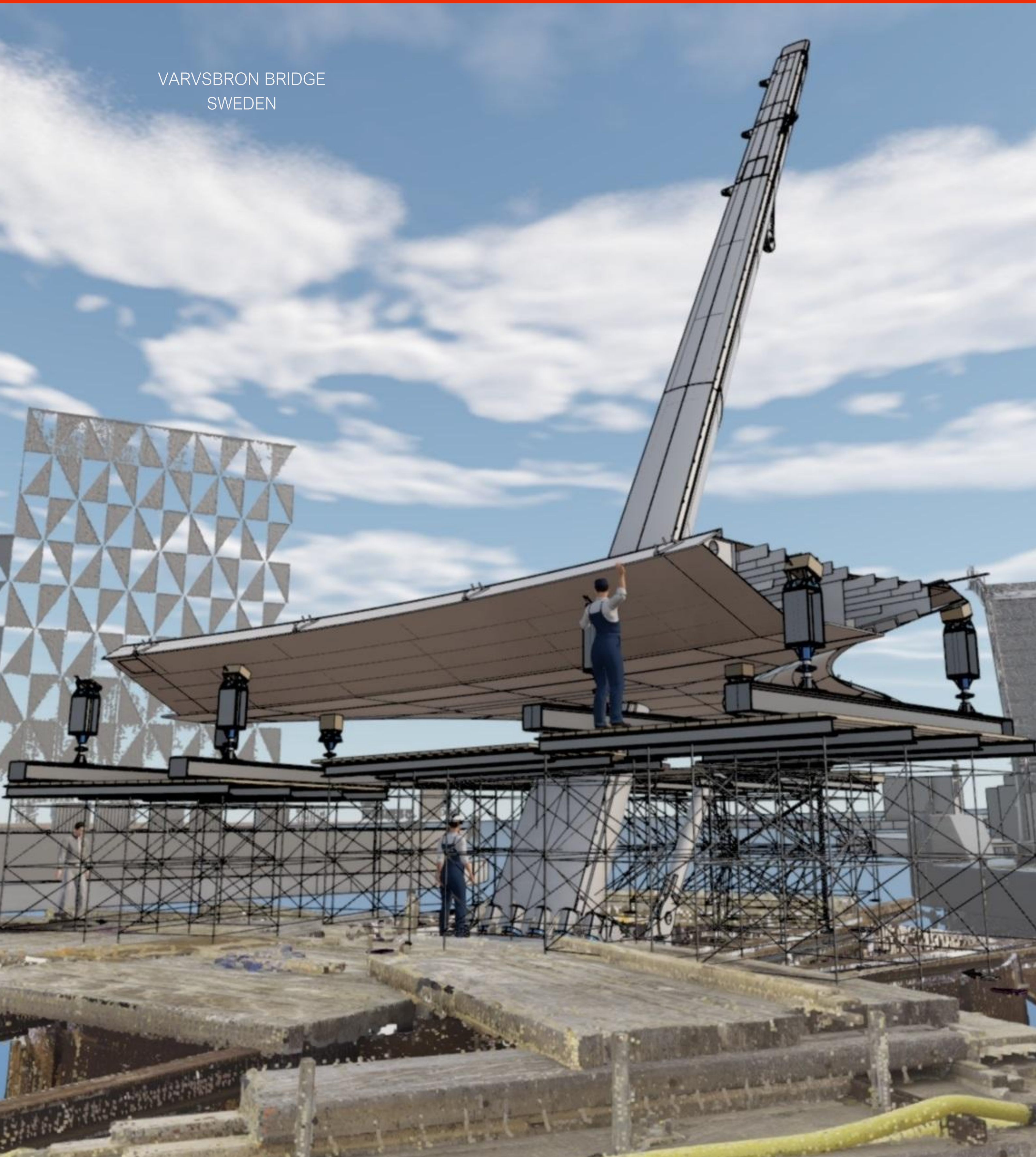
e-BrIM

ISSUE 03/2022 OCTOBER

VARVSBRON BRIDGE
SWEDEN



LIST OF CONTENTS

Front Cover: Varvsbron Bridge in Helsingborg, Sweden. Credit: VisoPro Sverige AB
Photo on the back cover: Fully parametric model incl. reinforcement of a motorway bridge, Czech Republic. Credit: AFRY

International, interactive magazine
about Bridge Information Modelling. Peer-reviewed.

It is published at www.e-brim.com. Open Access.

Released on:

20 February, 20 May and 20 October

Number: 03/2022, October. **Year:** I.

Chief Editor: Magdaléna Sobotková

Contact: magda@e-mosty.cz

Editorial Board

The Publisher: PROF-ENG, s. r. o. (Ltd.)
Velká Hraštice 112, 262 03 Czech Republic
VAT Id. Number: CZ02577933

ISSN: 2788-0540

Dear Readers

The first article of this issue brings information about 3D Modelling and the utilization of CATIA software for the Varvsbron Bridge in Sweden. The sweeping curvature of the steel structure required specific 3D-modelling work; **Tomasz and William Gapinski from VisoPro** describe their involvement in the project.

In the second article of this issue, the team from **COWI North America** focuses on the task to find a new workflow to integrate the structural analysis and drawing production efforts while increasing efficiency, quality, and automation. They describe their journey of implementation of the new 3D BrIM workflow since 2016.

In the third article of this issue, **AFRY CZ** presents an example of the use of the parametric design on a single-span rigid frame motorway bridge, which was entirely - including 3D reinforcing bars - designed using the parametric model in Rhinoceros, Grasshopper and Tekla Structures. The design won the Czech - Slovak round of the prestigious international construction project competition Tekla BIM Awards 2022 in the Small Projects category.

With the kind permission of **IABSE**, we re-publish **three papers** that were presented at the IABSE Symposium in May 2022 in Prague. They are followed by a **brief report** from the Symposium, with the overall theme "Challenges for existing and oncoming structures".

We would like to bring your attention to the last article, in which the authors are looking for an **owner or maintenance company that wants to collaborate in innovation** for the vulnerability assessment of bridges and/or structures with an innovative method that uses the dynamic input of two blasts into soils before and after the retrofitting, and compute the Spectra at a node with high precision monitors (piezoelectric cells/geophones) that record vibrations with millimetre precision.

I would like to **thank all people and companies** that have been cooperating on this issue and helping me put it together; big thanks to the members of the **Editorial Board** for reviewing the articles and their cooperation, especially **Vanja Samec** and **Antonio Caballero**, and to **Sandra Komar (WSP USA)** who helped with the final language check of the articles.

We would also like to thank **our partners for their support and IABSE for their cooperation**.

On the following pages, you can also find more information about both our magazines e-mosty & e-BrIM, and also our Partnership Offer. I can also prepare a tailor-made partnership plan for you and your company; we will be happy to welcome you as our partner.

We are already working on the next issue of e-BrIM which will be released on 20 February. We welcome your articles for it, and we also already accept articles for the May 2023 edition.

The next issue of the e-mosty magazine will be published on 20 December and will bring articles about the Padma Multipurpose Bridge in Bangladesh. The March e-mosty will be dedicated to the Chenab Bridge in India.

Magdaléna Sobotková

Chief Editor

e-BrIM

In August 2021 we established a new magazine, **e-BrIM,** which focuses on Bridge Information Modelling. Its first regular issue was released on 20 February 2022. The September 2021 edition of e-mosty was also a "zero" edition of e-BrIM.

We follow the concept of the e-mosty magazine; e-BrIM is also an international, peer-reviewed magazine with open access and the possibility to subscribe.

Our plan is to publish it three times a year (20 February, 20 May and 20 October); we believe that with the current development of BIM, there will be plenty of interesting and useful content to share.

Let us introduce and welcome our **Editorial Board Members.** Thank you all for accepting our invitation.

We all do our best to prepare technical, educational and informative content for our readers.

We would like to invite you to contribute with your articles to this newly established magazine e-BrIM:

CALL FOR PAPERS

20 February 2023 Edition:

Deadline for first drafts: 20 November 2022

20 May 2023 Edition:

Deadline for first drafts: 20 March 2023

The text shall be in MS Word, 3 – 5 pages plus relevant images, drawings, 3D models, links and videos and shall be sent to our email address.
You may also send an abstract before starting work on the article or contact us to discuss other options.
All abstracts and articles will be peer-reviewed and also subject to approval by the Editorial Board.

READ OUR LATEST ISSUE:

INTERNATIONAL ONLINE PEER-REVIEWED MAGAZINE ABOUT BRIDGE INFORMATION MODELLING

e-BrIM

SUBSCRIBE

The magazine **e-BrIM** is an international, interactive, peer-reviewed magazine about bridge information modelling.

It is published at www.e-brim.com and can be read free of charge (open access) with the possibility to subscribe.

It is typically published three times a year:
20 February, 20 May and 20 October.
The magazines stay **available online** on our website as pdf.

The magazine brings **original articles** about **bridge digital technology** from early planning till operation and maintenance**, theoretical and practical innovations, Case Studies** and much more from around the world.
Its electronic form enables the publishing of high-quality photos, videos, drawings, 3D models, links, etc.

We aim to include **all important and technical information, to share theory and practice, knowledge and experience** and at the same time, to show the grace and beauty of the structures.

We are happy to provide media support for important BIM and bridge conferences, educational activities, charitable projects, books, etc.

Our Editorial Board comprises BIM and bridge experts and engineers from academic, research and business environments and the bridge industry.

The readers are mainly bridge leaders, project owners, bridge managers and inspectors, bridge engineers and designers, contractors, BIM experts and managers, university lecturers and students, or people who just love bridges.

ISSN: 2788-0540

INTERNATIONAL ONLINE PEER-REVIEWED MAGAZINE ABOUT BRIDGES

e-mosty

SUBSCRIBE

The magazine **e-mosty** ("e-bridges") is an international, interactive, peer-reviewed magazine about bridges.

It is published at www.e-mosty.cz and can be read free of charge (open access) with the possibility to subscribe.

It is published quarterly: 20 March, 20 June, 20 September and 20 December. The magazines stay **available online** on our website as pdf.

The magazine **brings original articles about bridges and bridge engineers** from around the world. Its electronic form enables the publishing of high-quality photos, videos, drawings, links, etc.

We aim to include **all important and technical information** and show the grace and beauty of the structures.

We are happy to provide media support for important bridge conferences, educational activities, charitable projects, books, etc.

Our Editorial Board comprises bridge engineers and experts mainly from the UK, US and Australia.

The readers are mainly bridge engineers, designers, constructors and managers of construction companies, university lecturers and students, or people who just love bridges.

ISSN: E-MOSTY 2336-8179

Offer of partnership and promotion of your company in our magazines

e-BrIM e-mosty

We would like to offer you a partnership
with e-BrIM and e-mosty magazines.

Depending on the type of a partnership – Platinum, Gold or Silver - the partnership scheme typically involves:

- Your logo on all pages of the magazine website.
- 1-page interactive presentation of your company in every issue which we can help you prepare (free of charge).
- Your logo and /or the name of your company on every publication and output we release.
- Continuous promotion of your company and projects on our social media.
- Publication of one technical article during the year (which we can help you prepare).

The Partnership can be arranged for either magazine separately, or for both magazines – for a discounted price.

Both the price and the extent of cooperation are fully negotiable.

Please contact us for more details and partnership arrangement.

