further improvements are also discussed.

2 Hams Way Footbridge

Completed in 2020, Hams Way Footbridge carries pedestrians and cyclists over the busy Powick Roundabout in Worcester, UK.

The bridge is 220m in length, comprising a 42m trussed-arch main span and long approach ramps with repeated 12m continuous spans. The main span is structural steel supported on leaning reinforced concrete piers on piled foundations. The approach ramps are also steel, supported on single columns on reinforced concrete plinths and shallow foundations.

Figure 1. Hams Way Footbridge, Worcester, UK

Hams Way Footbridge was designed in 2018, before COWI and Moxon routinely quantified embodied carbon in their bridge designs. COWI has since established a carbon management process which includes estimating the embodied carbon associated with each new project and selected historic projects.

https://doi.org/10.2749/manchester.2024.0947
Distributed by structurae

Sustainability and Beauty in Bridge Design

Hector Beade-Pereda

Design Director at Knight Architects, London, United Kingdom

Contact: h.beade@knightarchitects.co.uk

Abstract

Bridge designers have a great responsibility to the planet and future generations. When designing bridges, we must contribute to addressing the current climate and biodiversity emergency and to the industry's awareness of our dual role in causing and addressing this crisis. Bridge designers also have a great responsibility to the users and perceivers of these crossings, as their scale, exposure, and long life make them have a tremendous visual and social impact. The bridges we design must also be functional, appropriately respond to every constraint, meet every technical criterion, and have a cost appropriate for their scale and complexity. This is an article on holistic bridge design, specifically focusing on how to harmonise, when designing bridges, efficiency from a carbon footprint perspective with beauty, so the design of such emotive, prominent, and enduring constructions improves the quality of the built world in multiple ways.

Keywords: holistic bridge design; responsibilities of bridge designers; sustainability; functionality; beauty; aesthetics; perception; emotion.

1 Introduction

Bridge designers have a great responsibility to the planet and future generations. When designing bridges, we must contribute to addressing the current climate and biodiversity emergency. It is part of the designer's responsibility to help achieve zero-emission status in their work as soon as possible. Also, to contribute to the industry's awareness of our dual role in causing and addressing this crisis.

Bridge designers also have a great responsibility to the users and perceivers of these crossings. Bridges have a tremendous visual and social impact because of their scale, exposure, and long life. They are crossed and perceived by countless people, whose experience will be determined by the quality of the work done in their design and construction. Designing something that transforms the territory for centuries must be aesthetically appealing, reflect emotional and cultural values, and raise experiences and feelings.

The bridges we design need to be functional, appropriately respond to every constraint, meet every technical criterion, and have a cost appropriate for their scale and complexity.

Is this an either-or exercise? Is it necessary to drop some of these project aspirations for a bridge to be delivered? The author believes that with a good team that follows an appropriate project methodology, a good client, an appropriate procurement route, and a budget and time allocation suitable to the characteristics of the crossing problem, it is possible to systematically design bridges that respond satisfactorily and simultaneously to all aspects relevant to the project and not only to some of them.

This article focuses, with a more qualitative than quantitative approach, on holistic bridge design, specifically on how to harmonise, when designing

https://doi.org/10.2749/manchester.2024.0955
Distributed by structurae

Humber Bridge side span rocker bearings replacement

John Collins, Peter Campbell
Roughan & O'Donovan, Leeds, UK

James Barnes
Humber Bridge Board, Hessle, UK

Mark Bulmer
AECOM, Leeds, UK

Contact: john.collins@rod.group

Abstract

Opened in 1981, the Humber Bridge (UK) is a suspension bridge carrying a dual carriageway and footpaths. It has a main span of 1410 m, and side spans of 280 m and 530 m. Ensuring that strategic bridge crossings remain safe for operation following unforeseen events is essential. Works to the side span bearings supporting the steel deck box at the concrete towers and anchorages provide a case study of such works. In February 2020, new cracks were identified around rocker bearing welds. Lane closures were implemented and repairs of welded steel plates around the cracks were installed. Subsequent investigations included structural health monitoring, inspections and non-destructive testing. While rocking of the A-frames was observed, stick-slip rotation of the pinned connections was present with flexure in the A-frames induced. These findings justified and helped inform parameters for the temporary replacement of the tower rockers in 2021 and 2022.

Keywords: suspension bridge; Humber Bridge; articulation; steelwork.

1 Introduction

1.1 The Humber Bridge

The Humber Bridge is an iconic landmark crossing the Humber Estuary, connecting Yorkshire and Lincolnshire in the UK (Figure 1). Opened by Queen Elizabeth II in 1981 it was the world's longest single span suspension bridge until 1997 and remains the longest in the UK at 1410 m. It has asymmetrical side spans of 280 m and 530 m (Figure 2). A Grade I listed structure, as designated by Historic England, the bridge plays a vital role in helping the Humber region reach its potential. It is owned, operated and maintained by the Humber Bridge Board (HBB), who collect tolls to finance the crossing. The bridge carries the A15 trunk road, north and south, utilising four lanes with two additional walkways and passes over a main line railway, the A63 trunk road and two other minor roads. On average there are 33,000 crossings per day. Between June 2022 and June 2023 an estimated 120,864 pedestrians and 74,563 cyclists used the walkways.

Figure 1. The Humber Bridge, viewed from Hessle.

https://doi.org/10.2749/manchester.2024.0964
Distributed by structurae

Strategies for saving the existing Infrastructure in Germany

Ioannis Retzepis

KREBS+KIEFER Ingenieure GmbH, Karlsruhe, GERMANY

Contact: retzepis.ioannis@kuk.de

Abstract

In the past decades great efforts have been undertaken in Germany for saving the existing highway and railway infrastructure due to limited financial and natural resources. Sophisticated evaluation methods have been established, which take into account the current state of the structure as well as the results of the recalculation. Furthermore, many repair and strengthening strategies have been developed and applied successfully. In addition, experience with the structure plays an important role as well. The recent strategies which are applied in Germany for preserving the existing infrastructure are presented.

Keywords: Bridges; sustainability; recalculation; retrofitting.

1 Introduction

Most of the existing highway infrastructure in Germany is over 40 years old and those of the existing railway infrastructure even over 70 years old (Fig. 1 and 2).

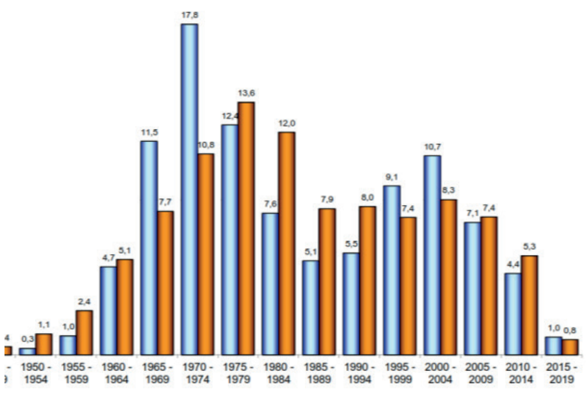

Fig. 1 Age of the highway bridges in Germany [BMVI.de]

Due to the limited financial and natural resources, great efforts have been undertaken in the past decades to save the existing infrastructure in Germany. Many sophisticated evaluation methods have been established which take into account the current state of the structure, the results of the recalculation as well as the experience with existing structures. In addition, repair and strengthening strategies have been developed and applied successfully.

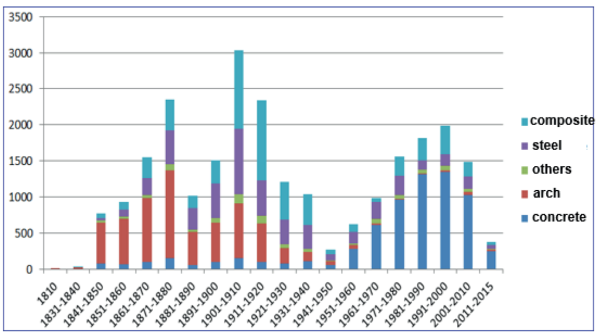

Fig. 2 Age of the railway bridges in Germany [DB Netz AG]

https://doi.org/10.2749/manchester.2024.0972
Distributed by structurae

From the Drone to the BIM-Model - A Method for Creating As-Is Models in Bridge Construction for the Use Case of Digital Bridge Inspection

Johannes Krasa, Sebastian Baumgartner, Markus Vill

University of Applied Science FH Campus Wien, Austria

Contact: sebastian.baumgartner@fh-campuswien.ac.at

Abstract

The implementation of Building Information Management in bridge construction and public administration continues to progress. As part of the research project "Public Administration 4.0", a prototype for digital bridge inspection was developed for this purpose, based on the creation of BIM models of existing bridge structures. International studies attest to the method of photogrammetric point cloud generation based on drone images, for the intended use of existing bridge modelling, a high potential. In the course of a feasibility study, a creation process chain - with the drone to the BIM model - could be derived and the results generated could be considered applicable. The creation process consists of three sequential phases: as-is data acquisition, point cloud generation, and as-is modelling. The generated as-is model of the bridge can be implemented in a BIM software and used for digital bridge inspection and additional use cases.

Keywords: as-is model, BIM, bridge inspection, creation process, drone, mesh, photogrammetry, point cloud

1 Introduction

Building Information Management is becoming increasingly important due to the promotion of digitalisation both in the construction industry and in public administration. The "Public Administration 4.0" research project is focussing on the development of a procedural and technological prototype for carrying out a digital bridge inspection, in which damage recording on the BIM model plays a central role [1]. The creation of the required as-is models proves to be a special task due to the often insufficient as-is data and often challenging accessibility in bridge construction. However, the modelling process based on photogrammetrically generated point clouds has emerged as a promising solution [2] and will be described in more detail in this paper. In the second chapter, the basics of the process components are described. It starts with the creation of as-is models is as a bottleneck in the implementation of BIM for existing buildings, as the BIM approach is model-based. And ends with the main components of the creation process: drone, data set, photogrammetry and point cloud . In the fourth chapter, the creation process is explained in detail and the individual process steps are discussed. The last part of the research contains a list of further process potentials. The final section discusses the results and provides a summarised conclusion.

2 Basics of the process components

2.1 The bottleneck of BIM-implementation

Research and working groups around the world are focusing on the potential of BIM methodology in existing buildings. [3] The research focus is on the one hand on the overall process chain and on the other hand on finding solutions for individual sub-process chains. The creation of as-is models can be emphasised as a key topic with enormous development potential and can also be identified

https://doi.org/10.2749/manchester.2024.0980
Distributed by structurae

Strengthening of the A52 Clifton Stage 2 bridge in Nottingham

Riccardo Stroscio, Akram Malik

Tony Gee and Partners LLP, Esher, Surrey, UK

Frédéric Turlier

VSL Systems (UK) Ltd, London, UK

Malcolm Dangerfield

National Highways, Annesley, Nottinghamshire, UK

Contact: Riccardo.Stroscio@tonygee.com

Abstract

The A52 Clifton bridge is a 6-span post-tensioned concrete bridge, which carries the A52 trunk road in the City of Nottingham (UK). The bridge was built in the early 1970's and comprises two distinct bridges: the South Approach Viaduct and the Main Bridge over the River Trent. In February 2020, severe corrosion was identified within the external strands inside the South Viaduct. Lane restrictions were implemented while further investigations confirmed additional corrosion in the prestressing strands for both superstructures. The assessments revealed shortfalls in strength and led to the design of a deck strengthening solution using additional prestressing tendons. This paper describes the strengthening solution for both superstructures including the construction sequences and discusses the destressing works of a selected number of external redundant strands within the Main Bridge allowing the new strengthening tendons to be fully jacked to their final specified forces.

Keywords: bridge; post-tensioning; box-girders; assessment; strengthening; rehabilitation.

1 Introduction

The A52 is one of the main trunk roads in the National Highways network, joining the A1 towards Grantham with the M1 at East Midlands Airport. It is a commuter route and access via the bridge is key for the city of Nottingham.

The A52 Clifton bridge (Stage 2) is a 21.6m wide 6-span concrete bridge, with both internal and external prestressing, and it carries the A52 trunk road over the River Trent and Clifton Lane.

The bridge was built in the early 1970's as part of the A52 widening project offering 5 additional lanes of traffic over the river Trent, next to the original 1950's bridge (known as the Stage 1 bridge). The crossing comprises two distinct skewed bridges separated by an expansion joint.

The South Approach Viaduct is 82m long and consists of 3 continuous, constant depth box girder spans (Spans 1 to 3, 27.457m/27.432m/27.102m).

The Main Bridge is 159m long and consists of 3 continuous spans (Spans 4 to 6) with an 83m

https://doi.org/10.2749/manchester.2024.0988
Distributed by structurae

Management of Corrosion Damage in Locked Coil Cables of the Galecopper Bridge: Case Study, Detection, Assessment, and Strengthening

Janwillem Breider (Presenting), Charlotte Murphy, Richard Hornby

Arup, Amsterdam/London, Netherlands/United Kingdom

Contact: janwillem.breider@arup.com

Abstract

Corrosion damage in locked coil cables can pose a significant threat to the structural integrity of bridges worldwide. This paper presents a comprehensive analysis of the management of corrosion-related issues in the Galecopper bridge cables to ensure the structural safety of the bridge and discusses their implications for other bridges facing similar challenges. The study encompasses the detection, assessment, and temporary strengthening of damaged strands.

Temporary strengthening measures were designed, constructed, and monitored, focusing on the most severely damaged strands, to allow time for the design and execution of permanent solutions. The findings and lessons learned from the Galecopper Bridge case can serve as a reference for bridge engineers and managers facing similar challenges, contributing to the long-term safety and maintenance of critical infrastructure.

Keywords: Locked coil cables, corrosion, Galecopper Bridge, assessment, strengthening, inspection, renovation, temporary strengthening.

1 Introduction

Corrosion damage in locked coil cables poses a significant threat to the structural integrity of bridges worldwide. This paper presents a comprehensive analysis of corrosion-related issues in the Galecopper bridge cables and discusses their implications for other bridges facing similar challenges. The study encompasses the detection, assessment, and temporary strengthening of damaged strands.

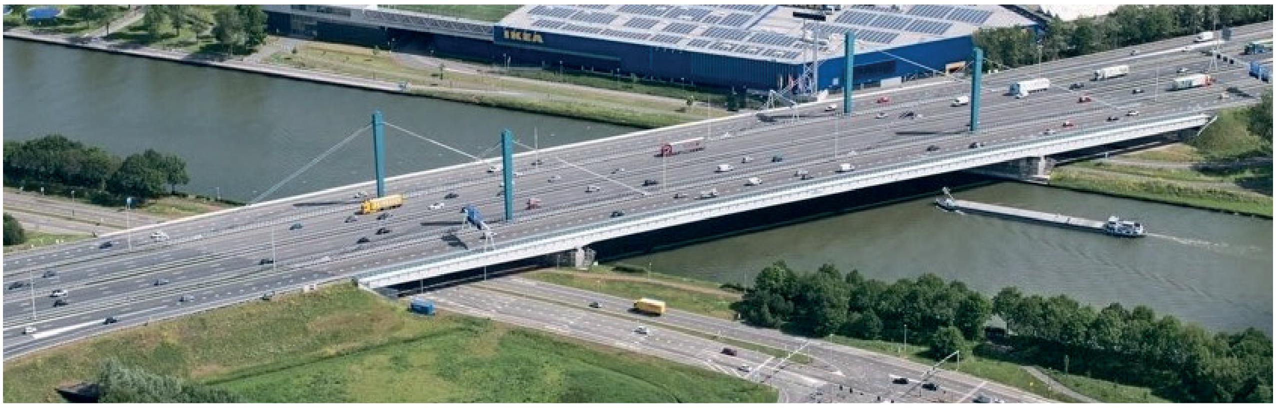

Figure 1: Galecopper Bridge

https://doi.org/10.2749/manchester.2024.0997
Distributed by structurae

Tests of stainless steel circular tubular stub columns with seawater sea-sand concrete infill

Yancheng Cai

Department of Construction and Quality Management, Hong Kong Metropolitan University, Hong Kong, China

Albert K.H. Kwan

Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Contact: yccai@hkmu.edu.hk ; khkwan@hku.hk

Abstract

A series of cold-formed austenitic stainless steel (CFASS) circular tubular stub columns infilled with seawater sea-sand concrete (SWSSC) were designed, fabricated and tested. The CFASS circular tubes had 3 different cross-sections with its nominal outer diameter of 60.5, 114.3 and 165.2 mm. The concrete mixes were of strength levels 35 and 70 MPa. Axial compression tests were carried out to study their structural behaviour in terms of load-strain curve, strength, ductility and failure mode. The test results revealed that the use of SWSSC in place of conventional concrete in CFASS tubes has little effect on the structural behaviour. The test results were also compared with predictions by existing design equations in the codes. It was found that the existing design equations are either un-conservative or overly conservative. A new and more accurate design equation for axially loaded concrete-filled stainless steel circular tubular stub columns was proposed.