PARTNERSHIP OFFER - CONDITIONS

3D MODELLING OF CABLE-STAYED PEDESTRIAN BRIDGE IN HELSINGBORG, SWEDEN

Tomasz Gapinski, CEO & Founder
William Gapinski, Design & Manufacturing Engineer
VisoPro Sverige AB

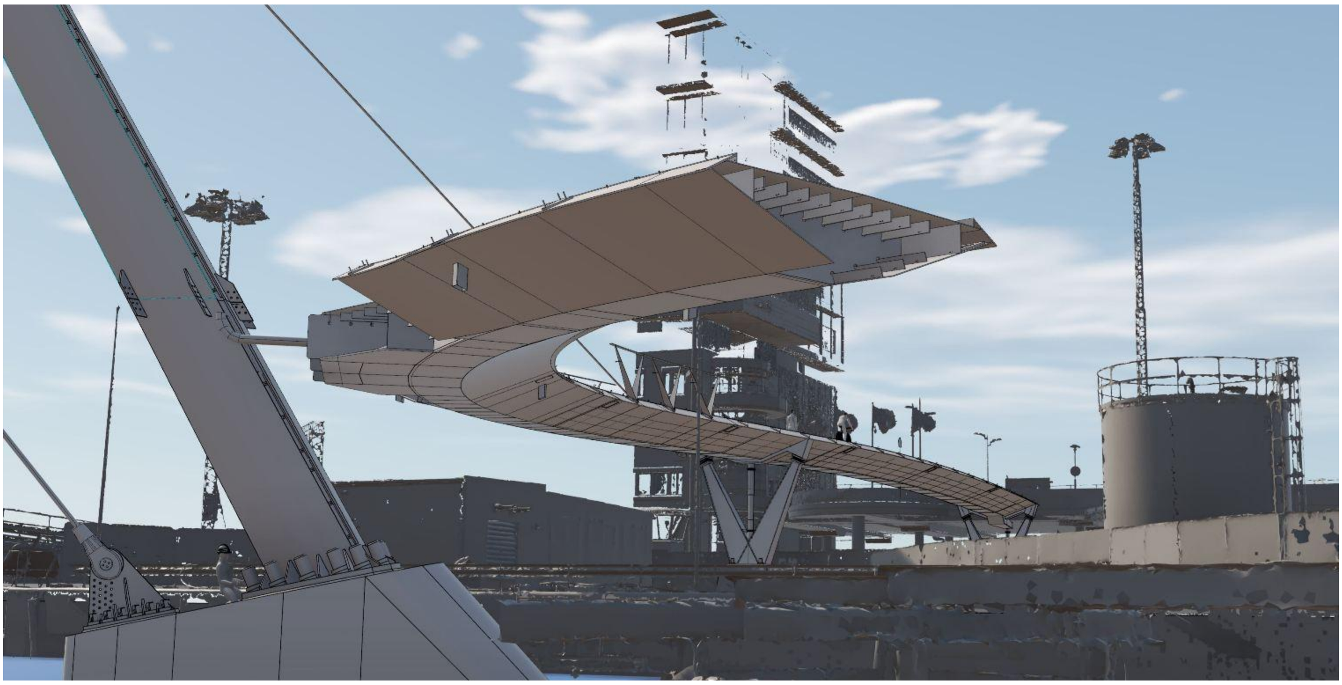


Figure 1: The distinct sweeping curvature of the bridge steel structure

INTRODUCTION

The Varvsbron Bridge, a cable-stayed pedestrian and cyclist bridge, is a part of the development programme of the City of Helsingborg, Sweden to create new vibrant neighbourhoods and revitalise its urban traffic.

The new neighbourhoods in the southern part of the city are planned within the urban development project called H+. Oceanhamnen, which is one of these four areas, forms part of the harbour but it is isolated by the busy access road to the ferry.

The bridge is spanning this ferry access road, then turns and traverses the waterway of the docks to connect with a dry dock planned as a future public parkland, then turns again and continues to Oceanpiren and the new mixed-use development.

The bridge is essential to reduce car traffic, promote walking and multi-modal transport, and complete the strategic cycle routes.

The bridge was opened to traffic on 30 September 2021.

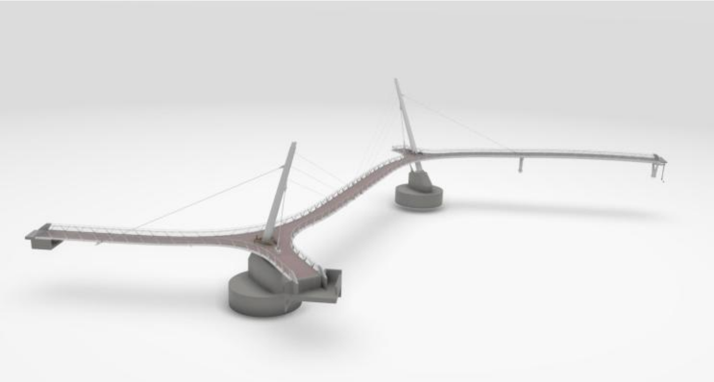


Figure 2: Isometric view of Varvsbron Bridge

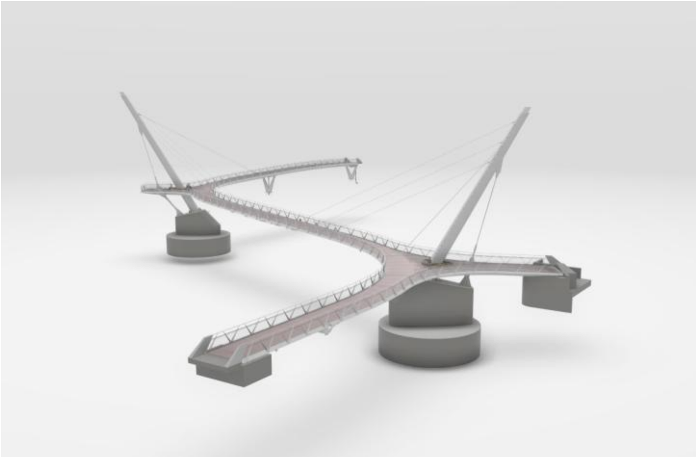


Figure 3: View of the oppositely inclined pylons

CHALLENGES IN THE FABRICATION OF THE BRIDGE

The deck is supported by three cables strung between two oppositely inclined pylons.

There are no cable anchors at or above deck level because the cables swoop beneath the deck to cradle it from below so the curved lines of the bridge sweep across the dock uninterrupted.

Four further backstay cables, two at each mast, stabilise the bridge and anchor the masts to the ground.

Because of the swept curvature and complex geometry of the bridge, which posed a significant manufacturing challenge, commonly used CAD software was not deemed sufficient for the accurate and full capture of the complexity and curvilinear form of the bridge.

The data from the architectural 3D model of the bridge could not be used for precise fabrication.

The main contractor of the bridge, PEAB, came across the company VisoPro Sverige and CATIA software.

VISOPRO

VisoPro Sverige AB is an engineering consulting firm. We provide special competence in 3D modelling for fabrication in the industrial, civil and automotive industries.

We are also providing services in 3D scanning which we often apply to our own engineering projects.

We were contacted by the Swedish building company PEAB AB regarding their issues with the curvilinear shape of the Varvsbron Bridge for the production stage.

Even though we have a background in complex surface modelling, especially for the automotive industry, we have never been involved in a bridge project before.

The generating and handling of the sweeping curvature of the steel structure required a specific 3D-modelling work structure to achieve, and Tomasz Gapinski (CEO, VisoPro Sverige AB) saw the advantages and possibility to use the 3D-modelling software CATIA in this bridge project.

VisoPro received 2D drawings from the structural engineering firm Leonhardt, Andrä und Partner who dimensioned the bridge steel structure in this project.

VisoPro converted the 2D data to parametric wireframes and surfaces, which then were refined into manufacturable correct individual 3D parts.

These 3D parts were then transformed into 2D data which then was sent to the laser cutting production stage.

CATIA SOFTWARE

CATIA is a high-end parametric 3D modelling software primarily used in the aircraft and automotive industries; they have the strictest requirements for accuracy in production.

It was made by Dassault System and its parametric approach has been used by both industries for more than 20 years.

The software enables the interplay between wireframes, surfaces, solids, parts, assemblies and parameters to build up high-complex structures. Input data can be changed to affect the final shape and function.

CATIA "Parent – Children" entities hierarchy approach works like DNA by alternating the molecules.

As a result, the organism changes and adapts to new conditions and environments. Its DNA can also replicate itself to new organisms, use previous states and store knowledge.

This approach made thousands of relation connections possible. At any time, a parent could be replaced or changed and it affected the whole parametric chain.

For its usage in the project, special parameter-driven features were developed, e. g. to define section positions of various steel thicknesses defined by structure engineers along the bridge lane.

The "Steel Master" 3D model connected steel thickness to the bridge "Shape Master". New design features were developed to add new functions in CATIA.

The software also had the required power to host very large 3D data sets. Live work on large 3D data sets together with 3D scanned environments made true virtual design, construction and montage possible.

MODELLING

The first main challenge of the project was to retain the defined cross-section throughout the whole swept S-shaped architecture.

It was necessary to connect the balcony and the ramp decks smoothly to the main bridge curve.

Video: Click on the image to play the video

The work started by importing all the 2D DWG data which was used as source data in CATIA without any manual data input. From the DWG file, wireframe entities were acquired directly by using CATIA's extract function.

The bridge´s S-shape in XY plane and plane elevation curve along the bridge centre curve was extracted.

To generate the parametric main 3D curve of the bridge, the predefined elevation shape of the curve was converted into a mathematical function.

The S-curve was generated by sweeping along the bridge´s XY curve and drowning the curve height, by the controlling mathematic standard function in CATIA.

This approach made the bridge curvature main spine fully parametric and ready to be applied to the precambered shape in the project's fabrication stage.

A skeleton methodology, which is a 3D-modelling approach, has been implemented and refined by VisoPro over many years.

It was adjusted and expanded to match all new needs of the bridge project. The Axis system allows positioning of bridge frames along the bridge curve.

The bridge steel rib frame position was connected to parameters driven by measuring direct 2D tables on imported DWG entities.

This way of work eliminates the rework of the model when changes were made in the tables.

It was easy to reconnect the parameter source when new DWG 2D data was imported.

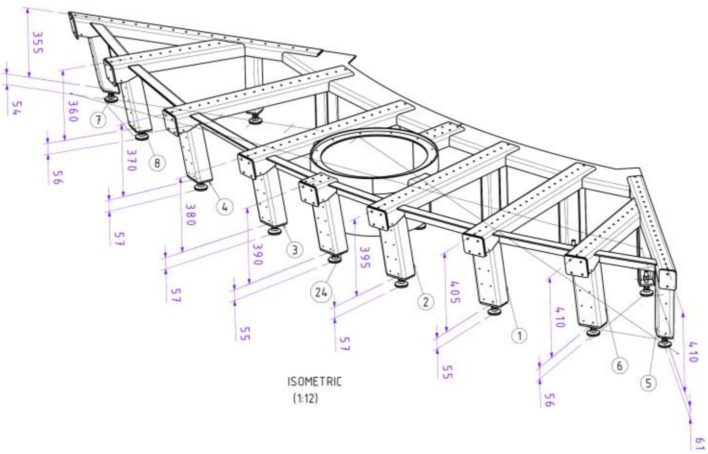


Figure 4: Isometric view of one of the sub-assembly drawings of the bench steel structure

Working directly with 2D DWG data made it easy to see how the parameters were connected to the source data and eliminated errors from manual input.

To secure CATIA curvature data from the Rhino model, the bridge structural engineering team exported coordinates to Excel.

The points with coordinates were imported and created in CATIA. Then measurements were made to secure and confirm the parametrical generated 3D curve.

The generic CATIA S-curve became the main bridge skeleton spine which controlled the bridge's core positions.

All the surfaces of the bridge were made by advanced surface sweep features with the main spine curve as foundation.