Keywords: Concrete-filled steel tubes; seawater sea-sand concrete; stainless steel structures.

1 Introduction

Concrete-filled steel tubes (CFSTs) have become quite widely used in various structural members. Recently, their possible applications in submarine pipeline structures have been explored [1]. There are also investigations on high performance CFST columns made of high-strength steel tubes with proof stress higher than 1000 MPa [2], and those made of high-strength concrete with cylinder strength up to 190 MPa [3]. Due to the acute shortage of fresh water and river sand in many places, especially remote coastal areas [4] such as outlying islands, and the large carbon footprint of cement manufacturing, which has been causing global warming, it has been advocated in recent years to reduce fresh water, river sand and cement consumptions. To solve these problems, various attempts from the materials standpoint have been made, such as using seawater and sea-sand to replace fresh water and river sand, e.g. [5], adding alkali activated binders to completely replace cement, e.g. [6], and adding limestone fines, e.g. [7], to partially replace cement. Attempts from the structural standpoint of employing more efficient structural forms, such as CFSTs, to make better use of concrete and reduce cement consumption have also been made, as in the present study.

The uses of seawater and sea-sand to replace fresh water and river sand have led to the development

https://doi.org/10.2749/manchester.2024.1006
Distributed by structurae

Analysis and Design of Steel Structures Equipped with Pressure-Adjustment Fluid Viscous Dampers for Wind-And-Seismic Double-Excitation Vibration Mitigation

Chornay Morn

Tongji University, Shanghai, China

Xin Zhao*

Structural Engineering Department, Tongji University, Shanghai, China

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Bingjie Du

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Wang Gang

ABC Building Systems (China) Co., Ltd., Shanghai, China

Contact:22zx@tjad.cn

Abstract

Fluid viscous dampers have been successfully and extensively adopted in both existing and new structures to improve structural performance under external excitations, namely wind and seismic excitations. During excessively large excitations, the failure of fluid viscous dampers can affect the structural dynamic performance as the supplementary damping is reduced significantly or completely. This study introduces a pressure-adjustment fluid viscous damper (PA-FVD, hereafter) consisting of pressure-adjusting devices to limit generated axial force and potentially prevent failure associated with its high axial force. Steel structures equipped with traditional FVDs and PA-FVDs is presented to compare important structural performance indices including acceleration, velocity, and displacement time history; additional damping ratio; and maximum structural internal forces under wind and seismic excitations. The analytical results have shown a substantially better structural response when the structure is equipped with PA-FVDs.

Keywords: pressure-adjustment fluid viscous damper; fluid viscous damper; dynamic performance; large earthquake; building structure.

1 Introduction

A variety of revolutionary technologies has been developed to meet the constantly challenging demands to provide structures with better performance under lateral loads, namely seismic and wind loads, and the application of passive energy dissipating devices into the structures is one of the main solutions [1] as the inherent damping ratio of structure is limited and qualitatively small [2]. The following sections briefly discuss the

https://doi.org/10.2749/manchester.2024.1015
Distributed by structurae

Unlocking Modularity Benefits with the Use of Precast Segmental Technology

Martin Rettinger, Sofia Moissiadis, Alex Hückler, Mike Schlaich

Chair of Conceptual and Structural Design, Technische Universität Berlin, Berlin, Germany

Contact: martin.rettinger@tu-berlin.de

Abstract

Modularity plays a key role in the rationalisation of industrially produced consumer goods and the optimisation of their fabrication technologies. With reduced numbers of individual components, rationalisation, automation, and digitalisation of involved processes become more feasible, and reduction of material quantities and process waste can be achieved. The user further benefits from the possibility of replacement and repair of damaged components as well as disassembly and reuse of components at the end of life. To transfer these benefits to loadbearing engineering structures, the authors propose a modular product family for footbridges using precast segmental technology with dry joints and external CFRP post-tensioning. This article describes the applied principles and benefits of modularity, the modular footbridge design and the influence of dry joints and external CFRP post-tensioning on the bridge's overall structural performance.

Keywords: modularity; automation; structural design; footbridge; precast segmental construction; CFRP; concrete; precast; dry joint.

1 Introduction

On a global scale, continuous population growth creates the demand for an ever-increasing rate of building and infrastructure construction. However, not only population growth in absolute numbers, but also the endeavours of billions of people around the world to increase their prosperity and well-being is leading to a demand for new houses, schools, hospitals, commercial buildings, spaces for public life, bridges and other infrastructure.

The delegates of the IABSE Congress 2023 in New Delhi had the privilege to become first-hand witnesses of the enormous growth in Indian urban areas. The organisers of the conference had very aptly chosen the theme "Engineering for Sustainable Development", highlighting the need for future growth to not only meet the short-term needs of society, but to be long-lasting, resilient, adaptable to future generations' needs and to take into account the protection of the climate and natural environment. In many European countries, the maintenance of a large and aging building stock as well as construction in heavily congested urban areas pose further challenges.

A promising strategy to improve the productivity of the construction industry on the one hand, and to achieve greater speed and flexibility, higher quality and less disruption on construction sites on the other, is to utilise the benefits of modularity [1, 2]. The principles of modular design have been applied for many years in the production of consumer goods like cars, electronics, furniture, and even software. By embracing modularity, the total number of individual components within a product family

FLOW Bridge - A modular FRP footbridge designed Through an innovative procurement process.

Davide Meucci

Knight Architects, London, UK

Contact: d.meucci@knightarchitects.co.uk

Abstract

This paper showcases designing, prototyping, and developing the Network Rail FLOW footbridge, an innovative composite FRP bridge meant to replace level crossings in rural and semi-rural UK areas.

The design brief was to create a lightweight, cost-effective, eye-catching modular system as an alternative to existing structures in the Network Rail catalogue.

Adopting a centralised workflow, challenging traditional procurement routes, early involvement of fabricators, unconventional thinking, and a positive attitude led to delivering the first full-sized prototype in under a year. The final design iteration is now set for large-scale manufacturing.

The design prioritised user experience, aesthetics, functionality, material quality, cost, and structural performance. This comprehensive approach resulted in an innovative and visually appealing solution that integrates route-wide repeatability and off-site manufacturing, adaptable to local contexts.

Keywords: FRP; Fiber Reinforced Polymers; Carbon Fiber; Glass Fiber; Flax; Design; Parametric; Modular; Aesthetics; User Experience.

1 Introduction

In 2010, Network Rail, the railway operator in Great Britain, initiated a program to enhance the safety of level crossings, aiming to mitigate risks for the public and passengers while enhancing the network's capability and performance. Notably, the network comprises over 6,000 level crossings, with more than 2,000 dedicated solely to footpaths.

The most effective strategy for enhancing safety and eliminating risks involves eradicating level crossings by exploring alternative routes or substituting them with alternative structures like bridges and underpasses. While these alternatives maintain connectivity, their implementation may entail significant costs, particularly in remote locations, or they may not align with the aesthetic preferences of local communities. For those reasons, the structures currently in Network Rail catalogue often not present a viable business case.

In response to these challenges, Network Rail engaged a multidisciplinary team comprising designers and manufacturers in 2020 to develop an innovative Fiber Reinforced Polymer (FRP) bridge. The primary goal was to create a cost-effective, aesthetically appealing, and easily constructible structure to address these concerns.

During the pandemic, the team developed the first design iteration within a year, adopting innovative processes necessitated by limitations on in-person meetings. They showcased a full-scale working

https://doi.org/10.2749/manchester.2024.1034
Distributed by structurae

Novel engineering solutions for incremental launching of bridges on low-friction materials: case studies of Nowra and Sydney Gateway bridges in Australia

Michal Ambor, Laura Farina, Mauro Sartori

Freyssinet Products Company, Milan, ITALY

Nikolaj Pedersen

Freyssinet Australia, Sydney, AUSTRALIA

Contact: michal.ambor@freyssinet.com

Abstract

Bridge erection by sliding or incremental launching is well appreciated when crossing obstacles like heavy-traffic infrastructures that cannot be temporarily closed, difficult-to-access areas such as rivers or deep valleys, or even environmentally protected sites. Thanks to casting or assembling of structure on a dedicated area with good access conditions, it considerably improves workers' safety.

This article describes the development of novel launching equipment featuring sliding material of fluoropolymer type, vulcanized to engineered rubber components and placed on mechanical articulated supports. Various laboratory tests were performed to validate the solution and define friction factors, which were later confirmed during site operations.

Case studies of application in launching of concrete multi-span double-T deck of Nowra Bridge and steel arch bridges of Sydney Getaway are presented.

Keywords: incremental launching; skidding shoes; heavy loads sliding material; friction test; bearings; extension of lifespan

1 Introduction

1.1 Introduction to launching of structures

The traditional principle of incrementally launched bridges is to build the bridge deck in segments in a casting bed located behind the abutments of the bridge, and gradually push the bridge incrementally until the superstructure is completed [1] [2].

This makes incremental launching a good option when there is limited access under the bridge, for example over water ways or otherwise inaccessible terrain.

The launching technique is used extensively in traditional incremental launching of concrete superstructures, but also used for launching of steel structures.

Sliding of structures using low-friction materials is a key part of construction of bridges in general, but in incremental launching it is key to have precise and reliable of the friction between the sub- and superstructure, to make accurate planning and optimize the launching equipment.

https://doi.org/10.2749/manchester.2024.1043
Distributed by structurae

Potential of the structural application of GFRP bars reinforcement as an alternative for recycled aggregate concrete slabs

Marina Traykova, Roumiana Zaharieva, Irina Kerelezova

University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

Contact:marina521961@gmail.com

Abstract

Two types of reinforcement: GFRP (Glass Fiber Reinforced Polymer) rebars and traditional steel reinforcement, have been used in one way reinforced concrete slabs, made of RAC (Recycled Aggregate Concrete) where 30% of coarse aggregate have been replaced by high quality industrially produced recycled aggregate and NAC (Natural Aggregate Concrete). The results obtained from experimental investigation bring information concerning the crack patterns, evaluation of the crack force, ultimate deflection and bearing capacity. The aim of the present study is to report and discuss the experimental results. Comparisons with a numerical model of the test specimens in ANSYS are made. Some peculiarities of GFRP rebars, RAC and their combination are outlined. The details of the presented investigation provide further information for the engineering practice and contribute to the wider use of alternative reinforcement and RAC in the construction sector.

Keywords: Glass Fiber Reinforced Polymers (GFRP) rebars, Recycled Aggregate Concrete (RAC), slabs, numerical modelling, ANSYS

1 Introduction

The problems of structural safety and high maintenance costs caused by steel bar corrosion have become relevant in the last decades. To avoid reinforcement corrosion in aggressive environments, Fiber Reinforced Polymer (FRP) bars have been proposed. Compared to traditional steel bars, FRP bars have the advantages of being lightweight, high strength and more resistant to some aggressive impacts. The recovery of construction and demolition waste contributes significantly to the sustainable development. In the context of sustainability and circularity in construction, recycled aggregate concrete (RAC) offers many opportunities to improve the resource efficiency. RAC lessens carbon dioxide emission, land required for disposal of construction and demolition waste, and aggregate transportation distance by meeting the desire for environmentally friendly, low-carbon, and sustainable production.

However, due to the porous structure of recycled aggregate, its larger use is hindered by some durability issues, including those related to faster carbonation and bigger permeability and thus menacing the passivation of steel rebars in RAC.

So, the combination of FRP rebars such as Glass Fiber Reinforced Polymer) bars (GFRP) and RAC is one promising combination for the practice, especially in concrete structures subjected to an aggressive environment. According to [1], GFRP has relatively low cost comparing to other kinds of FRPs and makes it one of the most used alternatives to the steel rebars in construction industry.

https://doi.org/10.2749/manchester.2024.1051
Distributed by structurae

Sensitivity Analysis and Optimization of Coupling Trusses under Wind Stiffness Constraints for Multi-Petal Supertall Buildings

Yuzhou Hou, Xin Zhao

Structural Engineering Department, Tongji University, Shanghai, China

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Yutong Xu, Bingjie Du

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Kun Ding, Yiqing Zhao

China Overseas Holdings Limited, Shenzheng, China

Contact:22zx@tjad.cn

Abstract

The multi-petal tower is a favorable alternative type for supertall buildings because of its distinctive appearance and high wind-resistant performance. The coupling trusses are the important member to connect tower petals to form a stable structural system. The selection of its location and material distribution are of great research value. In this paper, the characteristics and application scenarios of various sensitivity analysis methods are compared. And the incremental sensitivity analysis method is selected to assist determining about the optimal arrangement of the coupling trusses of multi-petal tower under the wind stiffness constraint quickly and efficiently. Based on the sensitivity rank of each coupling truss, the cross section of coupling trusses is optimized. The structural cost of coupling trusses is effectively reduced at the cost of tiny stiffness reduction, which provides an efficient and simple optimization method and application case for similar engineering optimization needs.

Keywords: multi-petal supertall building; coupling truss; incremental sensitivity analysis method; wind stiffness constraint; structural optimization.

1 Introduction

In recent years, the proposal of the multi-petal supertall tower reflects the innovation and optimization of the supertall building shape, which makes the appearance of the building look slender and light, and the vertical members concentrated in the triangular corner can provide greater stiffness for the structure, and the transparent space in the middle of the tower petals can allow the wind to pass freely, reducing the vibration response brought by the wind load to the structure (Figure 1)[1].

The structure system of multi-petal supertall tower is complex, which is a good carrier for studying the design of supertall building wind resistance. In this

https://doi.org/10.2749/manchester.2024.1058
Distributed by structurae

Selection and design of wind and earthquake double-excitation vibration mitigation system using fluid viscous dampers for steel residential towers.

Bingjie Du

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Xin Zhao*

Structural Engineering Department, Tongji University, Shanghai, China

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Yang Wang, Yi Huang

China Overseas Property Group Co., Ltd., Shenzhen, China

Contact:22zx@tjad.cn

Abstract

Fluid viscous dampers can be utilized to control structural vibration as well as to meet the requirements of structural stiffness and strength under both wind and seismic excitations. As they can operate with a wide range of excitation frequencies, a double-excitation vibration mitigation system is introduced. Moreover, various deformation amplification devices, double dampers configurations, and fluid viscous damper parameters are comprehensively analyzed for the system selection for wind and seismic excitations. Using the sensitivity analysis method, structural optimization with the proposed system is demonstrated in the case study of a tall steel residential building.

Keywords: A double-excitation vibration mitigation system; fluid viscous damper; structural optimization; tall steel structure

1 Introduction

The steel structure has the characteristics of long period and weak stiffness, and the wind vibration excitation is often the control load that affects the overall performance of the structure. With the continuous development of vibration reduction technology, the shock absorption design under earthquake excitation must be considered in the design process. As an effective vibration damping device, viscous damper can realize multi-excitation and multi-performance vibration damping of structures, improve the comfort, stiffness and strength of structures under wind excitation, and provide additional damping ratio for structures under earthquake excitation.

At present, the viscous damping technology under single excitation of earthquake or wind vibration has been fully studied. However, there is a lack of comprehensive discussion on the design of wind

Optimising material use and pedestrian comfort for the design of a hybrid steel-FRP bridge

Kees van IJselmuijden, Rik van Schaik, Lieuwe Cornelissen, Liesbeth Tromp

Royal HaskoningDHV, Amsterdam, The Netherlands

Dennis Schakel

Systra AB/Ramboll, Malmö, Sweden

Contact: rik.van.schaik@rhdhv.com

Abstract

In an ongoing project in Gothenburg, Sweden, challenging soil conditions necessitated a lighter bridge than the design with the originally planned steel deck. To address this, a hybrid structure with a steel support beam and a Fiber-Reinforced Polymer (FRP) deck was proposed. The steel structure was designed by Systra AB in Sweden, while the FRP deck was designed by Royal HaskoningDHV in the Netherlands. This cooperation on vital structural components called for a collaborative model. A parametric coordination model was created using Rhino/Grasshopper, thereby facilitating the generation of calculations in SOFiSTiK and drawings in Tekla Structures. This streamlined workflow was accessible to all involved parties, ensuring they worked with the most up-to-date design version at all times. The dynamic behavior of the bridge emerged as a significant design challenge during the project. Human-induced vibrations posed limitations on pedestrian comfort, influenced by the interaction between the steel and FRP elements. Initial calculations indicated that merely increasing the bridge's dimensions would not sufficiently address this vibration issue. Leveraging the parametric model, a variation study involving over 200 design variants was conducted. This approach allowed for the retrieval of relevant data, enabling design exploration to select the optimal variant. The chosen bridge design achieved the dual objectives of minimizing material usage while adhering to pedestrian comfort and other design criteria. Through this collaborative and innovative methodology, the project successfully enhanced the efficiency of the bridge design while ensuring optimal collaboration between the two companies.

Keywords: Parametric, vibrations, pedestrian bridge, design exploration, hybrid, FRP, steel, coordination model, collaboration

1 Introduction

In Gothenburg, for the first time in 100 years, a new bridge over the canal is being built. It is a bike and pedestrian bridge designed by architect Malin Mirsch of Systra AB. An impression of the bridge is shown in Figure 1. After considering various options for the bridge, a construction with a steel "arch" was chosen, which supports the deck at two points at approximately 1/3 and 2/3 of the span. The end of the deck is supported on concrete abutments.

Originally, a steel deck was considered. Due to poor soil conditions in the area a lighter Fiber-Reinforced Polymer (FRP) deck was chosen. Dennis Schakel of Systra AB took the FRP course at TU Delft and had previously been in contact with Kees van Ijselmuijden of Royal HaskoningDHV about FRP

https://doi.org/10.2749/manchester.2024.1077
Distributed by structurae

New Precast Concrete Segmental High-Speed Railway Bridges from Lianyungang to Xuzhou: Donghai Viaduct and Daxu Viaduct

Chongju Peng, Binyi Dai, Wenbin Lei

Sun Engineering Consultants International, Inc., Guangzhou, China

Contact: daibinyi@sunengineering.cn

Abstract

Donghai Viaduct and Daxu Viaduct as parts of Lianyungang to Xuzhou high-speed railway bridge, are both the first high-speed railway continuous girder bridges using short-line precast segmental method in China. A big achievement of the project is realizing a high prefabricated proportion of 99.1% and 98.8% respectively for main bodies of both viaducts.

The Accelerated Bridge Construction with the precast segmental bridge technology, using the short-line match casting method and balanced cantilever construction method without closure pour at end spans in the Lianxu project, has built up a good basis for future projects.

This paper introduces several key factors during the construction process of Donghai Viaduct and Daxu Viaduct, including precast yards, construction method, geometry control and BIM, providing more choices for Accelerated Bridge Construction.

Keywords: high-speed railway; precast segmental bridge; prefabrication; geometry control; precast yard; Accelerated Bridge Construction.

1 Introduction

The new high-speed-rail line connects two cities Lianyungang (4.4 million peple) and Xuzhou(8.6 million people), were built to reduce travel time from 2 hours to 45 minutes. Donghai Viaduct (Figure 1) and Daxu Viaduct (Figure 2), as parts of Lianyungang to Xuzhou high-speed railway bridge, were selected to be the pilot viaducts for scientific research of precast segmental high-speed railway bridge. Donghai Viaduct and Daxu Viaduct are both the first high-speed railway continuous girder bridges using short-line precast segmental method in China.

Realizing the needs of rapid development of high-speed railway and significant advantages of prefabrication technology, as well as facing the research blank of precast segmental high-speed railway bridge in China [1], this pilot project was urgently started in August 2018, aiming at providing practice of industrialization technology of bridge design, prefabrication, erection and construction, and further verifying its feasibility and reliability.

The whole scientific research was officially completed in June 2020.

Donghai Viaduct is a three-span, 113.5m continuous rigid bridge with 40 segments, and Daxu Viaduct is a four-span, 161.1m continuous rigid bridge with 57 segments, both allowing a train speed of 350km/h. Short-line match casting method and segmental balanced cantilever construction method [2] were utilized on the both viaducts.

https://doi.org/10.2749/manchester.2024.1083
Distributed by structurae

FLO:RE – A new floor system made of reused reinforced concrete and steel elements

Numa Bertola, Célia Küpfer, Malena Bastien-Masse, Corentin Fivet

Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Contact: malena.bastien-masse@epfl.ch

Abstract

Carefully extracting reinforced concrete (RC) elements from soon-to-be demolished structures and reusing them as load-bearing components is an emerging circular low-carbon alternative to building new structures. As floor construction typically accounts for the most upfront carbon footprint of buildings, this paper presents the design, structural verifications and construction process of FLO:RE, a new floor system built with reused saw-cut RC slab elements and steel beams. To value all pre-existing properties, the new system reuses the RC elements in bending, taking advantage of the existing steel reinforcement. The life-cycle assessment (LCA) shows that the upfront carbon footprint of the reused system can be as low as 5 $kgCO_{2,eq}/m^2$, reducing by up to 94 % compared to conventional RC flat slabs. The construction and monitoring of a 30-m^2 mock-up demonstrate the new-system construction ease and structural performance. This study proves the technical feasibility of reusing old RC slab elements in new floor systems.

Keywords: structural design, component reuse, reinforced concrete floor, life-cycle assessment, embodied carbon, circular economy, concrete reuse

1 Introduction

Concrete is not only the most used construction material worldwide, with an estimated yearly consumption approaching 30 billion tons (1): it is also the most discarded construction material, e.g., accounting for about 35 % of Swiss demolition waste (2). Today, even if in good condition, discarded concrete is crushed and, at best, downcycled as aggregates in new concrete mixes, where it partly replaces natural stone aggregates. Still, this process does not reduce upfront carbon emissions as the same or even higher cement quantity is needed for these mixes (3), and cement is responsible for the main part of carbon emissions during concrete production.

Figure 1. FLO:RE mock-up, made of reused reinforced-concrete and reused steel elements.

https://doi.org/10.2749/manchester.2024.1092
Distributed by structurae

Modular construction and component-based bridge design to minimise waste

John Armitage
Ramboll, Southampton, UK

Philip Robinson, Musa Chunge
Laing O'Rourke, Dartford, UK

Contact: john.armitage@ramboll.co.uk

Abstract

Modular construction and component-based design present significant opportunities to improve the efficiency of the design and construction process for bridges. Development of a lean system for the construction of bridges in recent years has driven significant increases in construction productivity. The associated programme savings have led to environmental benefits including carbon savings from reduced timescales on site and reductions in associated preliminaries. The system also facilitates reduction in numbers of people required on site.

A modular system was developed for construction of bridges for HS2 at Birmingham Interchange. Here the system resulted in savings of 8 weeks in the construction of bridge abutments, as well as an 8% reduction in embodied carbon for the abutments and wingwalls, and a reduction of construction labour for the abutments of 84%. Subsequent schemes have seen further development of the system and repeating and increasing benefits.

Keywords: DfMA, modular, sustainability, concrete, bridges

1 Introduction

While components such as precast beams have been used for bridge superstructures for a number of years, the use of component-based design and construction has been less common for bridge substructures. A component-based system was used for four new bridges for HS2 at Birmingham Interchange, and this has led to significant improvements in productivity and reductions in embodied carbon. This challenges traditional design methodologies and workflows. It has also enabled learning to be carried through to subsequent schemes, driving continuous improvement.

2 Development of modular bridges for HS2 Birmingham Interchange

2.1 Background to modular bridges

Offsite manufacture has the potential to deliver improvements to bridge construction processes, by allowing elements to be constructed in advance in factory-controlled conditions, thereby taking construction activities off the critical path. It has the potential to move work activities from site to factory, smoothing labour demands, allowing more of the labour force to work close to home and in

https://doi.org/10.2749/manchester.2024.1100
Distributed by structurae

Computational modeling of flat slabs with openings reinforced with HPFRC under punching shear stress

Igor de Almeida Gonçalves, Orlando Matheus de L. Almeida, Leandro Mouta Trautwein, Luiz C. de Almeida

Universidade Estadual de Campinas (UNICAMP), Campinas, BRA

Rafael Sanabria Díaz

Delft University of Technology, Delft, NLD

Contact: igor.goncalves.ia@gmail.com

Abstract

Flat slab structures have been largely studied over the last decades since its structural behavior presents complex phenomenon, particularly the punching shear. The implement of openings near the columns is a common procedure and can affect the slab punching shear capacity. The high/ultrahigh-performance fiber-reinforced concrete (HPFRC/UHPFRC) has been demonstrated an alternative for structural reinforcement and connections. In this context the study of reinforcing the shear punching region with HPFRC has been carried out and showed positive results in terms of punching shear strength. This research carried out the simulation of a flat slab structure with openings reinforced with HPFRC in the punching region. The validation of the numerical model is done by comparing it with the results obtained from the experimental test and the behavior of the slab in relation to the shear caused by the punching. The numerical model will be developed by the commercial finite element software ATENA. Finally, a parametric study was conducted to evaluate the influence of the slab opening and the improvement in this behavior with the presence of HPFRC reinforcement in the column region.

Keywords: Reinforced concrete; Flat slabs; Parametric structural design; Punching shear; HPFRC.

1 Introduction

Over the past few years, concrete technology has been developing different types of concrete with the presence of fiber that improve their mechanical properties. And among these materials are high/ultra-strength concrete with fiber reinforcement (HPFRC/UHPFRC), being a new type of concrete with unique characteristics, such as a low wat-binder ratio, the inclusion of pozzolanic materials, high tensile strength and low permeability. The use of these concretes with advanced characteristics has been used in various structural applications aiming to design slender, lighter and more sustainable structures due to the possibility of minimizing material consumption.

Due to its high tensile strength and good toughness, it has proven to be an excellent solution for reinforcing structural elements subjected to shear stress, such as slab-column connections in flat slabs where there is a high concentration of shear stress and bending moments in a small area of the structure. Isufi and Ramos [1] carried out a study reviewing tests carried out using HPFRC as structural reinforcement in flat slabs subjected to punching, and a better final performance in the ultimate limit state and serviceability of the slabs was observed, increasing their capacity of shear resistance and better control of cracking in the internal region. Recently, Isufi et al. [2] investigated the behavior of large flat slabs with the hybrid use of normal strength concrete (NSC) and HPFRC. The results of these experimental tests showed better

https://doi.org/10.2749/manchester.2024.1108
Distributed by structurae

Sensitivity analysis of controlling indices and structural optimization for reinforced concrete shearwall residential towers

Sheng Yang

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Xin Zhao*, Yuzhou Hou

Structural Engineering Department, Tongji University, Shanghai, China

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Contact: 22zx@tjad.cn

Abstract

Reinforced concrete shearwall structure has been widely used in high-rise and super high-rise residential towers because of its high stiffness, high damping, low cost and good adaptability of component layout. Shearwall structure assembly are composed of shearwall limbs and coupling beam component. The shearwall is generally arranged along the vertical height, the lower part extends into the basement, and finally supports on the foundation. In addition, due to the needs of the entrance hall at the bottom of the residential tower or commercial functions, some shearwall assembly are often converted into frame structures at the bottom of the building, which is called frame-supported shearwall assembly. The structural system composed of full-height shearwall is called full-height shearwall structure, and the structural system composed of partial full-height shearwall and partial frame-supported shearwall is called partial frame-supported shearwall structure. The shearwall structure component need to consider both vertical gravity and lateral load to design the strength, stiffness and comfort of the structure. This paper studies the design of shearwall component of residential towers with a height of 100-200 meters, and adopts sensitivity analysis method to analyze the control indexes of components with different heights and positions. It is found that the design of low-zone components is usually controlled by the requirements of seismic ductility, while that of middle-zone components is usually controlled by the requirements of stiffness under earthquake or wind loads. High-zone components are usually controlled by structural requirements. On the basis of sensitivity analysis, this paper further discusses the design optimization method and flow of shearwall assembly. Finally, the sensitivity analysis and optimization design methods are discussed based on a real case of residential tower. The case analysis and optimization results verify the effectiveness of the relevant analysis and design methods.

Keywords: Reinforced concrete shearwall residential towers, shearwall assembly, frame-supported shearwall assembly, performance control index, sensitivity analysis, optimal design method.

https://doi.org/10.2749/manchester.2024.1118
Distributed by structurae

Sensitivity Analysis and Optimization of Coupling Trusses under Earthquake Stiffness Constraints for Multi-Core Supertall Buildings

Dinan Shao, Yutong Xu

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Yuzhou Hou, Xin Zhao

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Structural Engineering Department, Tongji University, Shanghai, China

Zhongjun Yu

Tongji Architectural Design (Group) Co., Ltd., Shanghai, China

Contact:22zx@tjad.cn

Abstract

Multi-Core Supertall Buildings is connected by coupling trusses, whose main structural feature is significantly different from traditional core-tube structures. The strength of the connection between the coupling trusses and the main structure is the main influence factor of the structure index and the bearing capacity of the main components. Therefor sensitivity analysis should be conducted on the impact of the coupling trusses and adjustments should be taken to control the structure index. The paper takes a multi-core supertall as an engineering case to explore the impact of the coupling trusses under earthquake stiffness constraints on the structural performance. The case showes that sensitivity analysis can comprehensively test the impact of coupling trusses on multi-core supertall buildings and the key parts that need to be strengthened, which improved the performance of the structure, promoted the rationality and economy of engineering design.

Keywords: Multi-Core Supertall Buildings, Coupling Trusses, sensitivity analysis

1 Introduction

With the development of office buildings, the demand for large space is increasing rapidly. The frame-corewall structure is one of the most commonly used structural system for high-rise office buildings. Separating the core tube from the frame in order to release the spatial layout of the building is becoming an increasingly common design method for office buildings. Multi-Core Supertall Buildings with large space is the separation of the corewall and frame which bring new features and challenges to the traditional structural system. It has become the focus of attention to deal with the irregular layout of the structure brought by the building demand.

Existing literature has summarized theoretical research and design practices for Multi-Core

https://doi.org/10.2749/manchester.2024.1127
Distributed by structurae

Bridge Rehabilitation with Thermal Spray Zinc Coatings

Martin Gagné

ZELIXIR Inc, Toronto, ON, Canada

Martin van Leeuwen, Bernardo Duran

International Zinc Association, Durham NC, USA

Contact: mgagne@zelixir.ca

Abstract

Rapid overconsumption of natural resources is a primary driver of climate change. Reinforced concrete and steel, the two primary construction materials for bridges, have a heavy environmental footprint and can fail prematurely from corrosion. Extending the lives of existing bridge structures reduces mining and processing activity needed to produce new construction materials. Thermal spray zinc (TSZ) coatings have proven to be very durable for protecting and extending the lives of both reinforced concrete and steel bridges. Corroding reinforcing steel in concrete structures can be protected using TSZ external anodes. The anodes easily adhere to the contours of the bridge and colour match with the concrete. Steel bridges can be protected with TSZ coatings alone or as painted 'Duplex' TSZ coatings. TSZ coatings can be applied in the factory or in the field, making them ideal for the rehabilitation of existing bridge structures showing signs of corrosion.