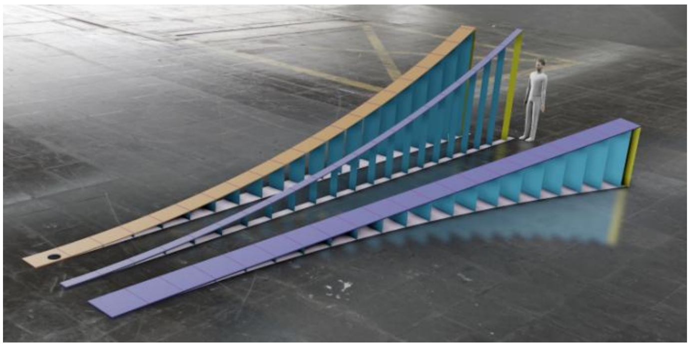


Figure 6: Curvilinear plates from the bridge steel structure

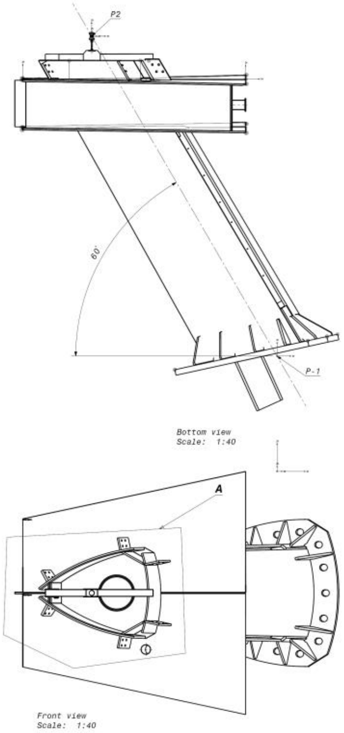


Figure 5: Drawing of the bottom shop section of the Pylon axis 3

The surfaces and axis system features, which all were connected to the S-curve became a parametric shape definition "The Shape Master" for the complete bridge steel structure.

After that, steel thickness data were distributed and connected to the bridge shape definition given by the length position on the bridge curve from the bridge start.

This position was defined by connection parameters to measurements direct on imported DWG. This data was also included in the imported DWG 2D table.

The bridge was divided into shop sections given by the steel contractor and transportation limitations. Every shop section was modelled in an internal coordinate system.

This simplified the construction and manufacturing of the positioning and welding fixtures.

The position of the bridge shop sections on the bridge was defined by the coordinate system in the "wireframe master" model.

This secured the communication between "steel master" elements with the shop section parts, even though they did not share a common coordinate system.

Figure 7: Combining 3D-scandata with the 3D-model in the digital twin of the building site

Figure 8: Planning of the Scaffolding positioning before the montage sequence

A generative part was developed. All the knowledge was stored and was ready to be replicated.

In the process of part instantiation, inputs from the master skeletons were connected to the generative part and CATIA built up the 3D part together with unfold and bending references.

It also retained relation to the main skeleton masters.

By parametric control of the "wireframe master" and "steel master" and connection to the building part level through CATIA "parent – children" relation to entities and parameters, the bridge could be adjusted and changes could be communicated to the construction level.

This enabled us to work dynamically and in parallel on the bridge design and with final fabrication models and manufacturing data.

Thanks to this process the bridge shop form was applied and adjusted dynamically during the 3D modelling.

No modelling work needed to be reworked because the parts could be updated by their "parent-children" relation to the master skeleton models.

FABRICATION

The bridge model and its surroundings are in a high level of detail. The building site was 3D laser scanned with high accuracy and GEO referenced by surveying.

3D scan point cloud and extracted models of the environment were imported into the cloud-based CATIA 3D Experience platform.

The 220m-long footbridge consists of more than 3,500 unique steel plates.

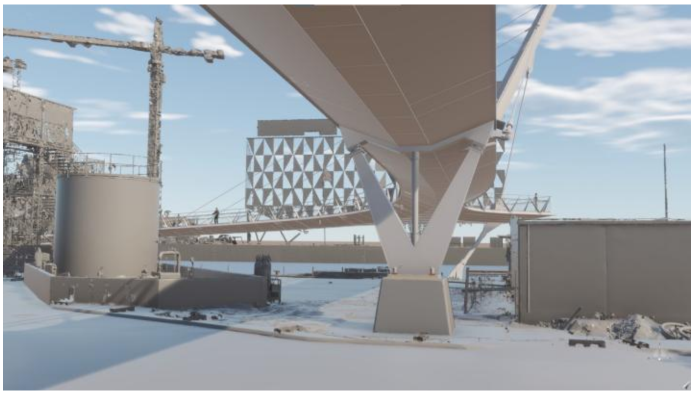


Figure 9: View from E47 (EUROPEAN ROUTE 47) which goes underneath the bridge towards the ferry boarding area

Figure 10: Hidden steel structure beneath the walkway

Figure 11: Simulation of the shop section montage close to the pylon bottom section

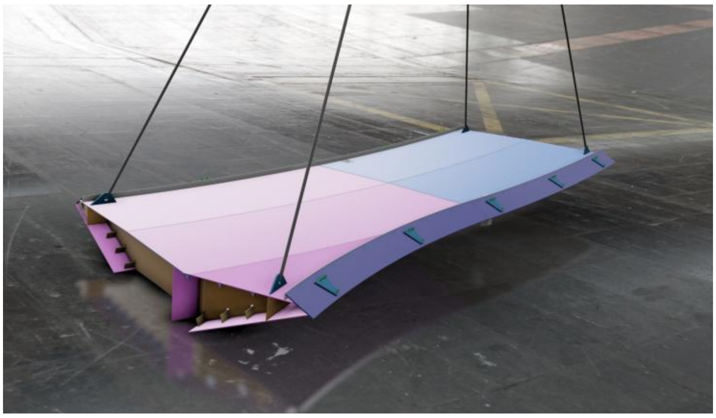


Figure 12: Shop section of the Varvsbron bridge

The parts and cutting data had to be generated automatically; their manual generation would be time-consuming and would need to be reworked in case of any changes.

In the production of the bridge, 500 tons of steel were used.

Every shop section was built up by using defined generative templates. The final shop section was checked with the CATIA clash tool.

Interferences between internal shops section parts and shop section against its neighbours and steel master were performed.

By this check, the quality of all parts was secured and assembly errors were eliminated.

The DXF numeric unfold data was extracted from 3D parts by developed software that was executed in CATIA.

The 3D model of the shop section was exported to STEP and sent in a complete package of data together with DXF files and an Excel Bill of Materials (BOM) list to the steel contractor.

This data was sent by the steel contractor directly to their supplier of plasma-cut steel parts.

The smooth 3D S-shape of the bridge body surfaces could not be manufactured by rolling.

The surfaces are a combination of rolled and twisted shapes.

CATIA extended unfolding feature had to be applied to prepare numeric data for NC plasma cutting on every part in DXF format.

Along with the 3D model and unfolding data, a special bending measuring reference feature was developed.

The long side of the unfold was divided into even segments and vertical references were extruded up to the parts mid-surf.

It was possible to easily show on the model the curvature height level along the unfolded side edge as well as to show it on the fabrication drawings.

On every 3D part, a text was placed to show which side is up on the plain unfolded plasma cut part.

Every aspect of the project phases could be tested and evaluated.

The 3D Experience enabled anyone also to experience the virtual project site with VR without any preparations.

PDF

In this pdf, you can see the many variable parts in the 2D BOM

Click on the icon to open the pdf

Figure 13: Verification of montage with 3D-scandata from the building site

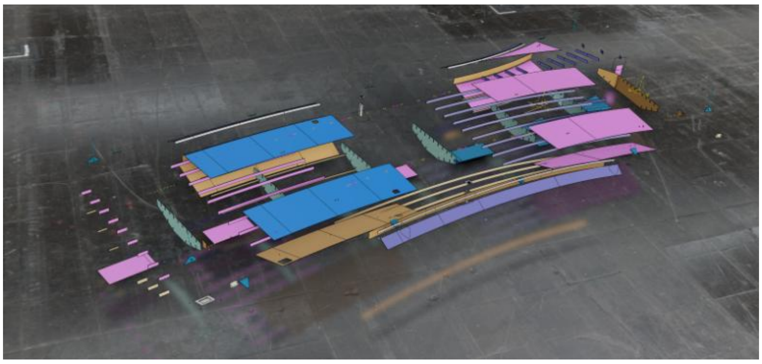


Figure 14: "Exploded View" of one of the shop sections

At every moment, it was possible to jump in to look at the work in progress to evaluate design, construction or assembly issues.

The 3D Experience platform delivered live rendering; the data with outdoor lighting looked very natural.

No special renderings were needed to experience real-life environments live.

CATIA virtual manufacturing possibilities enabled testing of the final assembly work.

Lifting plans for the shop sections were simulated and all scaffolding was virtually built up to support the complex bridge segments.

World coordinates positions of scaffolding and the height level of supporting "rocking heads" was exported from the model and delivered to the surveying team.

The positions of the supports were then defined on-site for the positioning and levelling of the scaffolding.

This made the lifting and positioning of bridge segments less time-consuming and safe.

Throughout the installation on-site, a large amount of surveying data was exported from the CATIA model to verify the installation.

3D laser scanning was also used to verify the position of installed bridge segments.

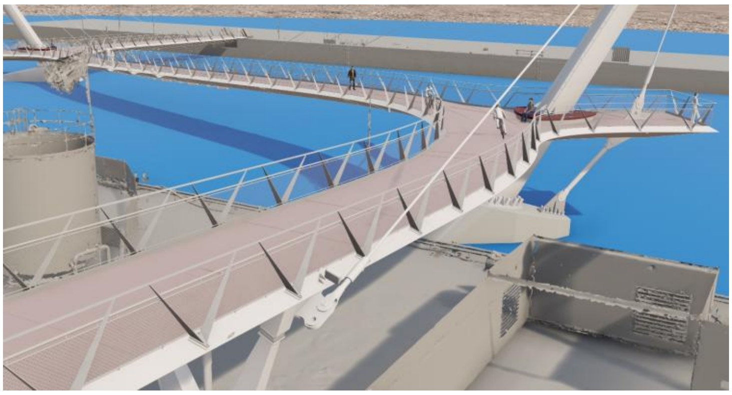


Figure 15: View from Helsingborg Central

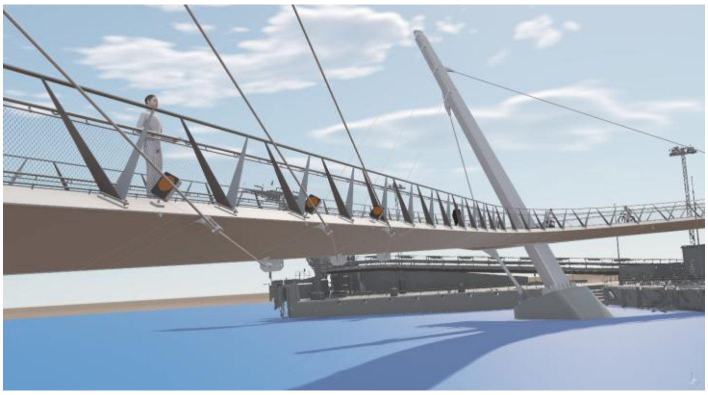


Figure 16: View of the bridge mid-section

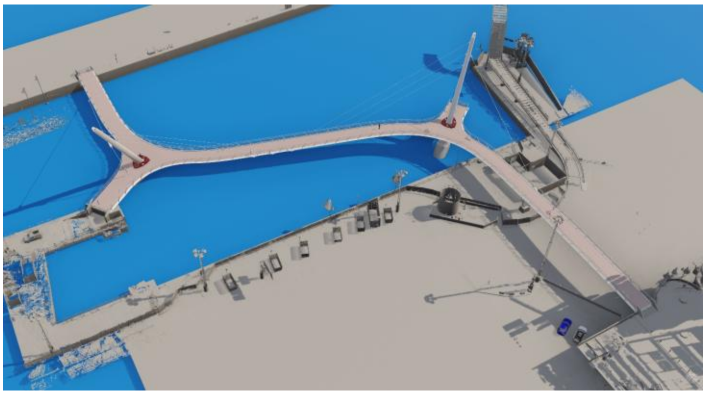


Figure 17: 3D-scandata from the bay area in Helsingborg

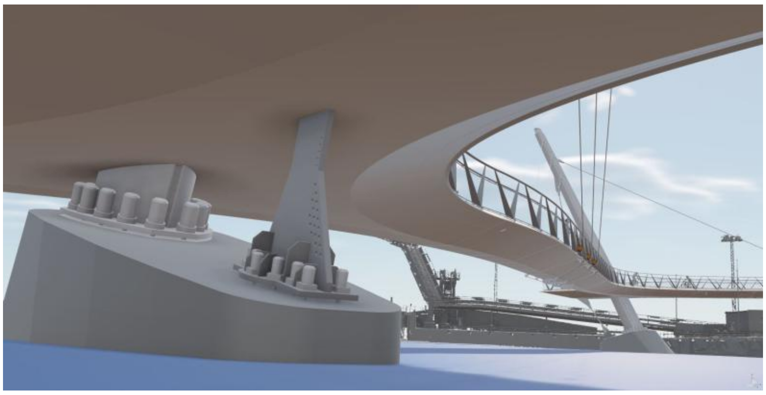


Figure 18: View underneath the bridge towards the ferry boarding area in Helsingborg

CONCLUSION

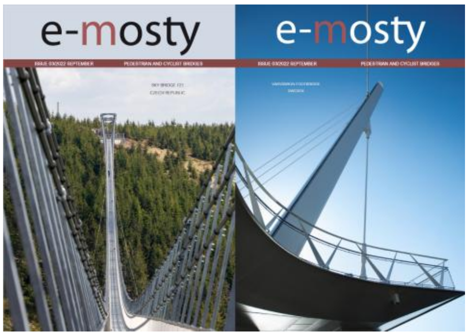
The Varvsbron Bridge in Sweden has a very complex geometry and is comprised of more than 3,500 various parts for fabrication.