Keywords: Corrosion, rehabilitation, thermal spray zinc, external anodes, cathodic protection, metallic zinc, duplex zinc coatings, zinc

1 Introduction

Reinforced concrete and steel are two widely used construction materials. Concrete is a mixture of cement, aggregate and water with good compressive strength. It is reinforced with steel bars to provide better tensile strength. Steel is an iron-carbon alloy, strengthened with the addition of other elements. In 2020 global cement production was 4.2Bmt [1], while crude steel production was 1.9Bmt [2].

The production processes for the main component of each material, cement and iron, both have a high carbon footprint. In 2020, CO_2 emissions for cement were reported as 988kg per tonne of cement [1]. For steel, CO_2 emissions were reported as 1,890kg per tonne of steel [2].

Based on the high volume of production of both materials, the manufacture of cement and steel are major contributors to greenhouse gases that contribute to climate change. In 2020 global CO_2 emissions for cement production were 4.1Bmt, and 3.6Bmt for steel. Further emissions will arise from production of other components, transportation, and installation, all adding to the carbon footprint. Extending the life of existing structures will be an important way to reduce CO_2 emissions from the production of new construction materials.

https://doi.org/10.2749/manchester.2024.1134
Distributed by structurae

ElevArch® - Jacking heritage masonry bridges to allow for railway electrification

Kevin Bennett

Freyssinet Limited, Telford, UK

Hamish Harvey

Bill Harvey Associates Limited, Penarth, UK

Contact: kevin.bennett@freyssinet.co.uk, hamish@billharveyassociates.com

Abstract

Hundreds of Britain's masonry railway bridges are in the way of Network Rail's electrification programme. ElevArch® is a unique method to raise a masonry arch to create sufficient space for the overhead line equipment to be installed beneath. The full-scale demonstrator on East West Rail in 2016 proved the method was viable by successfully lifting a farm accommodation bridge by 900mm.

The secret to its success is the careful sequencing of operations to control the arch thrust when the arch is cut free from the foundations. The method is cheaper than the two current alternatives of track lowering and bridge reconstruction and is, therefore, of interest not just for heritage structures but across the railway network. With Network Rail's electrification programme restarting after a long pause, it is time to reconsider ElevArch as a viable and cost-effective option. This paper explains ElevArch in detail to enable designers, contractors, and asset owners to assess whether the technique could be suitable for their structures.

Keywords: ElevArch, masonry arch, bridge jacking, railway electrification, route clearance, heritage structures, sustainability.

1 Limitations of existing methods

Many of Britain's historic masonry arch bridges are in the way of railway electrification schemes because there is not sufficient space beneath the arch to fit in the Overhead Line Equipment (OLE). The two principal solutions for creating substantially more headroom are track lowering and bridge reconstruction and both can present problems.

Track lowering can cause or exacerbate flooding and may require geotechnical works to protect bridge foundations, which are often shallow. Excavation and re-laying of track typically extends over several hundred metres to limit gradients. If the structure is close to another asset, such as a station, altering the track level might not be viable. The method is very disruptive to the rail user and is expensive, typically £1,5-2 million per bridge.

Bridge reconstruction usually involves demolishing the masonry arch and installing precast reinforced concrete portal beams in its place. There are risks associated with demolition and with heavy cranage, especially if overhead utilities are present. Access for the crane and delivery of precast concrete can be problematic. The removal of the arch destroys any heritage value. The solution usually requires two weekend possessions of the

https://doi.org/10.2749/manchester.2024.1140
Distributed by structurae

Neural Network Dynamic Metamodels for a Highly Detailed Cable-Stayed Bridge Finite Element Model

Koravith Tiprak, Kouichi Takeya, Eiichi Sasaki

Tokyo Institute of Technology, Tokyo, Japan

Contact: tiprak.k.aa@m.titech.ac.jp

Abstract

Despite Finite Element Analysis (FEA) having a strong theoretical foundation with high accuracy, its significant limitation in computational time is highlighted when a large number of FEAs is required. This study thus desires to address the issue by investigating the capabilities of Neural Networks (NNs) in being surrogate models of highly detailed FE models. The generalized processes of the NN model development and the exemplar architectures of the NN models for predicting the frequencies and mode shapes are first proposed before being applied to the task of high dimensional Finite Element Model Updating (FEMU) of a complex cable-stayed bridge. Then, the aspects of the computational time, accuracy, and challenges of the NNs in future works are discussed. Results from the FEMU that utilizes the multi-restart Genetic Algorithm (GA) emphasize the efficiency of the NNs in leading the GA toward an updated FE model that better replicates the actual dynamic responses.

Keywords: structural health monitoring; bridges; cable-stayed bridges; finite element model; finite element model updating; surrogate models; machine learning; neural networks; genetic algorithm

1 Introduction

Due to the strong theoretical foundation and high accuracy in describing the actual structural behaviour of Finite Element Analysis (FEA), it is utilized in various tasks such as structural design and health monitoring (SHM). When it comes to the tasks that require a large number of FEAs such as design optimization and Finite Element Model Updating (FEMU), however, FEAs' limitations are emphasized.

One of the significant limitations is that FEA requires more computational power if more details of the structures with the finer meshes are utilized. Traditionally, to overcome this issue, structural details are simplified to reduce the inherent complexities. This undeniably magnifies the mismatching between the actual structural behaviour and the simulations if the simplification has not been done carefully or is oversimplified.

To address this issue, many studies have utilized mathematical functions, known as surrogate models or metamodels, to approximate the results of FEA. For instance, Kriging models were employed in [1] to approximate underlining links between six model parameters and dynamic responses, i.e., natural frequencies and mode shapes, for the FEMU of a bridge. Ren and Chen [2] estimated implicit relationships between three model parameters and modal frequencies using the Response Surface Methodology. The numerous metamodel utilizations were reviewed in [3].

To broaden the frontier of solutions paying particular attention to the vibration-based FEMU, the implementation of Neural Networks (NNs) as metamodels is investigated in this study. The intention is to explore the capabilities of NNs in estimating the implicit relationships between model parameters and FE-simulated dynamic responses using the Multi-Layer Perceptron (MLP)

https://doi.org/10.2749/manchester.2024.1149
Distributed by structurae

Weldability and post-welding fatigue strength of older railway bridges

Takahiro Hirano

East Japan Railway Company, Tokyo, JAPAN

Daisuke Uchida

Hosei University, Tokyo, JAPAN

Takanori Murakami

MIYAJI ENGINEERING CO., LTD. , Chiba, JAPAN

Masaya Hirabayashi

East Japan Railway Company, Saitama, JAPAN

Contact: takahiro-hirano@jreast.co.jp

Abstract

Steel railway bridges in Japan were built in large numbers following the standard design established in 1885, and many older steel bridges are still in service today. One standard structure is that of an I-beam bridge with an I-beam main girder. One typical damege of these bridges is the fatigue crack, occurring near the radius of the bottom edge of the girder plate just above the fulcrum, propagating parallel to the bottom flange in an axial direction. The authors considered welding as a countermeasure for such cracks, but the guidelines for repair and strengthening of steel railway bridges in Japan do not provide details for welding steel members of steel bridges manufactured before 1940. In this study, we examined six bridges constructed in different years between 1889 and 1932, and after confirming their weldability, fatigue tests were conducted on butt welded joints made from their steel material to confirm fatigue strength.

Keywords: older steel railway bridges; repair; welding.

1 Introduction

Steel railway bridges in Japan date back to the later part of the 19th century, when a large number were built starting with a standard structure designed by British engineer Charles Pownall in 1885, and many of these older steel bridges are still in service today. One standard structure is the I-beam bridge with an I-beam main girder, as shown in Figure 1. I-beam bridge construction is shown in blueprints and six bulletins published by railway agencies from 1897 to 1931 [1], and in the 1966 National Railway Standard Design [2]. These bridges reflect the establishment and revision of the Specifications for

https://doi.org/10.2749/manchester.2024.1158
Distributed by structurae

Experimental Study of Compressive Strength of CFRP Reinforced Steel Columns

Takeshi Miyashita

Nagaoka university of Technology, Nagaoka, Japan

Yuya Hidekuma and Syunta Sakurai

Nippon Steel Chemical & Material, Tokyo, Japan

Kazuo Ohgaki

Institute of Technologists, Gyoda, Japan

Masafumi Hattori and Ryouta Takahara

Nippon Expressway Research Institute Company, Machida, Japan

Contact: mtakeshi@vos.nagaokaut.ac.jp

Abstract

Seismic reinforcement for steel members employing carbon fiber reinforced plastic (CFRP) bonding, which has been recently implemented in the repair and reinforcement of steel structures, can be expected. However, no examples exist wherein the superstructure is seismically reinforced using CFRP. Therefore, the author's group intends to perform tension loading tests, compression loading tests, and cyclic loading tests to examine the suitability of the CFRP bonding technique as a seismic strengthening method for axial members with H-shaped or rectangular cross sections in steel truss and arch bridges. In this paper, the outcomes of monotonic compression loading tests for H-shaped column specimens, with a focal point on local buckling, is presented.

Keywords: seismic reinforcement; steel truss bridge; steel arch bridge; H-shaped column; carbon fiber reinforced plastic (CFRP); monotonic compression loading test; local buckling

1 Introduction

After the Great Hanshin-Awaji Earthquake in 1995, the seismic design of road bridges in Japan was revised, resulting in the standard use of dynamic response analysis. Steel members such as the lower chords and diagonal members of steel truss bridges utilized in various expressway projects have a small cross-sectional area. Dynamic response analysis judges these members incapable of supporting sufficient loads and therefore they undergo seismic reinforcement.

Seismic reinforcement for steel members employing carbon fiber reinforced plastic (CFRP)

https://doi.org/10.2749/manchester.2024.1165
Distributed by structurae

Experimental and numerical study on the seismic performance of irregularly concrete-filled steel tube column to steel beam joints with inner semi-diaphragm

Wang-Hui Liu, Yan-Lin Guo

Tsinghua University, Beijing, China

Contact: liuwangh19@mails.tsinghua.edu.cn

Abstract

This paper studies a new kind of irregular-shaped concrete-filled steel tube column to H-shaped steel beam joints with inner semi-diaphragm (ICFSTC-Joint), which exhibits excellent seismic performance, bearing capacity and stiffness in the engineering structures. Firstly, the experiments of four ICFSTC-Joint specimens under cyclic loading are carried out to investigate their hysteretic behavior and failure mode. It is found that the axial compressive ratio has significant negative influence on the hysteretic behavior of ICFSTC-Joint. Secondly, the finite element (FE) models of ICFSTC-Joint are established and verified by the experimental results. The hysteretic curves and skeleton curves of FE model are obtained and agree well with the experimental results. Thirdly, a parameter analysis on the size of diaphragm is carried out by using established FE model. This paper can provide guidance for the engineering design of CFST column to beam joints under earthquake.

Keywords: Concrete-filled steel tube; Joint; Seismic performance; Hysteretic curve; Finite element

1 Introduction

Irregular-shaped concrete-filled steel tube column has attracted widespread concern of researchers and been used in residential buildings for its superiority in spatial shape, which enables it to avoid the protrusion of the column relative to adjacent wall and increase the available area and aesthetic of indoor space [1]. However, for its irregular-shaped and multi-cell section, the irregular-shaped concrete-filled steel tube column to beam joint is complex in terms of construction method and mechanical performance, which has been a focus of current research in the field of building engineering.

In authors' previous paper [2-3], we proposed a kind of irregular-shaped CFST column (ICFSTC) formed by I-shaped steel, U-shaped steel and infilled concrete. In this paper, to match the proposed irregular-shaped CFST column,proposes a new kind of irregular-shaped CFST column to H-shaped steel beam joints with inner semi-diaphragm (ICFSTC-Joint), as shown in *Figure 1*. The flange of H-shaped steel beam is welded with the outer surface of column wall, and the web of H-shaped steel beam is connected with the plate welded with the column wall by bolts. The inner semi-diaphragm is placed inside the joints and its three sides are welded with the inner surface of column wall. The inner semi-diaphragms stand directly opposite to the top and bottom flanges of H-shaped steel beam. The inner semi-diaphragm has two small round holes to facilitate ventilation during the concrete pouring. The inner semi-diaphragms can increase the bearing capacity of

https://doi.org/10.2749/manchester.2024.1173
Distributed by structurae

Experimental bending tests on filler beam section with SFRC

Riccardo Zanon, Markus Schäfer

Structural Engineering and Composite Structures, University of Luxemburg, Luxembourg

Gonzalo Ruiz, Angel De la Rosa Velasco, Willson Vaibhav

University of Castilla La Mancha, Ciudad Real, Spain

Sebastien Wolf

ArcelorMittal Fibres, Luxembourg, Luxembourg

Contact: riccardo.zanon.001@uni.lu

Abstract

Filler beam decks are a traditional steel concrete composite deck for railway and roadway bridges which has been in use since decades without major changes in its configuration. The use of steel-fibre reinforced concrete (SFRC) as complement to the traditional reinforcement is investigated to reach a more optimized, environmental-neutral and resilient structural form.

In this frame a large experimental campaign has been initiated, whereas in this paper the monotonic bending beam tests will be discussed. In term of resistance the major difference is the superior ductility of SFRC which permits to fully exploit the resistance of the steel profile. On the other side, the presence of the steel fibres highly enhances the tensile properties of the concrete matrix contributing to a significantly higher bending stiffness.

Keywords: filler beam decks, steel-fibre reinforced concrete, high-strength steel, composite bridge.

1 Introduction

Fibre reinforced concrete (FRC) is established as the solution of choice in several industrial or tunnelling applications. The trend is towards an increased use in structural applications [4], where it can play a significant role both at serviceability limit state (e.g. increasing concrete tensile properties permit to decrease crack formation and width) as well as ultimate limit state (e.g. for flat slabs they can be a substitute of traditional reinforcement). They may bring also other important benefits in specific fields (e.g. reduced concrete spalling in case of fire exposure).

Fibre reinforcement may be realized out of a variety of materials. Amongst them steel fibres is the solution of choice for standard structural applications thanks to their high strength (commonly available products over 1500 MPa yield strength) and moderate unitary cost.

The structural behaviour of fibre reinforced concrete has been intensively researched over the last decades and the knowledge is now mature enough to be transferred into design codes ([10]). In this sense it can be expected that practitioners will increasingly use this product in the future.

Several research studies were already performed (e.g.[3], [4], [5], [6], [7], [8]) but the use of SFRC in

https://doi.org/10.2749/manchester.2024.1182
Distributed by structurae

Suitability of EN 1317 crash test parameters for determining accidental loads on bridges

Vazul Boros

Austrian Institute of Technology, Vienna, Austria

Contact: vazul.boros@ait.ac.at

Abstract

In Europe the EN 1317 defines testing and certification procedures for vehicle restraint systems depending on the containment level. The monitoring data obtained in these tests can be used to determine the accidental loads for bridges in case of vehicle impact. The present study investigates which quantile of real-life vehicle impacts the respective test conditions correspond to. Based on fundamental mechanical principles a ratio between the results obtained with the parameters of the crash test and the statistical parameters for real-life events with different vehicle mass, velocity or angle of impact can be calculated. The distribution function of this factor is determined in parallel by the orthogonal array and Latin hypercube sampling methods, using the Kolmogorov–Smirnov and chi-squared goodness of fit tests. Thus, the quantile corresponding to a given containment level, as well as a multiplicator required to reach a chosen level of safety can be determined.

Keywords: vehicle restraint system; roadway departure accident; impact load; accidental action; vehicle mass; angle of collision; impact velocity; orthogonal array sampling, latin hypercube sampling.

1 Introduction

In Europe the EN 1317-1 [1] and EN 1317-2 [2] standards define testing and certification procedures for road restraint systems. For each containment level the test conditions are specified, including the vehicle type, mass, its velocity, and angle of impact. In Germany the results of the tests and the accompanying measurements are also used to determine the accidental loads for bridges due to vehicle impact. In this case the question arises, if the test conditions specified in the standard may be considered as representative for vehicle impact in general. The present study aims to answer this question, more specifically to determine which quantile of real-life vehicle impacts the test conditions correspond to.

2 Background

2.1 Vehicle Restraint Systems

The purpose of vehicle restraint systems (VRS) is to minimise the consequences of accidents. On the one hand, they are intended to protect uninvolved persons or areas in need of protection next to the road as well as oncoming traffic on two-lane roads. On the other hand, they also serve to protect vehicle occupants from the serious consequences of a roadway departure.

In Europe, VRS are regulated by the EN 1317 series of standards. In EN 1317-2 [2], performance levels are specified for the following three key vehicle restraint criteria:

Rehabilitation of the flood damaged Mhlali River Bridge and adaptation for improved resilience to extreme weather events

Mohamed Parak, Kerusha Ayer

Naidu Consulting, South Africa

Contact: Mohamed.Parak@naiduconsulting.com

Abstract

This paper presents a case study on the rehabilitation of the Mhlali River Bridge from damage caused by catastrophic flooding on the east coast of South Africa in April 2022. Due to significant debris blockage, the bridge deck was overtopped and was displaced off its bearings by 600 mm in a downstream direction. Scour of the approach fill behind the abutments had left the concrete approach slabs unsupported and the bridge was immediately closed to traffic. The repairs involved jacking the superstructure back into position, as well as adapting the bridge to increase its resilience to extreme weather events in the future. These adaptive measures included the installation of breather holes in the beams to allow trapped air to escape in the case of inundation to reduce the effects of buoyancy, and the construction of shear restraint blocks on the abutment and pier bearing shelves, to improve the superstructure's resistance to lateral hydrodynamic and debris loads.

Keywords: flooding; extreme weather; lateral hydrodynamic forces; buoyancy; scour; bridge repair; resilience; adaptation.

1 Introduction

Flooding is one of the most frequently occurring impacts of extreme weather events in South Africa and poses a significant threat to transportation infrastructure, a key component of a country's economy. Bridges over rivers and floodplains are particularly vulnerable to the actions caused by floods such as scour at the supports, lateral and vertical hydrodynamic forces, hydrostatic or buoyancy (if submerged) and impact loads caused by large floating debris. The effects of these actions were seen in the damage caused to the Mhlali River Bridge by the floods that occurred on the 12th of April 2022 in Kwa-Zulu Natal, South Africa.

The Mhlali River Bridge is located on National Route 2 providing an important economic link to the port of Durban from areas north and south of the country and into Southern African countries. The bridge is owned and managed by the South African National Roads Agency Limited (SANRAL).

The Mhlali River Bridge was built in the 1960's and comprises of seven (7) simply supported spans, each spanning 17.6 m, giving a total length of 123.2 m. The superstructure consists of prestressed precast concrete beams with a reinforced concrete slab. The substructure consists of wall-type piers and full height abutments on pile caps supported off piles founded on rock. Figure 1 presents an image of the bridge in elevation while Figure 2 shows the bridge deck profile.

The flooding of 12th April 2022, as a result of storm Issa in the Kwa-Zulu Natal region, overtopped the Mhlali River Bridge and moved the bridge deck laterally 600 mm downstream. Both approaches to the bridge were scoured out leaving the approach slabs unsupported. The bridge was immediately

https://doi.org/10.2749/manchester.2024.1198
Distributed by structurae

An Experimental Study of Self-anchored Combined CFRP Cables

Guozhen Ding, Chao Wu

Department of Civil and Environmental Engineering, Imperial College London, London, UK

Peng Feng

Department of Civil Engineering, Tsinghua University, Beijing, China

Contact: fengpeng@tsinghua.edu.cn

Abstract

Carbon Fiber Reinforced Polymer (CFRP) is an advanced material known for its lightweight, high strength, corrosion resistance, and fatigue durability, making it an ideal choice for cables in structural engineering. However, being an anisotropic material, CFRP faces challenges in anchoring due to its lower transverse mechanical properties compared to its tensile strength. In response to this issue, this paper designs and tests a self-anchored combined CFRP cable with variations in anchorage type, joint type, and CFRP plate thickness. The results reveal that interface shear stress causes delamination failure in the anchorage, leading to lower-than-expected load-bearing capacity. Through improved design and processing methods, interface damage in the anchorage is reduced, enhancing load-bearing capacity and achieving an ideal failure mode of cable body rupture.

Keywords: Carbon fiber reinforced polymer (CFRP); cable; anchorage; Self-anchored.

1 Introduction

Carbon Fiber Reinforced Polymer (CFRP) is composed of carbon fibers embedded within a polymer matrix, showcasing notable attributes including lightweight characteristics, elevated tensile strength, resistance to fatigue, and corrosion resilience. These attributes make it a promising solution to address challenges encountered by traditional steel cables, including significant self-weight, susceptibility to corrosion, and fatigue issues. However, CFRP is an anisotropic material, exhibiting lower transverse mechanical properties compared to its longitudinal tensile strength. Consequently, anchoring and connecting the CFRP cables have presented formidable challenges in past engineering practices [1-3].

In addressing this challenge, researchers have put forth diverse anchoring solutions, systematically classified according to anchoring mechanisms, including mechanical-type anchorages, bonded-type anchorages, composite-type anchorages, and self-anchored systems. The first three types achieve anchoring through force transmission on the surface, but due to the relatively low shear strength of CFRP, their efficiency is often compromised, and their structures tend to be intricate. Self-anchored systems, on the other hand, efficiently convert cable tension into pressure on the anchoring ring, resulting in a simpler and more effective structure. Leveraging the principles of self-anchoring, we have introduced a novel self-anchored CFRP cable system, as illustrated in Figure 1 [4].

https://doi.org/10.2749/manchester.2024.1206
Distributed by structurae

Liaseal Design Concept - A new era of more durable and reliable segmental post-tensioned construction

Emil Delport

Freyssinet Limited, Telford, UK

Nuno Geirinhas

Freyssinet International, Paris, France

Contact: emil.delport@freyssinet,co.uk, nuno.geirinhas@freyssinet.com

Abstract

The construction of prefabricated segmental viaducts in the United Kingdom are subject to a ban following major incidents (collapse) on structures due to anticipated corrosion problems of internal prestressing tendons. On the HS2 project, the Client's specifications opened the possibility of deviating from this ban by specifying the highest level of protection against stray current induced corrosion to the prestressing tendons according to engineering industry standards such as FIB Bulletin 33.

The highest protection level specified as PL3 requires the non-destructive monitoring of tendons against corrosion, by monitoring the impedance current levels of each tendon. To obtain high level results, each duct must be completely insulated to any other metallic components of a reinforced concrete structure and to avoid any leakage current in the concrete surrounding the tendon ducts.

The standard solution adopted on the prefabricated segmental viaducts (the use of a foam/silicone seals at the joints between segments) and the use of steel corrugated ducts, were therefore not suitable for PL3 level requirements because they do not provide an Electrically Insulated Tendon (EIT) system. To achieve an ETI system is to use electrically isolating materials not only for the duct (normally polypropylene (PP) or high-density polyethylene (HDPE)), but also at the PT anchor head using an isolation plate and encapsulating the strand within a plastic duct with an alkaline, cement-based grout with limited chloride content.

Freyssinet provided an electrical isolated PT anchor, adopted to connect with the HDPE duct but to further ensure continuity between the precast segments developed a duct coupler seal called "Liaseal" in compliance with FIB bulletin 75, to ensure a sealed polymer-duct system for internal bonded post-tensioning tendons to PL3 requirements.

Keywords: Post-tensioning; Liaseal; PL3; Electrically Isolated Tendons (EIT); PSV; Freyssinet.

https://doi.org/10.2749/manchester.2024.1212
Distributed by structurae

Design and detailing of durable and sustainable Post-Tensioning structures with polymer ducts according to *fib* bulletin 75

Klaus Lanzinger, Larry Krauser

General Technologies, Inc., Stafford, TX, USA

Contact: KLanzinger@gti-usa.net

Abstract

In order to build durable and sustainable prestressed concrete bridges and structures, preventing the steel components and the tendons from corrosion is key. Accordingly, for bridges with internal bonded post-tensioning, polymer duct systems should be used. The article gives an overview of the 50-years history of plastic ducts in post-tensioning, the selection of tendon protection levels (PL's) according to *fib* bulletin 33 [1] and information for structural engineers regarding design and detailing of concrete structures with polymer ducts according to *fib* bulletin 75 [2].

Keywords: post-tensioning; fib bulletin 75, plastic ducts, corrosion protection, fatigue resistance, prestressed concrete bridge

1 Introduction

Polymer duct systems for internal bonded post-tensioning enjoy growing popularity as one of the key components for corrosion resistant, durable and therefore sustainable concrete bridges. fib Bulletin 75 "Polymer-duct systems for internal bonded post-tensioning" [2] was issued in 2014 and is considered a cornerstone for technical approval process of polymer or plastic ducts. It provides information for the structural engineer regarding design and detailing of concrete structures containing post-tensioning tendons with corrugated plastic ducts.

2 History of plastic ducts

The use of plastic ducts for internal bonded post-tensioning began in Switzerland. Between 1968 and 1974, around 300.000 m of corrugated black PE pipes were installed in highway bridges and overpasses [2].

One of the first major bridge projects to utilise plastic post-tensioning duct is the Chillon Viaduct, see Figure 1.

Figure 1. Chillon Viaduct
© Wikimedia, Zacharie Grossen

This structure is located at the eastern end of Lake Geneva and is part of the Swiss A9 motorway. It was completed in 1969 and consists of 23 spans

https://doi.org/10.2749/manchester.2024.1218
Distributed by structurae

A Finnish Case Study of U-Trough Underpasses in High Water Table Conditions for Gravity vs Anchored Structural System

Manish Mehta M. Sc, Yatharth Mathur M. Sc
Bridges & Civils, Ramboll India, Gurugram, India

Raul Vibo
Bridges, Ramboll Finland, Espoo, Finland

Contact: mthn@ramboll.com

Abstract

This paper presents a case study of underpass situated on Säterinpuistontie Street as part of the ESKA railway widening project in Finland which facilitates a cycleway, road, and tram tracks passing under the railway. Due to the proximity of the water table to the ground level in this area, specific design considerations are necessary to prevent structure uplift. The primary objective of the case study is to conduct a comprehensive comparison of the material, cost and carbon emissions between two distinct design approaches for watertight U-shaped reinforced concrete trough structures which involves a gravity structural system using high-density concrete and normal-density concrete with structure anchored to the base rock using steel anchors. The study aims to emphasize design methodology, variations in structural analysis methods employed by these approaches and provides a comprehensive understanding of the environmental and economic implications.

Keywords: trough; anchors; reinforced concrete; high density concrete; GWP; carbon; sustainability

1 Introduction

1.1 Project Background

Espoon kaupunkirata (ESKA) railway widening project includes construction of two additional tracks next to the current tracks between Leppävaara and Kauklahti in Espoo, Finland. Espoon kaupunkirata is the first phase of the Helsinki-Turku high-speed rail project. This will help to improve capital region public transport system. Along with the track, cycling corridor near the track is also planned. This project involves construction of Railway and Pedestrian bridges, Underpass, Pile slabs and Retaining walls. The focus of this case study is on one of these underpasses situated on Säterinpuistontie street. This underpass facilitates a road traffic, light traffic and tram tracks passing under the railway and cycle bridge. It also serves as a supporting structure municipal utility pipelines.

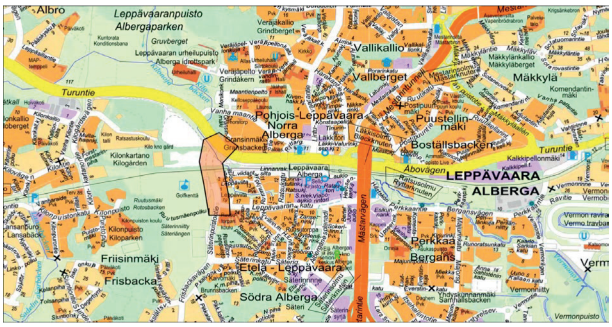

Figure 1. Location of Underpass

https://doi.org/10.2749/manchester.2024.1225
Distributed by structurae

Shake Table Studies of Precast Bridge Columns with a Novel UHPC Connection

Jianfeng Gao, Jianzhong Li

State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji University

Shanghai, China

Biao Ma

Shanghai Municipal Engineering Design Institute (Group) Co. Ltd

Shanghai, China

Contact: lijianzh@tongji.edu.cn

Abstract

A novel lap splice connection by ultrahigh-performance concrete (UHPC) was proposed to connect bridge columns with footings. The bond strength between UHPC and reinforcement was quantified by the genetic programming-orthogonal least squares tool. Then, an approach was advanced to guide the design of the proposed connection. Further, a 1/3.5 geometrically scaled bridge specimen was designed and tested on shake tables to validate the effectiveness of this connection designed by the proposed approach and to analyze seismic responses of the specimen. Test results revealed that the precast columns damaged in a flexural pattern reached a drift of 3.2% under the peak ground acceleration of 1.4 g. Moreover, most inelastic deformation and damage occurred above the column-footing connection segments which, designed by the proposed approach, remained barely damaged. Meanwhile, the strain concentration effect at the column bottom was less significant.

Keywords: accelerated bridge construction; lap splice connection; ultrahigh-performance concrete; genetic programming-orthogonal least squares; shake table test.

1 Introduction

To date, accelerated bridge construction (ABC) has gained popularity in low seismic zones by virtue of fast construction, stable quality, and less interference in traffic. Meanwhile, the advent of ultrahigh-performance concrete (UHPC), which owns a compressive strength of as much as 200 MPa and excellent post-cracking tensile behavior, offers opportunities to develop new connections for ABC. One of the most prevailing connections is the UHPC-based lap splice connection due to its friendly tolerance in construction. Nevertheless, its most critical problem is guaranteeing enough bond strength between UHPC and reinforcement to develop an expected reinforcement strength. Thus, many studies, including pullout tests [1-4] and quasi-static element tests [5-7], have been conducted to reach this purpose. Although some quantified guidelines have been made through pullout tests to develop a certain reinforcement strength, this strength is somewhat arbitrary and

https://doi.org/10.2749/manchester.2024.1234
Distributed by structurae

Chain reaction failure analysis for tied arch bridge considering cable corrosion

Yukari Aoki, Mami Kimijima, Humihiko Gotou
Akita university, Akita, Japan

Haruki Tsunoda
Yokogawa Bridge Corp. Tokyo, Japan

Shunichi Nakamura
Tokai University, Kanagawa, Japan

Contact:yaoki@gipc.akita-u.ac.jp

Abstract

Cable corrosion has been becoming significant issues for the bridge structures having with cable or hanger materials, such as suspension bridges, cable-stayed bridges, tied arch bridges and so on. Many of these bridges, which were built in 1980s and 90s, are possibly surviving under the cable corrosion. Existing tied arch bridge was collapsed in Taiwan in 2019. It is reported that cable corrosion is the one of the main reasons to trigger the entire bridge collapsed. In this study, the numerical bridge model inspired by the Taiwan arch bridge was designed for analyzing the dynamic analysis of chain reaction failure considering with the cable corrosion. The corrosion of cable is represented by the decreasing of yield stress and breakage strain, and the first ruptured cable which is represented by the decreasing tensile force instantly. According to this analysis, if the cables are corroded significantly, the chain reaction failure would be occurred.

Keywords: Cable-stayed bridge; cable corrosion; chain reaction analysis; dynamic analysis; FEM.