The data from the architectural 3D model of the bridge could not be used for precise fabrication and commonly used software may not be sufficient for the accurate and full capture of the complexity and curvilinear form of the bridge.

That is why we decided to use the CATIA software which has been used in the automotive and aircraft industries for more than 20 years because both industries have the strictest requirements for accuracy in production.

The software proved to be suitable and new design features were developed to add new functions in CATIA.

You can read about architectural concept, design and construction of the Varvsbron Bridge in the magazine e-mosty September 2022:



ELEVATING BRIM

Jan Žitný, Senior Bridge Engineer, COWI
Jindřich Potůček, Head of Section, COWI
Ivan Liu, Senior Bridge Engineer, COWI
Jerry Pfuntner, Technical Director, COWI

1. INTRODUCTION

COWI North America Southeast is a specialty engineering firm recognized nationally and internationally for its expertise in complex bridge projects of all kinds.

A major business focus has always been supplying the all-important link between engineering and construction on bridge projects and to understand both sides, design and construction.

In 2016, the transition began from traditional design approaches to parametric and bridge information modelling of bridges for both structural analysis and drawing production in a 3D environment.

This article will detail the introductions, achievements, challenges, and lessons learned over the past six years while using BrIM technology.

The parametrization and 3D modelling workflows will focus on prestressed concrete segmental bridges, highlighting some of the technical aspects of the design and construction.

2. BACKGROUND

Key factors leading to the company-wide design approach change in 2016 were a lack of software support from former software providers, a limited number of skilled detailers and CAD technicians, greater utilization of engineers for CAD production, and necessary improvements to quality control during drawing production.

These factors stemmed from a history of complex segmental bridge projects which would contain a large amount of design and client-driven revisions during integrated shop drawing production.

The number of revisions or modifications during the fast-paced, in-construction development can lead to production inefficiencies and increased quality control challenges.

In 2016, the firm's management selected a team of young engineers with a task to find a new workflow to integrate the structural analysis and drawing production efforts while increasing efficiency, quality, and automation.

This task was to be completed with the analysis and drafting software commercially available to the industry at the time.

After two months of testing several software platforms, SOFiSTiK was selected as the primary structural analysis software, with LUSAS as the secondary, and Autodesk AutoCAD & Inventor as the parametric 3D modelling and drafting tools.

2.1 Drafting using 3D Modelling

The first pilot project to implement new 3D BrIM workflow was the $875M Honolulu Authority for Rapid Transportation Airport Guideway & Stations Honolulu Rail Transit (HART 3) design-build project located in Honolulu, Hawaii.

COWI's scope of work was to deliver shop drawings, segmental geometry, and post-tensioning stressing data for 8.3 km of the new rail transit elevated structure which consisted of more than 2,700 precast prestressed concrete segments.

Figure 1: Honolulu Rail Transit (HART 3) - Elevated Structure

Although predominantly used in the mechanical engineering industry, Autodesk Inventor was chosen for its highly parametric 3D modelling capabilities and COWI's implementation and philosophy specifically for precast segmental bridges.

In short, a precast segment can be imagined as an assembly with a limited variation of internal or external parts, similar to a car engine.

For HART 3, two parametric 3D segment core models were created to include all possible variations of the 2,700 segments (e.g., variable length, number and diameter of reinforcement, post-tensioning, concrete blocks, embeds, and openings).

In total, 50 parameters have been identified for typical and expansion joint precast segments.

A database was established and maintained through the project duration to sort the segments with unique sets of parameters into families which shared the set of shop drawings.

In total, 674 unique segment type shop drawings were created using the parametric drawing template.

At the end of the drawing production, the positive feedback from the client, as well as the minimum number of revisions and overall quality of the shop drawings, encouraged everyone at COWI to fully implement this workflow to all prestressed concrete segmental projects in the future.

2.2 Analysis Based on BrIM

For analysis, SOFiSTiK was the selected software as it can be operated using fully text-based input in addition to a visual CAD input.

This quickly led to the development of fully parametric segmental bridge model templates, first created in Python's programming environment with input through excel spreadsheets and gradually transitioning to Grasshopper's visual programming environment as it has a broader appeal to engineers than pure coding.

Several existing tools have been gradually implemented into these templates to develop accurate segmental geometry, casting geometry and erection geometry for the superstructure.

Such project templates can now be applied to almost any type of prestressed concrete segmental bridges to deliver the first results and quantities within matter of hours.

All of these parametric modelling and analysis tools were implemented for the first time on the Wekiva River Bridges, a $235M design-build project in Lake and Seminole Counties in Central Florida.

Figure 2: Wekiva River Bridges - Service Road Bridge Construction

Figure 3: Wekiva River Bridges – Pier Table Construction

COWI was the Engineer of Record and the construction/specialty engineer for three new cast-in-place segmental bridges with span lengths of 260', 360', and 260', built in balanced cantilever.

COWI's scope of work included cofferdam, pier table falsework design, end-span falsework design, and form traveller design review.

Re-use of the parametric design templates together with parametric 3D models of the substructure and superstructure led to high efficiency and quick deployment of design modifications for all three structures.

Even though the bridges looked identical, in terms of detailed shop drawings, almost every segment was unique.

The segment variations in conjunction with the owner's requirements resulted in the development of a unique set of shop drawings for each segment.

Further workflow development efforts had to be invested to align the workflows with project-specific requirements, complex geometry of the segments, and detail variability.

Significant work was done in terms of background programming in both parametric 3D models and drawing templates to minimize the risk of future revisions and repeated thorough quality control processes.

3. MODELLING AND PARAMETRIZATION

This part focuses on the technical aspects of prestressed concrete segmental bridges with box girder superstructure, the geometry features which make such bridges complex for design and construction and why parametrization is a key to success.

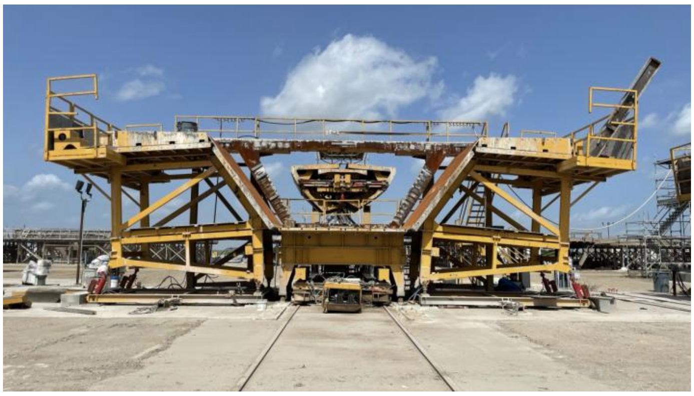


Figure 4: Short-line Precasting Cell

Key aspects of a prestressed concrete segmental bridge design and construction are segmental geometry during casting and erection, post-tensioning design and geometry, and construction sequence.

Especially for precast segmental bridges, the correct segmental geometry and geometry control during casting are crucial for successful erection.

A segment casting geometry is defined by the theoretical geometry of the superstructure adjusted by the precamber.

Due to the time-dependent behavior of the prestressed concrete material, the precamber analysis must accurately consider the contractor's construction means and methods and schedule.

Most of the precast segmental bridges designed in our office were fabricated using a short-line match-casting method.

Small adjustments are always hard to achieve during matchcasting segment positioning, and the segment can always move a little bit during casting, which leads to deviations from the theoretical casting geometry.

After every casting cycle, small adjustments to the theoretical casting geometry must be performed in order to get the theoretical casting curve as close as possible while maintaining reasonable angle brakes in the geometry between two segments and simultaneously accounting for the adjustment possibilities of the casting form itself.

These various steps described above highlight the need to integrate as many of the modelling, analysis, and geometry control tasks into one platform to minimize human error while transferring the data.

During the last few years, Rhinoceros together with Grasshopper has emerged as our single source of data for both analysis and construction models.

Each segmental job is unique in terms of setting up the theoretical segmental geometry and is tied to the roadway axis.

As the segment length is often fixed, and the precasting or form traveller side forms are perpendicular to the fixed bulkhead, the so-called

Figure 5: Blue Ridge Parkway Bridge over I-26 - Pier Table Construction

chorded superstructure geometry needs to be developed.

For precast segmental bridges, the segment length is typically measured along the chorded curve following the 3D bridge centerline.

To minimize the segment geometry deviation from the theoretical curve, horizontal adjustments of the pier table, or rock back of the pier segment, is usually required.

These fabrication principles and required corrections add extra complexity to developing the theoretical and casting geometry.

Because there is no commercial software capable of performing all these tasks, the design firms must often work with in-house built geometry tools.

Grasshopper has been developed to perform complex 3D geometry operations with the possibility to define custom scripting tools and clusters.

This has allowed us to define tailor-made geometry toolboxes which can be easily distributed to all engineers and code-based components allowing version control and documentation of code changes.

Established connectivity to SOFiSTiK allows us to use such geometrically accurate models directly as an input for global and local analysis models for both in-service and construction engineering stages of project development.

In addition, all post-tensioning geometry and data can be modelled in Grasshopper with options to transfer the data to both analysis model and to export as a 3D geometry for drawing production models.

It provides us with the possibility to retrieve the analysis results, especially local and global deformation of nodes, which is crucial, for casting geometry definition and erection geometry control.

For the majority of segmental bridges, the set of tasks which need to be performed to build the bridge is quite similar.

Therefore, once one bridge Grasshopper model is developed it can be connected to a database input and used as a template for future projects.

If we are responsible for both bridge design and construction engineering, it can significantly reduce manhours as 80% of the analysis model development and computational tasks are already prepared and can be reused.

Only with minor modifications of the input for roadway geometry, number, and length of segments on each cantilever, post-tensioning

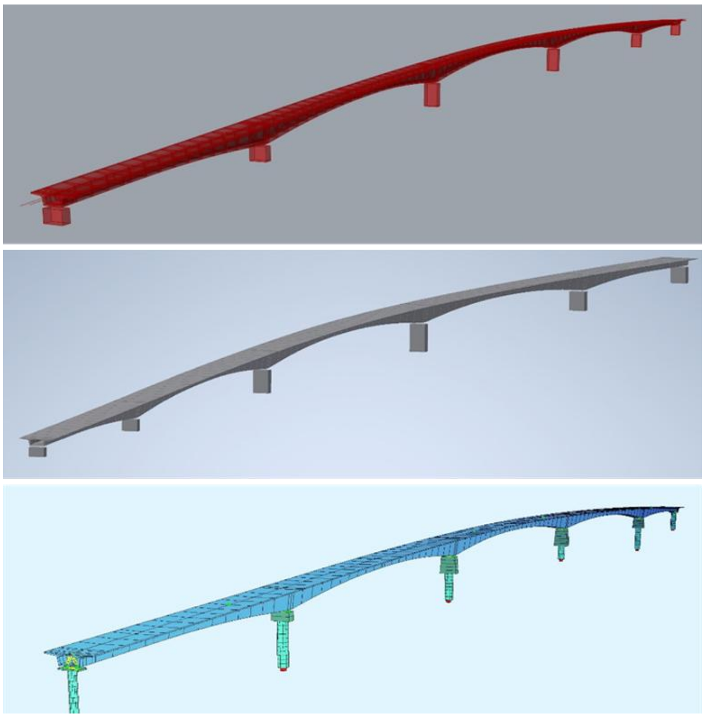


Figure 6: Metro Green Line Extension Minneapolis Bridge 27C10 - 3D models

layout and construction sequence, new bridge analysis and geometry control model can be prepared in an extremely short period of time.

Although, Autodesk Inventor does not support connectivity to Grasshopper and our 3D production models have been set up with sharing bridge data through well-defined excel tables.

However, as described in the Background Chapter we have a different philosophy to standard BrIM model production for our 3D models and design or shop drawing production.

Where the standard BrIM models aim to contain the full amount of data into a single model, our focus is on one segment environment at a time.

One fully parametric segmental model is created for each type of segment (typical segment, pier segment, expansion joint segment).

This model contains all possible occurrences of reinforcement, blocks, openings, and embeds.

Background macros are defined to set the model parameters and visibility of segment parts based on the Grasshopper generated excel input table.

To achieve the maximum amount of automation, it is necessary to avoid any manual updates to the model and parametric drawing template the drawings are generated from.

Once the new set of segment parameters is loaded, the macros rebuild the 3D production model and consequently update the parametric drawing template.

To avoid manual updates, a huge amount of upfront work and planning must be done to capture all the possibilities in both the 3D model and drawing file.

However, once such a template is set, everything can be cycled and both segmental models and drawings sets with bills of quantities are generated automatically.

Due to the significant time investment in the beginning of the drawing production as well as the tight submittal sequence and schedule, not all projects are suitable for full implementation of the parametric model and drawing setup.

However, with the growing number of projects developed in this BrIM workflow in addition to the growth of the engineers able to build the models efficiently, the minimum number of segments and minimum budget which is worth it is consistently decreasing.

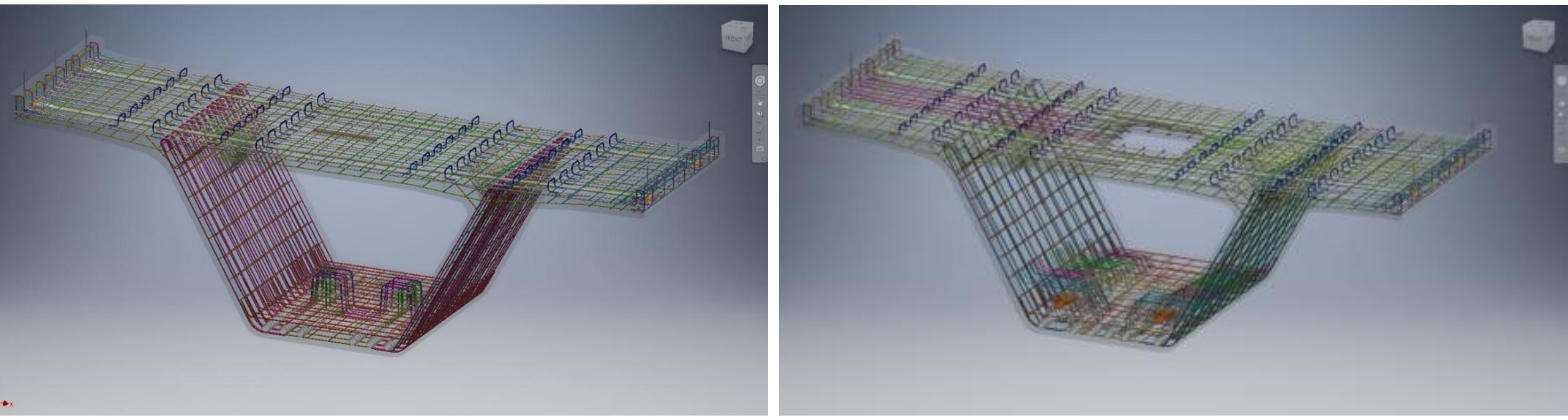
4. CONCLUSION

Our journey with BrIM has started six years ago and the most important lesson we learned is that the mission never ends.

Today, we do not work the same way we did three years ago, and we already know that in three years our workflow will be different again.

Working with BrIM inherently includes staying up to speed with the software development offering new tools and workflow.

We did not go exactly where we had thought originally, but by keeping in mind our ultimate goal of integration of analysis and drawing production, we continued to hone processes and could achieve better efficiency in our production.



Figures 7 and 8: Honolulu Rail Transit (HART 3) - Parametric 3D Model

The development of our drawing production workflow was mainly driven by the intent to aid the production with 3D modelling, but our clients did not require a full 3D BIM model of the bridge project with all related objects and utilities.

Therefore, the philosophy of having a single parametric 3D production model for each segment type was sufficient through the years.

We can see the recent change in the market where the clients start to realize that a BIM approach does not mean only pretty visualization but a completely different mind-set and opportunities it gives through the design process and for maintenance.

Why did we choose Grasshopper as our single source of truth?

Grasshopper is a tool with a large community that is constantly developing and sharing knowledge.

Many commercial software platforms are developing custom toolboxes for live connectivity with Grasshopper, which allows it to be used for pre- and post-processing of inputs and outputs, creating a single source of data for the bridge projects.

The ability to define our own scripts, clusters, and templates makes it a useful tool for all engineers within the team to use and easily understand all aspects of the bridge design.

What do we see as our challenges in the future?

- A complex parametric template can become a black box for an inexperienced engineer, especially when used under a tight project schedule.

  Without fully understanding all the defined processes and sub-tasks the risk of error increases. As this is somewhat similar to working with modern analytical software we use on daily basis, it could be addressed by proper training, visualization of the results, and good supervision.

- A parametric 3D modelling and drawing production increases the efficiency and automation to high levels and the quality control and assurance procedures start to become the bottleneck of the production process.

  In addition to checking the final output, quality control of the model input turns out to be an efficient way of ensuring we're working with the correct set of data.

  Smart version control of the database input data and of the parametric model will also decrease the risk of error.

  Modern tools, such as Bluebeam Revu offer the possibility of document comparison, highlighting only the differences.

- When using parametric design templates and tools it is necessary to establish quality assurance and version control of the tools itself, especially with growing project team members and user community.

The current development focuses on transitioning into 3D modelling software which allows live connection to the geometry models built in Grasshopper, such as TEKLA or Autodesk Revit.

With the experience and knowhow built over the past six years, the results look very promising from the beginning as the way of working with BrIM is not about software but about working smart.

USE OF PARAMETRIC DESIGN FOR MODELLING OF A HIGHWAY BRIDGE

Ing. Michal Marvan
Ing. Ondřej Janota
Ing. Pavel Vlasák
AFRY CZ

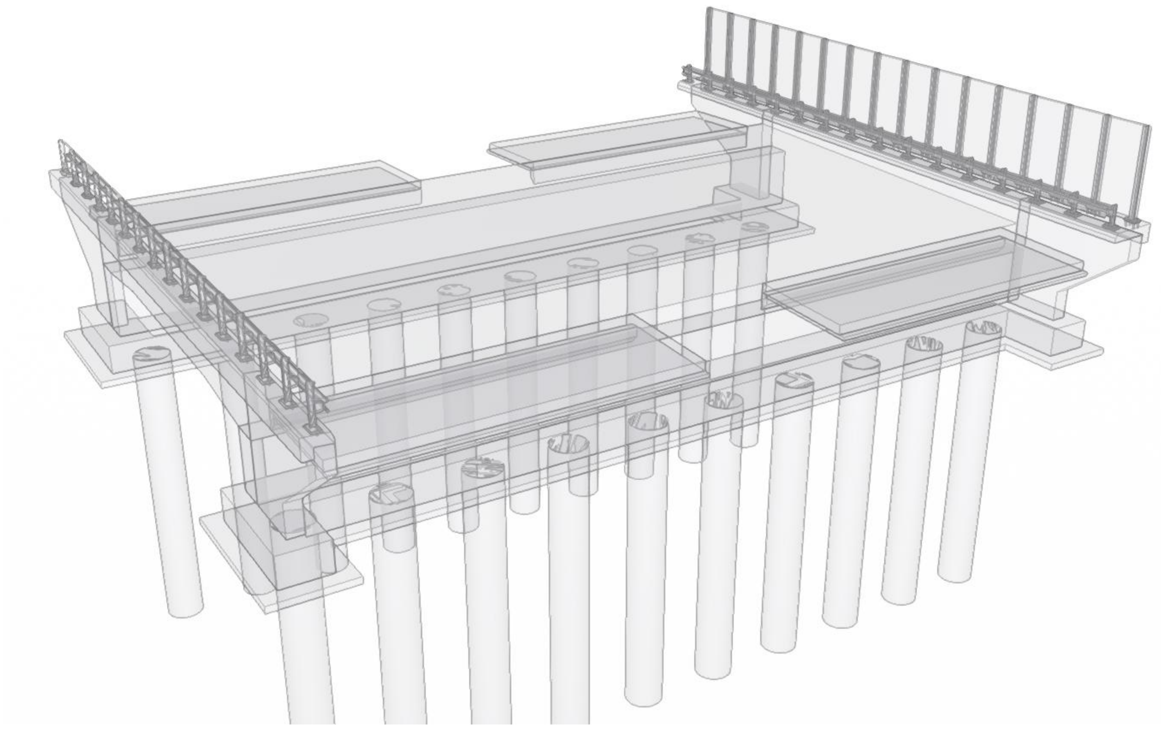


Figure 1: Model of the motorway bridge

INTRODUCTION

More than two years ago, we started looking for a way to make our work easier and at the same time give ourselves a little help with routine design; a way to do work more efficiently, better and faster, whether the client requires a BIM design or not.

We tried a number of programs that promised to create 3D models, but none could deliver simple repeatability. We always had to start the process from scratch. In the end, the parametric design turned out to be the path we were looking for.

Parametric models ensured the required repeatability of individual solutions and thus improved the quality of project processing.

In this article, we present an example of the use of the parametric design on a single-span rigid frame motorway bridge, which was entirely - including 3D reinforcing bars - designed using the parametric model in Rhinoceros, Grasshopper and Tekla Structures.

The design won the Czech-Slovak round of the prestigious international construction project competition Tekla BIM Awards 2022 in the Small Projects category.

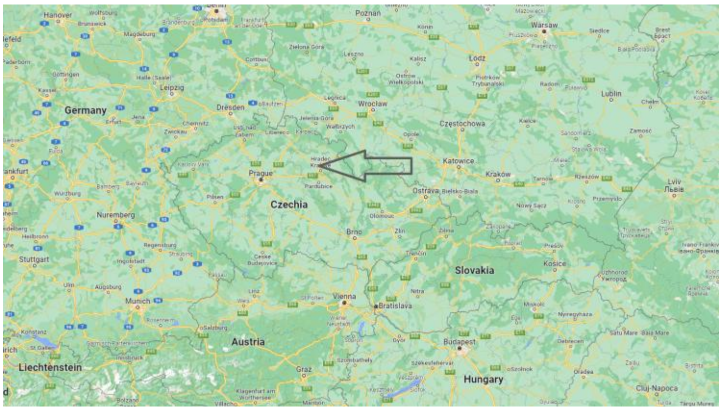


Figure 2: Location of the Bridge on the map

Source: Google Maps

THE MOTORWAY BRIDGE

The Motorway Bridge marked SO202 is located at km 32.788 in the Sadová-Plotiště section of the D35 motorway, which is planned as a northern backbone road connecting Bohemia and Moravia. It aims to improve the quality and efficiency of road travel.

It is a single-span frame bridge founded on large-diameter piles. It carries the D35 motorway over the Melounka Creek. The Sadová-Plotiště section includes three other bridge structures of a similar design solution.

WHY WE CHOSE PARAMETRIC DESIGN

The parametric 3D design has become an integral part of our work due to its indisputable advantages, which we describe below.