1 Introduction

Corrosion is one of the most significant issues for the steel structures, especially corrosion of the cables is critical to the bridges which have cables. Anti-corrosion and/or anti-rust are often painted on the surface of cables to avoid the cable corrosion, however, the painting would be peeled off due to aging. These cable corrosions led to significant accident including entire bridge collapses in many countries, therefore cable corrosion should be determined and examined the effect to the bridges, especially built in 1980s to 1990s. For example, a tied-arch bridge in Taiwan was totally collapsed, which was reported the cause of bridge collapses was due to significant cable corrosion. This collapse was also pointed out that it was "zipper-type collapse", which the first cable ruptured the second and third cables were ruptured one after the other [1].

https://doi.org/10.2749/manchester.2024.1243
Distributed by structurae

Effects of material properties on slipping behavior in high-strength bolted frictional GFRP joints

Toshie Habukawa, Gen Hayashi, Masaki Sekimoto, Takashi Yamaguchi, Hiroaki Kitoh
Osaka Metropolitan University, Osaka, Japan

Contact:a20tr039@st.osaka-cu.ac.jp, hayashi-g@omu.ac.jp

Abstract

This study aims to clarify the influence of the variability in the material properties of Glass Fiber-Reinforced Polymers (GFRP) and the modeling method of GFRP on the slipping behavior of high-strength bolted frictional GFRP joints. Therefore, study conducted a statistical evaluation of the variability in material properties and finite element (FE) analysis. As a result, the initial load-relative displacement relationship in the anisotropic model generally matched the experimental results. Furthermore, it was found that the Poisson's ratio did not have a significant impact on the slipping behavior in any direction. The material property that most influenced the slipping behavior was considered to be the shear modulus in the plate thickness direction.

Keywords: GFRP, high-strength bolted frictional joints, slipping behaviour, material properties, variation

1 Introduction

Glass fiber-reinforced polymers (GFRP) are often applied in civil structures and bridge members in harsh corrosion environments owing to their excellent lightweight properties and weather resistance. In such cases, bolted connections of the bearing type are commonly used as mechanical joining methods between GFRP members. However, these connections face challenges, such as low shear strength and elastic modulus. As a result, the joint resistance was low and the number of bolts increased. Additionally, challenges remain in on-site assembly, including the need to align hole positions. Therefore, to enhance joint strength and improve on-site constructability, high-strength frictional bolted joints, which resist the load through the frictional force generated by introducing axial force to high-strength bolts, have been attracting attention.

In contrast, GFRP underwent creep deformation. In practice, when applied to high-strength bolted frictional joints, the critical axial force in the frictional joint continues to decrease over time owing to the creep deformation [1]. Therefore, the current situation is that there are few applications of high-strength bolted frictional joints with GFRP. Hashimoto et al. [2] experimentally demonstrated that using steel in the connecting plate can mitigate the decrease in bolt axial force, focusing on thick hand lay-up molded materials used in civil structures. Therefore, our research team has experimentally shown that the reduction of the bolt axial force can be suppressed by using steel as the splice plates for thin GFRP joints and clarified the practical feasibility of bolted joints used in

https://doi.org/10.2749/manchester.2024.1251
Distributed by structurae

Interdisciplinary data collection for empirical community-level recovery modelling

Blythe Johnston, Lisa Wang, John W. van de Lindt, Mojtaba Harati, Katie Skakel, and Tu Nguyen

Colorado State University, Fort Collins, CO, USA

Shane Crawford, Thang Dao, and Chibuike Robinson

University of Alabama

Grace Yan

Missouri University of Science and Technology

Trung Do

University of South Alabama

Jarrod Loerzel

National Oceanic and Atmospheric Administration

Andre Barbosa

Oregon State University

Silvana Croope

Federal Emergency Management Agency

Contact: blythe.johnston@colostate.edu

Abstract

The Center of Excellence for Risk-Based Community Resilience Planning (CoE) has begun to provide analyses on damage, functionality loss, recovery, etc. at the community level for a suite of possible hazard events via the Interdependent Networked Community Resilience Modelling Environment (IN-CORE). These analyses are instrumental to leveraging state of the art science in community decision-making; however, for this work to be as actionable as possible, the outputs must be validated for a range of implementation contexts and communities. The work presented here describes a longitudinal study of a series of communities impacted to varying degrees by a tornado outbreak in December of 2021 and the way in which this longitudinal data will be used to validate models in IN-CORE. This longitudinal study is still underway as it serves to capture recovery data for three years following the event.

Keywords: Interdisciplinary disaster research; resilience modelling; natural hazards; field study; social vulnerability

https://doi.org/10.2749/manchester.2024.1260
Distributed by structurae

Productivity increase in the design and construction of bridges

Johan Lagerkvist
Chalmers University of Technology, Swedish Transport Administration, Sweden

Ola Lædre
Norwegian University of Science and Technology, Norway

Rasmus Rempling, Petra Bosch-Sijtsema
Chalmers University of Technology, Sweden

Fredrik Carlsson, Mats Karlsson
Swedish Transport Administration, Sweden

Contact: johan.lagerkvist@chalmers.se

Abstract

The construction industry is behind other industries in productivity. With more large infrastructure projects to be built, it is essential that design and construction could be performed with high productivity. This paper focuses on how standardisation of bridges can result in higher productivity. A quantitative study was performed to examine essential parameters that have potential to increase productivity in the Swedish bridge construction industry; it also examines how standardisation could increase productivity; and how specific incentives of the three significant actors (contractor, client and design engineer) could be obstacles to productivity. The main findings are that the actors believe in standardisation as a way to increase productivity. Reinforcement layout was one important parameter to increase productivity. Contractor's view on profit could be an obstacle to productivity. Increased productivity would be more sustainable infrastructure delivery and here the client has an important role to play.

Keywords: Productivity; Standardisation; Parameters; Obstacles

1 Introduction

Transport infrastructure is an essential part of developing society. The construction industry is also a significant contributor to the economy; globally, it accounts for 13% of the world's GDP [1]. It is also responsible for a significant part of the material resources used, representing 37% of the total CO_2-equivalent emissions [2]. At the same time, it is well-established that the construction industry in many countries can be more productive. Research shows that productivity has decreased [3–5], or at least is much lower than the rest of the economy [6–8]. A research study in Singapore shows that the annual growth in construction productivity was negative in 2 of 7 years, and in 4 of 7 years, it was below the growth of the rest of the economy [9]. A study in Sweden indicates that the construction industry has had a cost increase, which is twice as high as other industries for the

https://doi.org/10.2749/manchester.2024.1268
Distributed by structurae

Soho Loop Cantilever Footbridge

Ed Dablin

DYSE Structural Engineers, Manchester, UK

Contact: ed.dablin@dyse.com

Abstract

A new footbridge was required for the Soho Wharf residential development in Birmingham, UK. The bridge was to cross an existing canal from the development side and was to meet the far side through the parapet of a masonry arch footbridge without bearing onto the masonry arch barrel.

A low-cost static cantilever footbridge system was developed with no positive between the tip of the cantilever and the opposing side. This was in the form of an economic stiff and lightweight truss held down by a concrete kentledge under the back span. Existing structures were repurposed for use on both side of the canal.

The vertical deflection was found to be the governing design criterion. Sensibile construction sequencing and use of designed levelling devices were emoloyed to mitigate the risks associated construction and any longer-term movement.

Keywords: post-tensioning; cantilever; footbridge; steel; canal; Birmingham;

1 Introduction

The new Soho Wharf residential development has brought 750 new canal side homes to the city of Birmingham. During the construction, the developer, Galliard Homes, had a planning requirement to discharge to deliver a new footbridge to connect the development side to the far side tow path of the Old Main Line Canal.

Figure 1 The crossing in April 2021 with the development side to the left of picture

https://doi.org/10.2749/manchester.2024.1277
Distributed by structurae

Re-use of wind turbine steel towers for pedestrian bridges

Torben Forsberg

FORSBERGS, Copenhagen, Denmark

Nils Behrndt Ebbesen, Jesper Henriksen

Dissing + Weitling Architecture, Copenhagen, Denmark

Contact: tof@forsbergs.dk, nbe@dw.dk, jhe@dw.dk,

Abstract

Steel towers used for wind turbines are being decommissioned after relatively short service lives of around 25 years. This abbreviated lifespan is partially due to fatigue loading, although the steel itself may still be safe for normal loads. FORSBERGS and Dissing+Weitling Architecture are investigating the potential for reusing these towers as the primary structure for pedestrian bridges. The focus of these investigations lies in the structural design of a new bridge, constrained by the existing geometry of the steel tower. One approach involves longitudinally splitting a tower into two half-pipe structures that could serve as bridge spans. This study encompasses an assessment of the CO2 aspect, comparing the overall carbon footprint resulting from a conventional decommissioning of a steel tower with that of repurposing it for a bridge. The proposed concept could potentially apply to narrow pedestrian or bicycle bridges, or utilise side-by-side half-pipes for multipurpose use.

Keywords: steel towers; wind turbines; pedestrian bridges; architecture.

1 Introduction

The design of a steel bridge should adhere to specified standards, such as Eurocode 3 [1]. Similarly, fabrication and construction must comply with applicable standards, like EN 1090-2 [2]. Whether constructing a new steel bridge or repurposing steel from a wind turbine tower, the design and construction requirements remain largely consistent.

Over 25 years of supporting a wind turbine, the steel structure has largely exhausted its dedicated fatigue life. However, in the case of a pedestrian bridge with minimal design loads throughout its lifespan, fatigue considerations will not govern the design. While the steel structure might be considered worn out for use in a wind turbine, it remains virtually new for a pedestrian bridge.

The imposed geometric constraints could potentially result in an aesthetically displeasing appearance of the bridge, a concern addressed within this article. A recommended practice for structural engineers is to optimize structures based on specific constraints. Developing a structure to serve multiple purposes seldomly results in an excellent technical solution. Figures 1 and 2 depict the possibility of using a portion of the wind turbine tower by slicing it, resulting in shallow end sections while maintaining a full middle section. Several other purposes and ideas are briefly outlined here.

The debate over the carbon footprint of producing one ton of steel construction persists. As per [3], the global average in 2021 stands at 1.9 tons of CO_2 emissions per ton of crude steel. For simplicity, an additional 0.2 tons are considered for cutting, bending, welding, transportation, and installation.

https://doi.org/10.2749/manchester.2024.1285
Distributed by structurae

Design and Construction of the Flyover in the Intermodal Ferry Terminal in Świnoujście

Dawid Wisniewski, Patryk Stempin, Michal Majka

ASECon, Wrocław, Poland

Contact: dw@asecon.pl

Abstract

This paper presents various aspects of the design and construction of the flyover in the ferry terminal in Świnoujście, which has been recently developed to allow for the intermodal transport (by water, rail and road). The expansion of this terminal is the part of the wider transportation network development project aiming to improve connections between Scandinavia and Central and Southern Europe. In the first part of the paper detail description of the structure is made and the design process is briefly discussed. In the second part of the paper few interesting topics related to the construction are presented. Finally, topics related to the carbon footprint reduction on this project are discussed.

Keywords: Flyover, double composite, steel, concrete, curved girders.

1 Introduction

In the recent years, the "green" focus of Civil Engineering has shifted from the sustainability and life cycle cost optimization to the reduction of carbon footprint. This shift has been driven by rapidly progressing climate changes, being caused largely by the CO2 emissions resulting from human activities. In the current climate situation, the main role of the Civil and Bridge Engineering industry is:

- to support changing transportation infrastructure such that the use of more environmentally friendly transport modes is possible and it is preferred by the users;

- to re-think the approach to building the infrastructure in the first place and, if deemed necessary, to refurbish the existing infrastructure or to design and built new one with the aim of reducing the associated carbon footprint to the absolute minimum.

Recently constructed flyover in the Ferry Terminal in Świnoujście (Poland) is a part of larger project, which main aim was to adapt infrastructure of the terminal for intermodal transport and promote more environmentally friendly rail transport.

2 Description of the structure

The flyover in the Intermodal Ferry Terminal in Świnoujście was designed as five span continuous structure with the total length of 194,10 m. The theoretical span lengths are as follows: 35,00 m + 50,10 m + 41,00 m + 40,00 m + 28,00 m (see Figure 1). The structure is curved in vertical and horizontal planes. In the longitudinal profile the structure is designed with vertical radius R = 800,00 m and straight sections at both ends with 9% slope. In plan the structure is designed with horizontal radius R = 245,00m (see figure 2).

The bridge cross section consists of 7,20 m wide carriageway, two 0,50 m wide shoulders, one on each side of the carriageway, and safety barriers.

https://doi.org/10.2749/manchester.2024.1295
Distributed by structurae

Optimization Process of Railway Segmental Bridges Constructed by Balanced Cantilever Method

Jindrich Potucek, P.E., S.E.

COWI, Prague, Czechia

Vojtech Kolinsky, P.E.

COWI, Prague, Czechia

Contact: jipk@cowi.com, voko@cowi.com

Abstract

This paper highlights the challenges faced in large urban bridge infrastructure projects, including excessive material consumption and negative environmental impact. It focuses on the optimization process conducted for a new pair of railway double-track bridges in Tel-Aviv, Israel, featuring continuous prestressed concrete box girders. The design works began in late 2020, with construction currently underway. COWI was responsible for the superstructure design packages, optimizing the box section, resulting in increased post-tensioning design efficiency and a 30% reduction in materials. Through careful planning and teamwork with the contractor, the project achieved lower carbon footprint, decreased cost, and increased speed of mobilization.

Keywords: bridge, railway, post-tensioning, box girder, balanced cantilever, segmental

1 Introduction

The infrastructure projects of large and complex bridges in urban environments present a significant challenge in terms of quantity consumption, negative environmental impact around the area of the construction site and consequently increased carbon footprint of the project. A careful assessment of the adequacy of the proposed tender design meeting all durability and design requirements combined with good construction planning eliminating bottlenecks in the construction schedule, can result in building more economically, more rapidly and with less impact on the environment. It is the role of a bridge engineer to always consider the above regardless of the phase of involvement.

This paper presents the optimization process conducted for the new pair of railway double-track bridges BR-05 and BR-06 (total lengths 516 and 762 m) spanning over a complicated area of the Ein-Hakore intersection in the southern suburbs of Tel-Aviv, Israel. Each bridge features a continuous prestressed concrete box girder of variable depth (7.2 to 2.6 m), designed as segmental cast-in-place structure constructed by the balanced cantilever method. Design works began in late 2020 and construction of the bridge is currently underway.

2 Design Optimization

COWI was responsible for the superstructure Value Engineering Design and Construction Engineering

https://doi.org/10.2749/manchester.2024.1303
Distributed by structurae

Teaching Reuse of Existing Structures at the University of Sheffield

Richard Harpin, Jon Carr
The University of Sheffield, Sheffield, UK

Contact: r.harpin@sheffield.ac.uk

Abstract

In response to the Climate Emergency, and to reflect the fact that many practising Structural Engineers work on existing buildings and other structures, staff from The University of Sheffield set up a new 'Reuse of existing structures' module in September 2022.

The paper describes the rationale behind the module, the module content, the approach to learning, teaching and assessment., as well as reflecting on the overall success of the module, taking into account the quality of the working submitted and student feedback.

Keywords: Existing structures; reuse; retrofit; Climate Emergency; education

1 Introduction

Many practising structural engineers already work on existing buildings or structures, despite this topic not being covered in detail at university. Our response to the climate emergency means that reusing existing buildings and structures will almost certainly become an increasingly important part of what engineers do in the future.

In recognition of this, the University of Sheffield set up a 15-credit 'Reuse of existing structures' module for final-year Meng students in September 2022. This article discusses our approach and experience of introducing this module.

2 A different mindset

Although the underlying principles remain the same, working with existing structures requires a different mindset to designing new structures.

For a new structure, the structural engineer, in conjunction with the design team, has the luxury of being able to select the load paths and structural materials, but for an existing structure, the load paths and structural materials have already been determined.

Furthermore, it can reasonably be expected that a new structure will be built in accordance with the design intent, but an existing structure may have been altered over time (potentially changing load paths), while the condition of the fabric may have deteriorated.

Only when all these factors have been investigated and understood can new interventions be approached with confidence. Even then, the engineer must consider not only the behaviour of the structure in its final state, but also at every stage of construction.

3 Module overview

The 15-credit, 12-week module is led by two senior university teachers, who have significant industry experience of working with existing structures, and who deliver the core content. This includes the philosophy of working with existing buildings, a brief history of building construction, the inspection and appraisal process, and testing procedures.

Appropriate calculations are also covered, building on previous modules for steel, concrete and

https://doi.org/10.2749/manchester.2024.1310
Distributed by structurae

Challenging prior decisions relating to existing bridges

Peter Campbell, John Collins

Roughan & O'Donovan, Leeds, UK

Joe Kelly

Roughan & O'Donovan, Dublin, Ireland

Contact: peter.campbell@rod.group

Many existing bridges do not have any, or have very little, historical information available. They may not have an extensive body of evidence about their change in condition over time. In these cases, a considered and pragmatic engineering approach is required. Examples from the UK and Ireland are discussed that demonstrate how challenging prior decisions has resulted in a change of outcome for existing bridges and enabled them to remain in service. These included challenging the assumed condition of structures, scope of inspections, assessment outcomes and decisions, types of intrusive investigations, the use of instrumentation and monitoring, and ensuring that touching distance inspections were undertaken. Case studies are discussed that capture works associated with existing bridges of various forms including: in-situ post-tensioned concrete, precast prestressed concrete, in-situ reinforced concrete, masonry arch and steel half-through truss.

Keywords: existing bridges; inspections; intrusive investigations; assessment; PTSI; deterioration.

1 Introduction

It is best practice to use inspections over time to create a body of evidence about the condition of existing bridges and if / how this is changing. Inspections typically comprise a combination of routine surveillance, general inspections, principal inspections and special inspections. Progression of deterioration can then be monitored. and operational and financial risks and costs managed effectively. This type of approach is described in industry guidance such as the UK Road Liaison Group (UKRLG) Well-Managed Highway Infrastructure: Code of Practice [1].

While many bridges in the UK and Ireland have extensive historical records including design records, as-built drawings, inspection reports and maintenance records, others do not. The reasons for not having extensive historical records can be wide-ranging. This situation can be particularly prevalent amongst what might otherwise be regarded as low-risk bridges (e.g. masonry arches on lowly trafficked roads not otherwise showing signs of distress) or owners of bridges who are not in the transportation infrastructure industry otherwise (e.g. privately owned bridges). Where there is little information available, it can be challenging to be confident when making decisions about the future works required at a bridge. In some cases, a considered approach by experienced engineers including targeted inspection, investigatory and assessment works can greatly aid such decision making.

This paper discusses case studies undertaken by the authors' employer Roughan & O'Donovan.

https://doi.org/10.2749/manchester.2024.1316
Distributed by structurae

Sustainable salvation of deficient RC bridges by means of the UHPFRC Technology

Eugen Brühwiler

EPFL – Swiss Federal Institute of Technology and BridgIng Consulting, Lausanne, Switzerland

Contact: eugen.bruehwiler@epfl.ch

Abstract

Structural application of impermeable, tensile strain hardening UHPFRC (Ultra-High-Performance Fibre-Reinforced-Cementitious Composite) follows two fundamental concepts: 1) Rehabilitation and strengthening of existing bridges by adding a layer of UHPFRC, and 2) Construction of new bridges in UHPFRC. This paper presents recent UHPFRC project realized in Switzerland using UHPFRC for the salvation of deficient reinforced concrete bridges, to improve their structural resistance and durability, as well as to extend their service duration. This allows to avoid the common practice consisting in the material and cost invasive "demolition-replacement" still largely applied. In this way, the UHPFRC Technology using a small amount of a novel building material provides a significant contribution towards sustainability since UHPFRC allows to preserve the existing bridge, its original materials and embodied energy.

Keywords: UHPFRC; cementitious fiber reinforced composite material; rehabilitation; structural strengthening; existing structures; existing bridges; sustainability.

1 Introduction

The problems of insufficient durability of reinforced concrete bridges are known for several decades already, in particular in regions using deicing salts in winter and in marine environments. So-called "retrofit" implies traditional repair methods, often leading to high intervention and user costs as well as limited durability. Novel intervention methods are urgently needed to improve existing reinforced concrete bridges.

UHPFRC stands for Ultra-High-Performance Fiber Reinforced Cementitious Composite material. UHPFRC is composed of cement and other reactive powders, additions, hard fine particles, low amount of water (W/C≈0.15), superplasticizers and very high amount of relatively short and slender steel fibers (15/0.2mm). The composition of UHPFRC is optimized with respect to compaction of particles leading to a waterproof material up to a tensile strain of about 0,1 %. The tensile strength of UHPFRC typically is about 12 MPa and the material shows significant strain-hardening behaviour in tension. UHPFRC has compressive strength typically of 150 MPa. UHPFRC is nowadays used in many countries, mostly in the domain of new construction [1].

The author and his team have developed the UHPFRC rehabilitation and strengthening technology over the last 25 years by means of scientific research and applications [2,3]. In Switzerland (8,7 million inhabitants, area of 41'000 km^2) there are currently more than 400 reinforced concrete structures, mainly bridges, that have been improved using the UHPFRC Technology, since 2004. This is the by far highest UHPFRC application rate in the world with respect to the size of the country.

https://doi.org/10.2749/manchester.2024.1325
Distributed by structurae

M5 Exe and Exminster Viaducts - Strengthening and Safeguarding

Riccardo Stroscio, Akram Malik

Tony Gee and Partners LLP, Esher, Surrey, UK

Frédéric Turlier

VSL Systems (UK) Ltd, London, UK

Mark Maynard

National Highways, Bristol, UK

Contact: Riccardo.Stroscio@tonygee.com

Abstract

Exe (692m long) and Exminster (302m long) Viaducts were built in 1977 and carry the M5 motorway across the Exe Valley in the UK. The deck of both bridges consists of a pair of constant-depth twin-cell post-tensioned box girders with fully external prestressing tendons. In 2016, corrosion was observed in the end-span tendons of Exe Viaduct. A safeguarding solution was proposed comprising additional external post-tensioning. In addition, an assessment revealed that the superstructure did not have sufficient ultimate capacity in the mid-span regions. The assessment of Exminster Viaduct found a similar shortfall in resistance. This resulted in a scheme comprising of external unbonded tendon safeguarding in the end spans of Exe Viaduct and internal bonded tendon strengthening in all midspan regions for both bridges. The solution offered a positive environmental impact avoiding the need for demolition and deck replacement for these two significant motorway bridges.

Keywords: bridge; post-tensioning; box-girders; assessment; strengthening; rehabilitation.

1 Introduction

The two viaducts discussed in this paper are situated just southeast of Exeter between junctions 30 and 31 of the M5 motorway, which links Birmingham in the Midlands to Plymouth in the south.

The structures are separated by a 400m long embankment. Exe Viaduct comprises 11 spans (53.50m – 9 x 65.00m – 53.50m) over the Rive Exe and the Exeter Canal. Exminster Viaduct has 5 spans (53.50m – 3 x 65.00m – 53.50m) carrying the motorway across a double-track railway line.

The 2.80m deep twin cell concrete box girders (see Figure 1) were designed with only external, unbonded prestressing. Tendons are up to 170m long and pass through saddles cast within internal diaphragms spaced regularly within each span.

Each span contains 16 to 24 tendons (type 6-19 Dyform) formed from bundled sheathed monostrands and with stressing anchorages at each end as shown in Figure 2.

https://doi.org/10.2749/manchester.2024.1332
Distributed by structurae

Extended linear finite element calculation of a 70-years old prestressed concrete viaduct

René Veerman, Coen van der Vliet

Arcadis Nederland BV, Amersfoort, The Netherlands

Baptiste Korff

Rijkswaterstaat, Dutch Ministry of Infrastructure and Water Management, Utrecht, The Netherlands

Contact: rene.veerman@arcadis.com

Abstract

The many bridges and viaducts in the Netherlands that were built in de 1950s and 1960s are approaching the end of their service life. Instead of replacement, which costs a lot of money and resources, reassessments and rehabilitation can be used to extend the expected service life of existing structures. For one of these structures, Spoorviaduct Uitgeest (a viaduct in the Dutch highway A9), a refined reassessment was requested to investigate whether this viaduct is sufficiently reliable.

In a comprehensive reassessment, performed by Arcadis Netherlands BV, the total viaduct was modelled in a 3D FE model. With this FE model, creep, shrinkage, permanent loads, traffic loads and imposed deformations were considered. It turned out that the cross-sectional shear checks and the rotational capacity were governing. By sufficient use of monitored material properties and refined shear calculations, sufficient shear capacity could be proven. Moment-curvature diagrams were used to prove enough rotational capacity.

Keywords: Prestressed concrete; existing viaduct; reassessment, FE model; rotational capacity; shear force capacity.

1 Introduction

In 2016, Rijkswaterstaat (the Dutch Ministry of Infrastructure and Water Management) had applied a quick scan method to investigate the structural reliability of structures with prestressed T-shape girders. For most of these structures sufficient resistance against traffic load according to the current design codes could be proven by using this quick scan method. For a few structures, the quick scan method could not prove sufficient load bearing capacity. One of these structures is Spoorviaduct Uitgeest. For this viaduct, the quick scan method resulted in a unity check for the shear strength verification of 2.04, which means that the loads on this viaduct result in shear forces which are more than twice the shear load bearing capacity of the structure. However, investigations on the viaduct did not show any structural damage. No single crack had been observed during the investigations. This indicates that the structure is stronger than the quick scan method implied. It was expected that a comprehensive reassessment using extended FE calculations could avoid replacement or strengthening of the viaduct. The FE calculations were performed by Arcadis Netherlands BV.

https://doi.org/10.2749/manchester.2024.1340
Distributed by structurae

Climate Resilience of Long-span Bridges through Early-stage Aerodynamic and Climate Consulting

David Hamlyn, Tung Nguyen

RWDI Anemos Ltd, Milton Keynes, UK

Contact: david.hamlyn@rwdi.com

Abstract

Critical infrastructure, such as long-span bridges, is important for the sustainable economic development of society. The safety and serviceability of these structures is highly sensitive to wind hazards. Understanding the risks to the bridges from the wind is crucial to ensuring their resilience, particularly with the growing threat of climate change. In this work, the authors will present case studies demonstrating the benefits of early-stage aerodynamic and climate consulting in delivering climate resilience for new and existing long-span bridges. The assessment could enable structural engineers to refine wind loads for the design of new long-span bridges, reducing material usage and embodied carbon. For existing bridges, a better understanding of the current performance could lead to informed decisions on bridge rehabilitation for climate change adaptation, as part of effective asset management, to extend the service life of bridges and reduce user carbon.

Keywords: bridge aerodynamics; bridge rehabilitation; wind effects; carbon footprint; climate resilience.

1 Introduction

Bridges – in particular long-span bridges – are critical access to the transportation network. Under the growing threats of climate change, it is crucial to ensure the safety and serviceability of both new and existing bridge for the development of the economy and society, while reducing their environmental impacts.

Bridges are among the most capital carbon intensive elements of the transport infrastructure [1]. It is often related to investments required to ensure the structures meet usage demands and satisfy durability requirements against severe environment exposure. There is little opportunity to reduce operational carbon as the majority of such activities on bridges are independent of the structure itself. However, well designed and managed bridges could remain open during or could return to full operation shortly after extreme events. This helps reduce user carbon by limiting road traffic emission caused by longer journeys or travel time due to bridge closure. Also, well maintained bridges have prolonged service life and are capable of handling increased usage, without the need of constructing new crossings.

Unlike buildings which are typically designed for 50 or 60 years, bridges have a longer design life, up to a century or more. Bridges are there more likely to experience extreme environmental loads – including wind hazards which are predicted to be progressively more severe due to the impact of climate change.

In recent years and even more in the last three years, it has become apparent that aerodynamic studies targeting wind-related performance goals

https://doi.org/10.2749/manchester.2024.1348
Distributed by structurae

Bridge hangers as cruciform sections – Advantages and behaviour under wind loading

Miguel Candeias

ArcelorMittal Global R&D, Esch-sur-Alzette, Luxembourg

Riccardo Zanon

ArcelorMittal Steligence Engineering, Esch-sur-Alzette, Luxembourg

Jacques Berthellemy

CEREMA, Champs-sur-Marne, France

Contact: miguel.candeias@arcelormittal.com

Abstract

Tied-arch bridges consist in aesthetic crafted structures with efficient design, providing opportunities for cost reduction and increased sustainability when compared to other bridge configurations. One particular hanger solution, designed by Jacques Berthellemy and implemented typically in radial tied-arch bridge configurations, involves a cruciform element with a variable cross-section along its axis. In this paper the main advantages of using this type of hangers are presented and an assessment is shown regarding the response of this unique hanger under wind loading, an aspect that is not fully addressed within the scope of the simplified approach prescribed by the European standards. The outcome shows that the hanger geometry combines an optimised structural behaviour with an efficient performance, not susceptible to significant vibration risks arising from vortex shedding phenomena.

Keywords: bridge hangers; wind resistance; shape factor; CFD analysis

1 Introduction

Tied-arch bridges are recognized for harmonizing aesthetics with structural efficiency, providing an optimal choice for bridges spanning mid-range distances [1].

The primary structural mechanism of tied-arch bridges revolves around the interaction between the arch and the hanger elements. In the design, the arch is in equilibrium subjected to compressive forces and the hangers to tensile forces. The hangers are attached to the arch at various intervals along its length and connected at the lower part to the bridge's tie members.

There are multiple layout options available for the hanger arrangement, offering design flexibility and amplifying the potential of tied-arch bridges. Simple suspension arrangements, such as vertical or fan-shaped hangers, are generally preferred for short and medium-span bridges. Radial

https://doi.org/10.2749/manchester.2024.1358
Distributed by structurae

Design of the Bataan-Cavite Interlink Bridge (BCIB) Project in The Philippines

Marwan N. Nader, James Duxbury, Carol Choi, Alex Sanjines [1]

[1] *TYLin San Francisco, California, United States of America.*

Contact: marwan.nader@tylin.com

Abstract

The new 32-kilometer Bataan–Cavite Interlink Bridge (BCIB) Project in the Philippines is poised to be a vital, enduring transportation link over the Manila Bay, providing a major opportunity for local economic growth and tourism while supporting the flourishing growth in population.

The proposed infrastructure will incorporate a marine bridge comprised of two cable-stayed bridges with main spans of 900 meters and 400 meters, respectively, and 25 kilometres of marine viaducts in tandem with an additional 5 kilometres of approach roads and land viaducts.

This paper describes how the bridge is being designed for longevity and durability under extreme events, including large earthquakes, typhoons, vessel collision, and hydrodynamic forces.

Keywords: cable-stayed bridges, high seismic zone, tsunami, innovations, long-span bridges

Figure 1. Bataan-Cavite Interlink Bridge Rendering (Credit: TYLin)

1 Introduction

Designed for a 100-year design life and durability under extreme events, including large earthquakes, typhoons, vessel collision, and hydrodynamic forces, the new Bataan–Cavite Interlink Bridge (BCIB) in the Philippines is poised to be a vital, enduring transportation link over the famous Manila Bay. At 32 km in length, including two long-span cable-stayed bridges, this project significantly reduces travel times, traffic congestion, and emissions while providing a major opportunity for local economic growth and tourism.

https://doi.org/10.2749/manchester.2024.1366
Distributed by structurae

Structural configuration of negative bending moment zone in continuous MVFT girder bridge

Zhihua Xiong

Northwest A&F University, Yangling, China.

RWTH Aachen University, Aachen, Germany.

Zhenhua Pan

Northwest A&F University, Yangling, China.

Kevin Wolters, Markus Feldmann

RWTH Aachen University, Aachen, Germany.

Di Di

Northwest A&F University, Yangling, China.