It helps us address aspects that would be omitted if we used only standard 2D drawings (e.g. automation check of all requirements to the structures in the terms of spatial layout; better design and faster coordination with other parts of the project, collision control in all parts of the structure not only in the drawn parts, rebar collision check, formwork collision check if a complex shape is needed).

Since the 3D solution is significantly more illustrative, it is also generally preferred by the client. It also simplifies communication and cooperation with the investor's design team.

The workflow we adopted utilizes Rhinoceros, the Grasshopper plugin and Tekla Structures.

The Rhinoceros‘ open API enabled us to use the Python and C# programming languages to develop a shared library of our own components, which ensures better and easier repeatability of individual solutions and maintain the quality of work.

We used this workflow for the SO202 Bridge and two other similar bridges within the section and also apply it regularly in other projects.

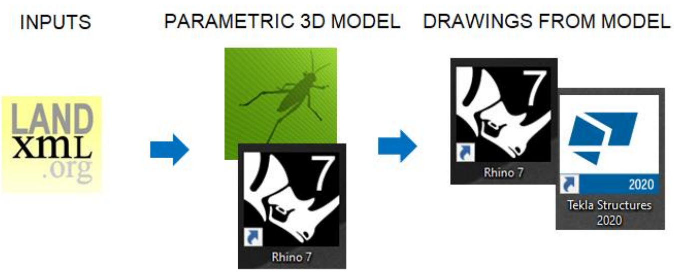


Figure 3: The used workflow

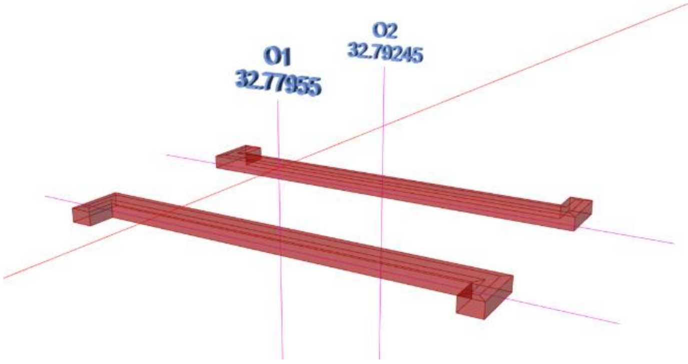


Figure 4: Axes of abutments and stationing related to alignment

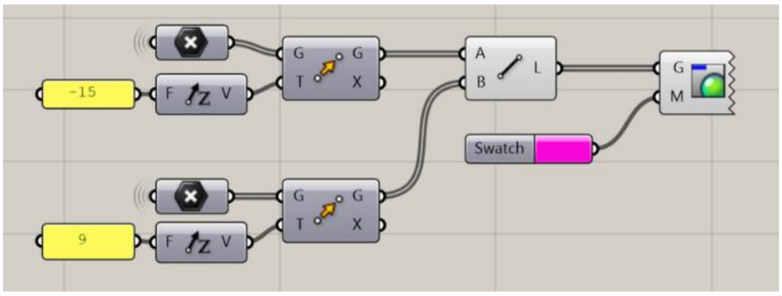


Figure 5: An example of components use in Grasshopper

Figure 6: An example of a custom component using the Python programming language

1. Creation of the model

The whole process starts with importing the alignment and corridors from the LandXML format. Subsequently, on the alignment to the given position, we start designing the bridge by entering the stationing of the axes of the individual abutments, which determine the main location of the bridge in relation to the road.

The process continues with the step-by-step parametric definition of the entire structure.

The structure can be specified either by a series of commands using native Grasshopper components or by using our own components, see Figures 5 and 6.

A library of components developed for our specific needs makes the model creation process in the Grasshopper script much easier and clearer.

The result is a parametric 3D model of the bridge.

Thanks to parametric input, we can design and coordinate other similar bridges, which differ only in the values of the given parameters (width, height, wing length, etc.), in a very short time.

2. Reinforcement of the model

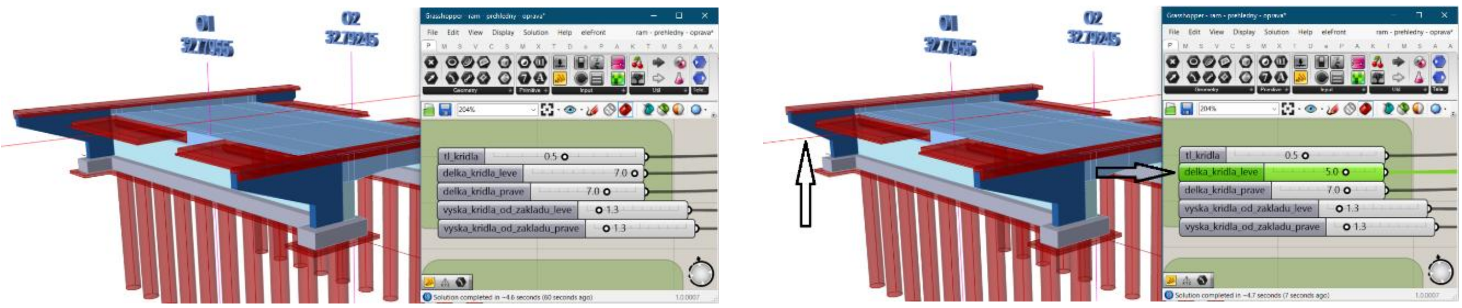
To reinforce the model, we used the Tekla Structures in connection with the Grasshopper.

In the first step, we created the shapes and placement of the rebars for the individual edges of the parametric bridge using the Python programming language.

After that, we connected the individual reinforcement groups with Tekla Structures and, using Grasshopper-Tekla Live Link components, we created individual native rebar groups in Tekla Structures.

The fundamental and unique advantage of the above process is that when the shape of the structure changes, the shape of the reinforcement also responds to the change.

That means that all parts remain parametric. In this way, we are able to effectively modify (update) the entire bridge in a fraction of the time compared to how long it would take to change the model and reinforcement using a normal non-automated procedure.



Figures 7a and 7b: Example of parameter change and 3D model response in real time

The result of our workflow is a fully parametric model of the bridge, both its shape and its reinforcement.

3. Creating 2D drawings directly from the model

Since we still need to deliver 2D drawings to the client and not a 3D model, we addressed the possibility of creating 2D drawings directly in the parametric model (drawing automation).

It is a process where we cut the relevant part of the structure with the cutting plane in which the given drawing should be located, in order to create the curves that are the basis for the drawings.

Using Grasshopper, we can set which layers in Rhinoceros the curves belong to and then use the "bake" command in the given layer.

Dimensions can be subsequently added to the drawing and finished according to the designer's wishes.

The disadvantage of "baking" the basis for the drawings created in this way is the loss of connection to the model, and thus the parametricity.

After "baking", individual curves are no longer able to react to changes in the shape of the bridge.

However, a script in the Grasshopper remains, therefore we can simply create new curves if the shape of the structure changes.

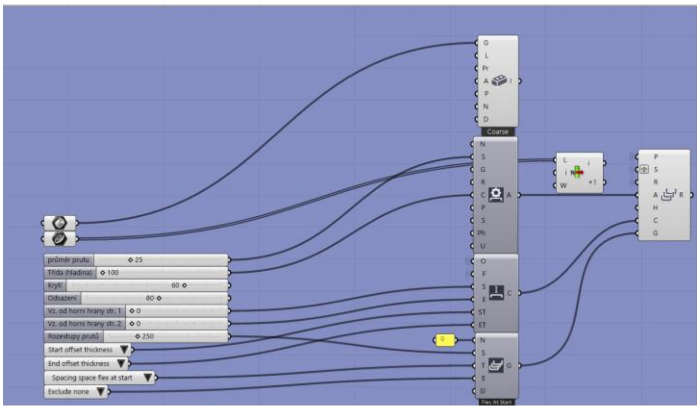


Figure 8: Creating a Tekla's rebar group using the Grasshopper - Tekla Live Link

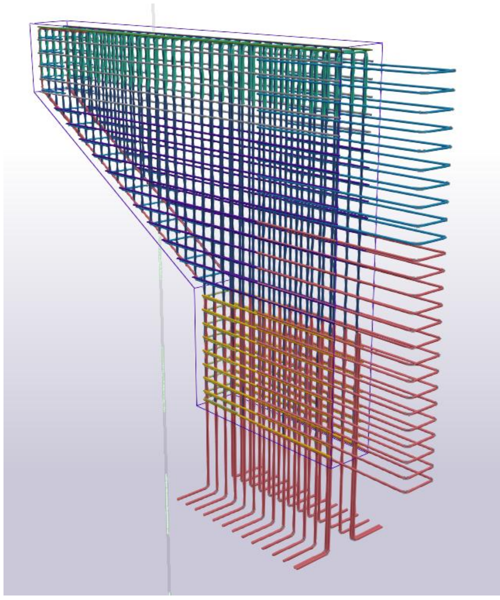


Figure 9: Reinforced wing

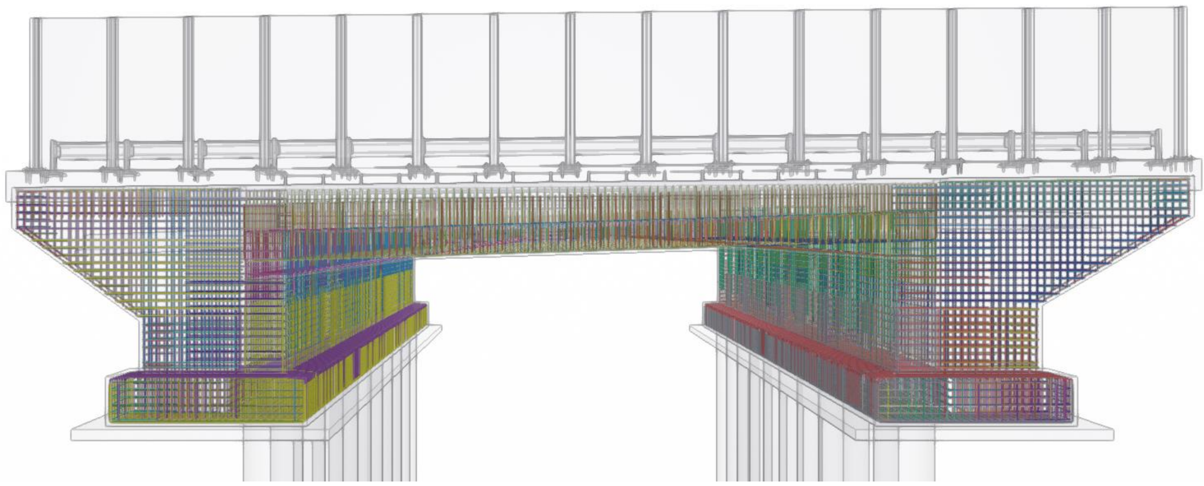
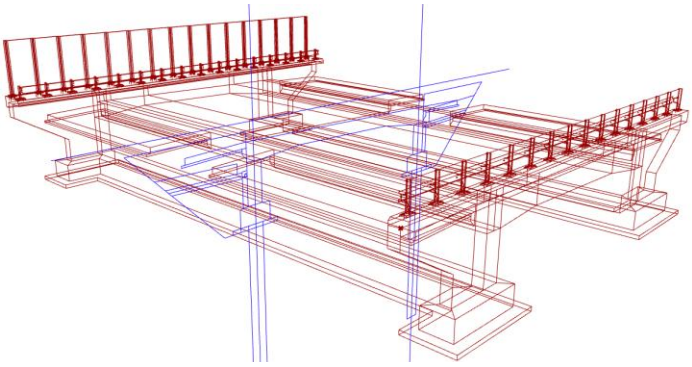
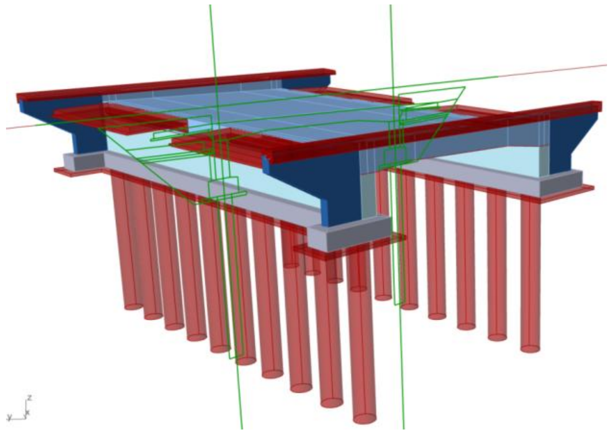


Figure 10: Reinforced bridge structure





Figures 11 and 12: View of a longitudinal section of the bridge structure

The curves can then be used to create a new drawing. Despite all the automation, the creation of drawings is still laborious and time-consuming.