Contact: zh.xiong@nwsuaf.edu.cn

Abstract

In order to apply a Modified-VFT (MVFT) steel-concrete composite girder to a continuous bridge, this paper investigates the structural configuration of the negative bending moment region of MVFT girder. Clothoid shaped composite dowels are designed in the hogging moment zone. Comparison studies were made for different geometric parameters of the connection. With the aim to increase the crack resistance of the concrete deck in the hogging moment region of the composite bridges, Ultra-High-Performance-Concrete (UHPC) is adopted. Wet joints schemes of shear studs and CL composite dowels are analysed.

Keywords: steel-concrete bridges; negative bending moment; MVFT; composite dowels; deck; UHPC.

1 Introduction

Steel-concrete composite bridges made of composite dowels have been widely employed in bridge construction in Europe due to their excellent mechanical capacity and outstanding economic features (1,2). To meet the demand of accelerated bridge construction (ABC), the authors proposed a small-span prefabricated Modified-Verbund Fertigteil Trager (MVFT) steel-concrete composite girder, in which the steel girder is made of composite dowels in previous work (3). The steel girder and the concrete slab of MVFT girder are both prefabricated in the mill, with a significantly reduced construction time on site (4,5). In order to make the MVFT girder suitable for a continuous bridge, the structural design and its performance in the negative bending moment zone of MVFT girder is the objective of this work.

Girder-to-girder joints are the focus of attention for prefabricated bridges (6). The precast concrete connection can be classified into dry and wet connections according to the construction method (7). Dry connection uses welded plates, bolts and dowels in the connection zone (8). Compared to headed studs, composite dowels provide an increased strength. They also show a good deformation capacity even in high strength concrete (9). In addition, composite dowels have an advantageous load-bearing behavior under

https://doi.org/10.2749/manchester.2024.1375
Distributed by structurae

Ship impact loads on construction pits of bridges

Claus Kunz
Bundesanstalt fuer Wasserbau (BAW), Karlsruhe, Germany

Contact: claus.kunz@baw.de

Abstract

While ship impact loads for the design and dimensioning of bridges over waterways are adequately regulated for a large number of cases in codes, cf. EN 1991-1-7 (2006), [1], there is a lack for the approach of impact loads during the construction period. The primary focus here is on the safety of the construction site situation with a view to protecting the lives of the construction workers and secondarily on avoiding major economic damage. The ship impact load approach from the relevant standards would not be feasible in some cases, would be uneconomical and would possibly not be implemented. In view of the concept of the remaining service life, which is already used for existing structures, [8], the concept was transferred to short periods of time such as construction periods. In recent years, BAW, the Federal Waterways Engineering and Research Institute, has developed impact loads for construction pits in waterways, protecting structures in front of these pits as well as auxiliary supports for bridge structures and has created a concept.

Keywords: ship impact; bridges; collision model; failure probability; construction pit, temporary structure, auxiliary structure, remaining lifetime.

1 Introduction

The determination of ship impact loads on bridges is sufficiently regulated in relevant codes, c.f. EN 1991-1-7 (2006), [1], for the design service life of the bridge, which often is at least 100 years. Both tabled values and methods for determining impact forces are available, [1].

For the construction of a new bridge, however, construction conditions are required, such as construction pits for bridge piers, which, as temporary structures, sometimes have a significantly shorter service life than the actual bridge structure. To dimension these construction pits for an impact load as for a bridge with a long service life would be uneconomical and, in some cases, not feasible.

Therefore, a concept for the dimensioning of construction pits and also protection constructions against ship impact is required. Often, it is not possible, to design the actual construction pit against ship impact, but a protection structure in front of it has to take over this function, which is subjected to the same problem. Figures 1 and 2 show some examples for such construction pits and their protection.

Figure 1 shows as example a topview with a dotted construction pit for a new bridge pier and a surrounding polygonal-shaped protection structure on the right hand side. The existing bridge pier of the old bridge is on the left hand side. The construction pit is located in the fairway. Figure 2 shows as example a construction pit of a new bridge abutment, in the bottom right corner, which is located besides the fairway on the embankment where ships can strand in case of an accident. A protection structure is located at the edge of the shipping lane, in the top left corner of the Figure.

Stainless steel as a structural material in the drive toward net-zero bridges

Andrew Backhouse

Outokumpu Stainless Ltd, Sheffield, UK

Nancy Baddoo

The Steel Construction Institute, Ascot, UK

Contact: andy.backhouse@outokumpu.com

Abstract

In the last few decades, duplex stainless steels have emerged as a candidate material for bridges situated in demanding environments. This paper outlines some of the new design rules in the Second Generation Eurocode for stainless steel, EN 1993-1-4, which are relevant to bridge structures. A main factor in choosing to use stainless steel in bridge building is longevity and very low lifetime maintenance requirements. The outcomes of a recent life cycle cost (LCC) comparison between a carbon steel and duplex stainless steel road bridge are presented. In recent years the carbon footprint of bridges has started to become more important. This paper outlines the current state of the art with respect to the carbon footprint of stainless steel production and offers an insight into how the use of stainless steel can reduce the carbon footprint of a bridge.

Keywords: Stainless steel; Eurocode 3; durability; bridge; composite; life cycle cost; carbon footprint

1 Introduction

The last decades of the 20th century saw advances in steelmaking technology and the development of a family of high strength and durable duplex stainless steels with properties that are suitable for a wide range of structural engineering applications. Stainless steel began to emerge as a candidate material for bridge construction at the beginning of the 21st century. Duplex stainless steels are the most widely used stainless steel family for structural components in bridges due to their superior strength and excellent corrosion resistance, weldability and fracture toughness. More than 30 bridges have been constructed using duplex stainless steels over recent years, including the new road bridge at Pooley Bridge in the UK (Figure 1), pedestrian bridges in the towns of Haro and Aguilas in Spain, and railway bridges in Stockholm. For further examples see references [1,2,3].

Although the cost of stainless steel per tonne is higher than that of carbon steel, the high strength of duplex stainless steel (F_y ~460MPa) allows this to be partly mitigated and the high durability is an important advantage when considering whole life costs.

In addition to iron, the main constituents of stainless steel are chromium, nickel and sometimes

https://doi.org/10.2749/manchester.2024.1390

Advanced steel solutions for a sustainable and economic bridge infrastructure

Mike Tibolt

ArcelorMittal Steligence®, Esch-sur-Alzette, Luxembourg

Wojciech Ochojski

ArcelorMittal Steligence®, Dąbrowa Górnicza, Poland

Contact:mike.tibolt@arcelormittal.com

Abstract

The present paper gives insights in the current efforts of the steel industry to reach net-zero in 2050. Different steel solutions can be combined to achieve major savings in weight, material, building time and costs in construction and infrastructure projects. **XCarb® recycled and renewably produced** steel is already available on the market: by combining scrap and renewable electricity, it offers very low levels of CO_2 emissions per ton of finished steel. Weathering steel can be used without any additional painting of the steel girders – preventing the detrimental impact of the paintings on the environment.

In the paper, the beneficial application of hot-rolled sections in weathering steel (Arcorox®460) and XCarb® is shown based on recently realised bridge projects in Poland.

Keywords: Decarbonization; XCarb®; High strength steel; Weathering steel Arcorox®; Steel-composite bridges.

https://doi.org/10.2749/manchester.2024.1399
Distributed by structurae

Environmentally conscious structural design and material selection of short-span bridges

Ákos Kővári, Gábor Németh, Róbert Bartus

Unitef'83 PLC, Budapest, Hungary

Contact: kovaria@unitef.hu

Abstract

In Hungary and in the Eastern European region the maintenance of small-span bridges built in recent decades – mostly for pedestrians and railways – tends to be less than perfect, so it is not a rare phenomenon that structurally adequate bridges have to be demolished well before their theoretical 100-year design life. Consequently, a critical part of current design tasks is to help our structures cope with very little maintenance but without reduction in their useful life. In addition, in new design tasks, sustainability must be pursued, keeping in mind the principles of environmental awareness that are increasingly coming to the fore. This can be achieved with smart structural design solutions and adequate material selection. This paper presents design principles used in recent projects to create more sustainable bridges supported by LCA calculations.

Keywords: design; weathering steel; short span bridges; corrugated girder; sustainability; LCA.

1 Introduction

The Hungarian road network has seen a previously unparallelled growth in the recent decades. Several roads and motorways have been built with the aim of closing up to the European state of development. In the course of reaching that objective the investors focused primarily on keeping the costs as low as possible while environmental costs were not considered high priority. That attitude shall be revised [1] as the EU targeted a 55% reduction in the emission of greenhouse gases (GHG). The FIT FOR 55% directive stipulates that all member states are set obligatory reduction quotas for their emissions, which concerns construction industry to a large extent – concrete and steel products are especially affected. At UNITEF '83 PLC structural engineers have been working on innovative structural solutions for the latest challenges and such solutions have been effectively used in recent bridge construction projects [2].

The vast majority of currently existing road, pedestrian and bicycle bridges in Hungary are reinforced concrete structures. The recent years of infrastructure development has also seen the dominant application of superstructures consisting typically of precast prestressed concrete bridge girders and reinforced concrete mass substructures based mostly on pile foundations.

In contrary to the sudden growth, maintenance of bridges is not really sufficient or systematic. The need for as little maintenance as possible coincides with the minimization of environmental effects, and is also an important aspect.

The central objective was to find a way of building ordinary bridges using sustainable solutions with reduced GHG emission. This paper presents our progress through our recent projects.

The impact on structural embodied carbon of using loads obtained from wind tunnel testing vs code-based loads

Tung Nguyen, Fabio Faseli and Pietro Manica
RWDI Anemos Ltd., Milton Keynes, UK

John Kilpatrick
RWDI, Guelph, Ontario, Canada

Contact: tung.nguyen@rwdi.com

Abstract

RWDI possesses one of the world's most extensive portfolios of data from structural wind tunnel tests. Drawing upon our wealth of experience, RWDI has carried out studies to compare wind loads achieved by undertaking site-specific wind tunnel tests against values obtained using an analytical code-based approach. In one of the studies, the peak overturning moments of ten prominent tall buildings in the UK were estimated from wind tunnel tests conducted by RWDI. Comparing these loads against values based on Eurocode and the UK National Annex, wind tunnel testing led to an average 35% reduction in wind loads for structural design. The loading reduction is attributed to various important factors that are elaborated further in this paper. In addition, notable UK and worldwide case studies are presented to demonstrate the benefits of wind tunnel testing in delivering more optimised structures and contributing to the reduction of embodied carbon.

Keywords: wind tunnel testing; code-based approach; wind loading; high-rise buildings; concrete and steel buildings; structural wind loads; wind-induced accelerations; embodied carbon footprint.

1 Introduction

With the increasing cost of construction materials and a move towards reducing the construction industry's carbon footprint, there is an increasing requirement for a building's structural system to be as efficient as possible. While accounting for a smaller proportion than the *operational carbon*, reducing the **embodied carbon** associated with building materials and construction is critical to achieving Net Zero targets.

Lateral **wind loads** govern the structural design of high-rise buildings in the UK and affect various critical elements such as shear walls, cores, and the layout of columns. Having a good estimate of wind loads acting on a building that are based on site-specific conditions becomes more critical than ever, to optimising the structural design, allowing efficient usage of materials and contributing to the overall reduction of carbon footprint.

Structural wind loads can be significantly affected by various parameters, including the building geometry and surrounding buildings. Wind loads for the structural design of tall buildings are often initially determined using analytical code-based analysis, such as the Eurocode (BS EN 1991-1-

https://doi.org/10.2749/manchester.2024.1415
Distributed by structurae

Probabilistic modelling of building stock properties for urban mining

Lombe Mutale, Ramon Hingorani, Nils Dittrich and Jochen Köhler

Norwegian University of Science and Technology, Trondheim, Norway

Contact: lombe.mutale@ntnu.no

Abstract

The construction industry is one of the biggest contributors to greenhouse gas emissions and unsustainable waste. A circular economy of the existing building stock can contribute to minimising mining of finite resources and reducing the construction industry's waste. However, stakeholders often list lack of information about the existing building stock as a barrier against implementing a circular economy in the construction industry. This study provides a framework for construction industry stakeholders to combine publicly available data sources to obtain probability-based information about the building stock. The study analyses existing building data at city level using Bayesian Networks, a probabilistic modelling approach that accounts for the missing data consistently in contrast to other methods. The framework can be extended to incorporate first principle, data-based and empirical models from disciplines such as structural engineering, architecture, and industrial ecology to facilitate a circular economy.

Keywords: circular economy; probabilistic modelling; existing building stock; residential buildings.

1 Introduction

The built environment stock and construction industry are among the biggest contributors to global greenhouse gas emissions, energy consumption, and unsustainable waste. This can partly be attributed to the production of building materials and components, construction, and demolition. In fact, in Europe, one third of all waste stems from construction and demolition activities [1].

A circular economy of the existing building stock can contribute to minimising mining of finite resources and reducing the construction industry's waste. Citywide circular economy approaches aim at implementing this approach at the local level. This makes it easier to set up a framework for a circular economy when working together with relevant actors, but also reduces the need for transport that can counteract the economic and environmental benefits of reusing and recycling. However, stakeholders often list a lack of information about the existing building stock as a barrier against implementing a circular economy in the construction industry [2].

There are attempts to collate information about existing buildings from several European countries including footprint, height, building type, and age [3]. However, not only are there many missing entries for these attributes, but also, countries such as Norway were not included and important information like the main construction material is missing. Moreover, there is no suggestion on the part of the researchers on how to deal with data scarcity.

Probabilistic modelling is one way to effectively capture information on the building stock to facilitate circularity, allowing us to deal with an increased level of uncertainty due to either random

https://doi.org/10.2749/manchester.2024.1424
Distributed by structurae

IABSE Symposium Manchester 2024
Construction's Role for a World in Emergency

Resource-efficient Excavation Pit Design and Construction with the Integration of Existing Structures

Grischa Dette, Szymon Sikora

Ed. Züblin AG, Central Engineering Division, Berlin, Germany

Contact: grischa.dette@zueblin.de

Abstract

Resource-efficient construction is a decisive factor for the development of sustainable economies and a sustainable way of life. In addition to material-saving technologies, the reactivation or conversion of existing structures is an effective approach to achieving resource efficiency. Particularly in densely built-up urban areas, there is the opportunity to reactivate elements of still existing but currently idle excavation pit structures, which belong to existing buildings. Also, permanent structural elements of existing buildings, such as basement-walls and base slabs, can be integrated into new excavation pit structures. The present paper reports on the experiences from construction projects, where elements of existing diaphragm walls as well as elements of existing buildings were integrated in the design and construction of new excavation pits.

Keywords: excavation pit, re-use of existing structures, sustainability in construction

1 Introduction

Resource-efficient construction is a decisive factor for the development of sustainable economies and a sustainable way of life. In addition to material-saving technologies, the reactivation or conversion of existing structures is an effective approach to achieving resource efficiency.

Particularly in densely built-up urban areas, underground structures are required for a variety of purposes: they serve as structures for underground transportation, water supply and disposal, rainwater management, and underground car parks. Deep excavation pits are usually required for the construction of such structures.

Nowadays, often existing robust underground structures can be found at the sites of new projected buildings. On the one hand, they can be found in the form of relics of former excavation pits. These can be former retaining walls, such as diaphragm walls or remaining sheet pile walls. They can appear as remains of former horizontal cut-off layers, made for example by jet grouting or underwater concrete. On the other hand, they also can be found in the form of deep basement structures: The traditional single-storey basement in masonry construction has made way for the reinforced concrete basement, sometimes in the form of a multi-storey underground car park.

The question of resource efficiency inevitably arises with respect to excavation pits. As a rule, excavation pits are only temporarily used for the erection of permanent structures. After construction, they remain unused in the ground. For reasons of sustainability and economic efficiency, it makes sense to reactivate or reuse

https://doi.org/10.2749/manchester.2024.1433
Distributed by structurae

Author Index