4. Parametric design as a basis for drawingless construction

In our opinion, parametric design is the future not only for designing bridge structures but also for other types of buildings.

It is a solution that puts the designer in control of the building and helps them address problems that could easily be omitted if only 2D drawings were used.

Thanks to the parametric design, the model's response to individual changes is also illustrative and processing is faster than with individual 2D drawings.

3D design requires some investment and may not be faster than classic 2D design at the beginning.

However, we believe that if the 3D design is developed, and appropriate tools are used, it is more advantageous even in a small project.

Moreover, with the use of parametric modules, most assignments can be well automatized.

It, therefore, makes sense to digitize not only the design but the whole process including construction.

Since 3D information models are illustrative and, unlike 2D drawings, also "international", the workflow described above (Rhinoceros > Grasshopper > Tekla Structures) provides the basis for construction without drawings.

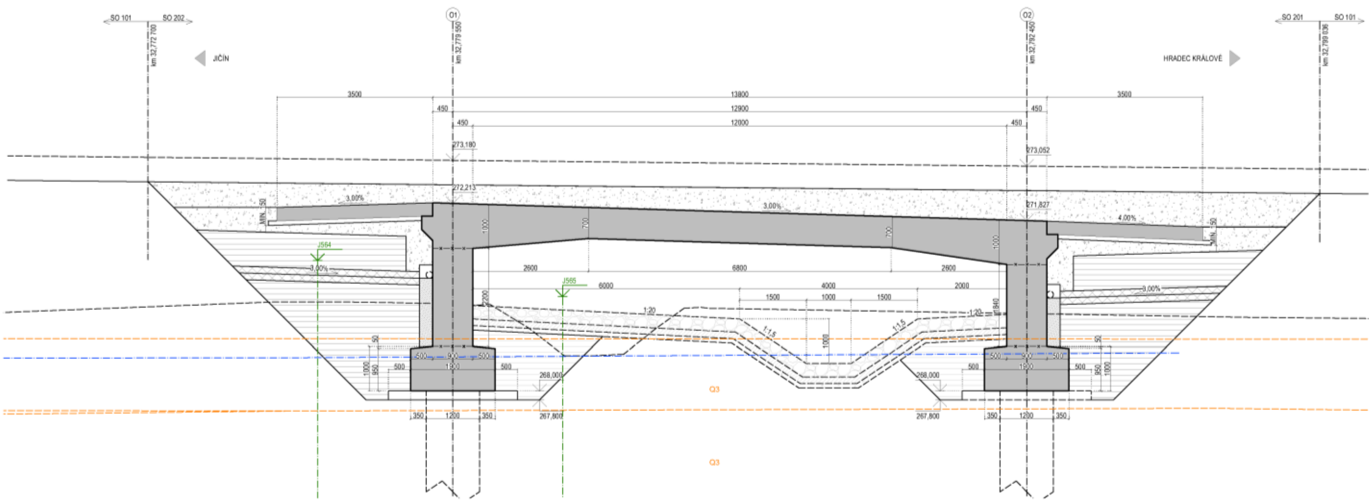


Figure 13: Longitudinal section of the bridge

In the future, our goal is to completely eliminate 2D drawings and move to drawingless construction working directly with models, and not with 2D drawings.

In addition, the creation of 2D drawings in the event that the project uses BIM is more laborious for the designer and, from our point of view, unnecessary.

We believe that it is sufficient to create only simple drawings and schematics since other information is part of the non-graphical data of the 3D model.

We therefore recommend, in accordance with the spirit and trends of BIM, not to degrade the illustrative international information model into non-machine-processable 2D drawings.

A drawingless project (construction) is a process that is based only on IFC files. It means that there is only information from the 3D model that is both sufficient and ready for use on the construction site.

Of course, there is still a need for general 2D drawings or information requested by the client, but these are only assigned to specific details in the model.

If there are differences between the 2D and 3D versions, the real value always comes only from the model.

CONCLUSION

Today's digital age allows all fields to optimize, streamline and move forward. Designing bridge structures is no exception. That is why we try to innovate and not continue in the old ways of the past.

We consider the application of non-digitized processes in the information age to be an inefficient waste of the designers' time, as they delay and distract from real professional problems.

We will continue to develop and refine our design workflow, thereby improving the working conditions for anyone interested in parametric design.

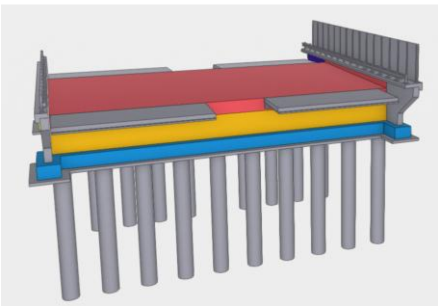
REFERENCES:

You can learn more about drawingless construction and how communication with the construction works in such a case from previous articles published in the e-BrIM & e-mosty magazines:

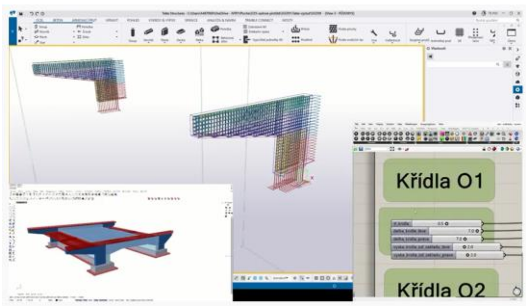
https://e-brim.com/e-brim-caissons-for-bridges-a-zero-edition-of-e-brim-together-with-e-mosty-magazine/

https://e-brim.com/randselva-bridge-digital-twins-bim-in-south-korea/

We also offer an opportunity to view the interactive model of the bridge including reinforcement in the CDE Trimble Connect environment, see the 3D model below and a video showing the parametric creation of the model, see video below:



3D model – click on the image to open it



Video – click on the image to open it

BIM AND BMS: CURRENT STATUS AND CHALLENGES

Rade Hajdin, University of Belgrade, Faculty of Civil Engineering, Serbia; Infrastructure Management Consultants GmbH, Switzerland

Vanja Samec, Independent Bridge and BIM Consultant, Austria

ABSTRACT

Bridges are a vital, but also extremely vulnerable part of transportation infrastructure.

The design and construction of a bridge have a large influence on its longevity although these phases are short compared to its life span.

It is therefore essential that at the acceptance the bridge together with the accurate as-built information is delivered to the owner.

A bridge owner relies on as-built high-quality information and on information on a bridge condition to initiate interventions that ensure its safety and serviceability. The information on the bridge condition is obtained through regular inspections as well as monitoring activities.

During the lifetime of a bridge, these diagnostic activities may generate a huge amount of data that needs to be managed.

With changing environmental actions, accurate and usable information from the inspection and monitoring – in conjunction with as-built data - is essential for efficient and timely maintenance planning.

Inspections and maintenance planning require organized, automated, open and intuitive digital processes, which should consider both object data and related condition data.

This seamless digital process is supported by existing Bridge Management Systems but can be vastly improved.

In particular, most BMS do not support geometric representation which makes data collection during inspections quite tedious.

The introduction of BIM in BMS can substantially facilitate the collection of inspection data and accurately localize monitoring data.

Moreover, the exact geometry of bridges can enhance maintenance planning by simulation of the structural behaviour of the as-is structure under different environmental actions.

BIM's incorporation would evolve BMS into a fully digital storage system and a platform for data exchange with existing BIM solutions as well as for maintenance planning that include deterioration forecast, optimization and analysis models.

The vision includes 3D+ software and hardware independent data exchange between different software technologies during life span and beyond.

Open BIM technology for interoperability from the technical, semantic and organizational points is of main interest.

The current status of development and challenges that need to be overcome for the successful fulfilment of the presented vision are discussed.

Keywords: Bridge Management System, BIM, Bridge Inspection, Digitalization

Reference: Hajdin, Rade – Samec, Vanja: *BIM and BMS: Current Status and Challenges.* IABSE Symposium Prague 2022. Proceedings ISBN: 978-3-85748-183-3

1. INTRODUCTION

Over the previous century, the human population has risen rapidly, from 2 billion inhabitants in 1920 to 7.8 billion in 2020.

The global population is currently growing by 1.1% per year and is expected to hit 9 - 10 billion in 2050.

Infrastructure expansion mirrors the growing population needs. More challenging than the construction of new roadway and railway networks represent the maintenance of the existing ones.

A massive rise in CO^2 emissions and related climate change lead on one side to an increase in the intensity and frequency of catastrophic events resulting in infrastructure failures and on the other side CO^2 emissions and related climate change accelerate some deterioration processes such as corrosion that can also lead to failures of infrastructure objects.

Another significant hazard is also fatigue. As the world's population grows, our infrastructure meets an increasing demand in terms of load cycles for people and cargo transport.

Environmental implications and structural deterioration of transportation network have become a daily challenge for bridge professionals worldwide.

Recent bridge disasters throughout the world are a strong reminder of the need for better knowledge and new approaches to infrastructure management.

The latest bridge failures have drawn significant attention to the topic of bridge maintenance and future design requirements.

Human lives have been lost irreparably, but the direct and indirect economic and societal consequences are also substantial.

2. DIGITAL TRANSFORMATION IN BRIDGE INDUSTRY

The term "digital transformation" refers to a process in which companies utilize technology to improve their performance, expand their market presence, and achieve better outcomes.

It is a structural shift in organizations in which technology plays a vital role.

Artificial intelligence, cloud and edge computing, big data analytics, and new generations of robotics and sensors may all be used to create a new ecosystem where assets represented by digital twins can communicate, dubbed the Internet of Things [1].

The Internet of Things (IoT) is an increasing tendency of interconnecting all types of physical items to the internet.

In this futuristic vision, so-called smart bridges including complete infrastructure assets will be continuously analyzed and managed, either in near real-time or over a longer period of time, by people or artificial intelligence applications.

Still, computer technology remains just a tool for improving the profession itself.

The bridge community is looking to employ digital solutions in practical terms.

For the creation of high-end bridge software, first and foremost technical bridge knowledge is needed. It is vital that the focus is set on the quality, sustainability and safety of bridges.

3. BIM FOR BRIDGES

For bridges, as part of the infrastructure, a BIM-based 3D digital model with information along the whole lifespan of a project (design, construction, operation, and maintenance) is required to improve the present workflows.

BIM has been a key component of infrastructure automation and digitalization for the past 20 years, although it is still mostly utilized for design and construction.

Bridges are one component of the entire infrastructure system.

Roads and tunnels, along with bridges, make up the transportation network which should be in the vision represented in the Infrastructure BIM model.

The bridge Information Model is more than just a visual representation of geometric properties; it also includes comprehensive data storage of assets across the life cycle of a bridge, including their graphic representation (geometrical, structural, deficiencies, etc.).

Due to the globalization of project teams, seamless workflows, and therefore lower costs by ensuring the integrity of all processes, the bridge community is looking for a "single source of truth."

The operation and maintenance phase is currently just partially involved in BIM processes.

The global interest in the digitization of the Operation & Maintenance life cycle and its link to earlier operations has grown as a result of tragic accidents, and the critical age of numerous bridges.

The majority of bridges were completed in the 1960s and 1970s of the previous century, and most of them are now five or more decades old.

The need for information-based solutions to improve the efficiency of transportation infrastructure maintenance, save costs, and minimize deadly hazards was recognized by owners and infrastructure authorities.

Many advanced economies are presently focusing to define the state-of-the-art in bridge maintenance and management, and also foresee the obstacles that this sector will experience in the upcoming years [2].

Existing Bridge Management Systems serve as a valuable basis for condition data collection and maintenance planning but can be substantially improved to mirror changes in physical objects. For this purpose, BIM can have a decisive role.

BIM should be understood as a process based upon a common 3D bridge model (as-design, as-built and as-performing ones), including non-geometric information over the life span from early planning over maintenance till demolition or rehabilitation.

Recently the term “Digital Twin[1]” has been chosen for the dynamic virtual representation of an object or physical system that is maintained throughout its life cycle and uses real-time data.

A digital twin is a digital representation of physical assets, processes, and systems that may be utilized for a variety of reasons, such as bridge maintenance, for example.

Models, scans, sensors, machine learning, data analytics, artificial intelligence, and other technologies are used in Digital Twins.

It is constantly focused on providing an easy-to-navigate and visual environment, which will help users better comprehend the constructed environment.

For Digital Twins technology, BIM provides organized and consistent data management in a collaborative manner, which will be used to advance the operation and maintenance phase until the end of the bridge lifespan (demolition, replacement or rehabilitation).

The use of Digital Twin technology is intended to provide advantages such as downtime reduction, predictive analysis, preventive maintenance, sustainability optimization, and transparency.

The usage of Building Information Modelling or Digital Twins must be tightly linked to recent improvements in bridge inspection and maintenance planning [1].

4. CHALLENGES

4.1 Conceptual challenges

It is obvious that 3D digital representation has clear advantages for owners, e.g.:

- Inspection findings, e.g. damage and deformations, can be accurately located allowing for a more precise analysis of their impact on safety and serviceability.
- The collection of inspection data, e.g. damage and deformations, can be accurately and easily collected using, for instance, augmented reality.
- The contracting of inspection can be substantially facilitated by handing over a 3D model to a winning bidder.
- Condition forecast including the development of safety and serviceability over time is possible based on “as-performing” BIM.

[1] It should be noted that the term “Twin” is not the best choice as it implies the birth of two offspring that may be genetically identical produced in the same pregnancy. This is hardly the case with a digital twin as it is mostly not produced at the same time as its physical counterpart, nor it is “genetically equal” to it. Furthermore, the behaviour of biological twins during their lifetime is (hopefully) not identical and this is exactly the requirement of a digital twin as it should mimic the behaviour of its physical counterpart.

This is an essential step in maintenance planning and setting up a work program.

- The tendering and contracting of maintenance intervention can be facilitated by handing over a 3D model to bidders. In turn, the bidders can estimate the quantities and price more efficiently.

In order to exploit these advantages, the main obstacles are the availability of BIM models.

In design and construction of bridges, 3D digital BIM technologies are still not routinely employed, but the advantages are so apparent that it is merely a matter of time until all new bridges will be accompanied by a 3D model with all necessary information including structural analysis.

However, this is for the owner of a limited benefit as the vast majority of bridges are existing ones and the major concern is the old bridges.

Additionally, in most cases, the delivered BIM model is hardly in a format that can be directly used for inspection and maintenance planning.

Simply put, there are two key challenges that need to be resolved in order to enable the broad use of BMS in conjunction with BIM:

- Define a BIM model that can fit the needs of bridge owners, and
- Establish an efficient procedure to obtain BIM for existing bridges.

This paper will address these key conceptual challenges in the example of inspection. Typical bridge inspections are currently performed manually.

It is very likely that new monitoring technologies will increasingly enhance visual inspections, but they will remain the most cost-effective method for some time to come.

The inspection results are stored in Bridge Management Systems and this process is at least in developed countries automatized.

The inspections are performed with hand-held devices and the collected data are automatically transferred to BMS.

The inspection report is often generated by BMS. The data structure of the BMS varies greatly amongst road authorities around the world.

These systems are highly customized to the needs of respective road authorities and are in general deployed quite successfully.

They also harbour large amounts of data that allow them to perform statistical analysis to derive forecast models, unit costs, the efficiency of maintenance activities, etc.

There is also a downside to the current situation as the absence of uniformity among road authorities makes it difficult for practitioners and academics to use inspection data for knowledge-generation purposes (see [3]).

However, the current situation is not likely to change in the near future.

BIM for owners needs to fit the data structure or more precisely the ontology of respective Bridge Management Systems.

Given that BIM for both existing and new bridges is likely to be developed by private consultants and contractors there is a need for clear rules for this purpose.

It seems that the best way is to develop a BIM with fine granular disassembly that can fit all ontologies. This approach is detailed in [4].

The second challenge mentioned above is related to obtaining the BIM model of existing bridges.

It seems that the segmentation of point clouds together with artificial intelligence is the way to go.

The first results are quite encouraging. Currently, the focus lies on segmentation that fits the ontology of road authorities, but it is feasible also here to achieve fine granular disassembly that would fit all ontologies.

To obtain point clouds ever improving scanning techniques and hardware devices will be essential for successful, rapid, and detailed digitization of those bridges that lack even 2D drawings.

Further development should enable the inclusion of relevant information (for example structural analysis, and erection methods) from the bygone phases of design and construction in BIM-based BMS models.

The possible approach to this challenge is outlined in [5].

4.2 Technological challenges

To ensure fair competition between the consultants, contractors and vendors, the owners need to allow for different methods and software and at the same time obtain the BIM they require.

Each kind of commercial BIM software comes with its own native file format.

For the delivery of a bridge model to the owner, the neutral IFC (Industry Foundation Class) file format, developed and maintained by buildingSmart International, is currently the most widely spread exchange format and can be understood as a communication interface format.

As mentioned before, the focus lies with the geometric representation as the ontology is defined by respective road authorities.

This can be regarded as an intermediate step toward an open BIM platform.

The open BIM platform with an exchangeable 3D representation that is supplemented with numerous features accommodating different ontologies is the ultimate goal.

Assets would be added to existing BIM models used by consultants/contractors' companies as a result of inspection and maintenance processes. It must be feasible to communicate data in all directions of the bridge life cycle.

Open BIM standards are constantly evolving, and they are primarily used for building; bridges are still an exception.

Information-based solutions have the potential to significantly improve the efficiency and safety of transportation infrastructure while also lowering costs.

Bridges are difficult constructions because of the geometry's complexity and the structural behaviour's significant reliance on building sequences and erection procedures.

There are some crucial challenges that should be researched and solutions developed if Open BIM for bridges should be realized and also include the operation and maintenance phase.

HW capabilities for data recording of larger bridge structures are not offering the required potential although the future of data storage is exciting: Bacteria, DNA, Sand, Helium drives, Quantum storage, Liquid-State Storage, etc.

Wireless networking technologies, such as 5G networks with high-capacity communication, high efficiency, and excellent coverage, might help in the digitalization of BMS and solve the problem of mobile inspections with huge databases.

As mentioned before, deep Machine Learning and Artificial Intelligence have become important tools for the digitalization of defected structures.

When the dataset is restricted to geometric data only and time as the fourth dimension is ignored, the benefit of end-to-end data management in BIM is frequently lost.

The history of inconsistencies and conflicts should be displayed along the time axis so that mistakes may be avoided before they happen on the job site.

Current BIM viewers cannot visualize the defects or the as-built 3D bridge model, which differs from the as-designed model.

All types of defects, time-dependent history of those, semantic information, also sensor locations, and performance indicator-based maintenance plans must be part of BIM if we want to benefit from it.

To achieve this requirement, digital technology in form of all aspects will become part of BIM.

A very innovative and interesting initiative has been started to integrate Bridge Defect Information into BIM Models (see [3] and [6]).

A prototype has been created, which served as a proof of concept for automated sharing and comparing of information needed in RC bridge inspections and for establishing a knowledge base for bridge performance over time and across authorities by using the latest Industry Foundation Class release [7].

Finally, it is critical that the software used be as user-friendly as feasible, and that the Open BIM database be relatively standardized and interoperable in order to accommodate the needs of different road authorities.

5. CONCLUSION

The bridge owner's/operator's aim is to have "as-performing" models along the time axis that can be "examined" at any time with an analytical tool to verify the global and local conditions of single elements or the whole bridge structure.

Digitalization of the infrastructure network, establishment of respective enhancement of current infrastructure assets database, more intuitive inspection procedures, reduction of bridge maintenance expenses, and especially the combination of the BIM with BMS is in the interest of all asset owners and infrastructure authorities.

To this end, this paper suggests a pragmatical two-steps approach using firstly an exchange format and ultimately Open BIM platform.

This refinement of current bridge management practice will lead to more efficient and timely intervention and ultimately to a safer and more sustainable transportation network.

6. REFERENCES

[1] T. N. Bittencourt, M. M. Futai, A. P. da Conceição Neto and D. M. Ribiero, "Digital Transformation of Bridges Inspection, Monitoring and Maintenance Processes," in Bridge Maintenance, Safety, Management, Life-Cycle Sustainability and Innovation, London, 2021.

[2] P. Hüthwohl, I. Brilakis, A. Borrmann and R. Sacks, "Integrating RC Bridge Defect Information into BIM Models," J. Comput. Civ. Eng., vol. 32, no. 3: 04018013-1, 2018.

[3] R. Sacks, A. Kedar, A. Borrmann, L. Mad, P. Hüthwohl, I. Brilakis, S. Daum, U. Kattel, R. Yosef, T. Liebich, B. E. Barutcu and S. Muhic, "SeeBridge as Next Generation Bridge Inspection: Overview, Information, Delivery Manual amd Model View Definition," Automation in Construction, vol. 90, pp. 134-145, 2018.

[4] D. Isailovic and R. Hajdin, "Geometry as a common ground for BMS and BIM," in IABSE Symposium Prague 2022, Challenges for Existing and Oncoming Structures, Prague, 2022.

[5] R. Hajdin, "Managing Existing Bridges – On the Brink of an Exciting Future," in Ninth International Conference on Bridge Maintenance, Safety and Management (IABMAS'18), Melbourne, 2018.

[6] D. Isailovic, V. Stojanovic, M. Trapp, R. Richter, R. Hajdin and J. Döllner, "Bridge damage: Detection, IFC-based semantic enrichment and visualization," Automation in Construction, vol. 112, no. 103088, 2020.

[7] C. Shim, H. Kang, N. S. Dang and D. Lee, "Development of BIM Based Bridge Maintenance System for Cable-Stayed Bridges," Smart Structures Systems, vol. 20, no. 6, pp. 697-708, 2017

INFORMATION IS FOR LIFE NOT JUST FOR BIM MODELS

Philip Jackson BSc, CEng, FICE, FRSA
IntraTeamIT Consultants;
University of Surrey

ABSTRACT

BIM or Building Information Modelling has become fashionable over the past decade but has often been misunderstood in its overall impact on the built environment industry.

Commonly it has been viewed as a 3D model used during the design process and has been very 'Task' centric rather than understood as a broader systematic approach to the process of the information life cycle of an asset including the gathering, development, delivery and operation stages of life.

As such it provides the digital information, the DNA, of an asset and would be better labelled as Asset Information Modelling.

This paper explores the concept of information modelling through the lifecycle of an asset proposing that an asset begins its information life when it is conceived and planned rather than when it is built and handed over for use.

All digital information develops and is progressively collected from that point.

Hence, we can understand the purpose, functional requirement and technical specification that an asset fulfils and needs to be maintained during operation.

Each intervention with an asset, whether it be new or being repaired, or modified, should be regarded as an opportunity to capture this data.

It concludes that we need to take a less siloed approach to information and embrace the potential of a systems engineering approach to digital engineering looking at the potential benefits that will accrue by taking this approach, particularly when dealing with operational management.

Keywords: Systems Engineering BIM; Asset Management; Life Cycle; Information Centric.

Reference: Jackson, Philip: *Information is for Life not just for BIM Models.* IABSE Symposium Prague 2022. Proceedings ISBN: 978-3-85748-183-3

1. INTRODUCTION

BIM (Building Information Modelling) has, over the last few years, become a common part of the procurement process for new infrastructure projects with public clients mandating its use on new assets and designers adopting BIM tools to produce construction information.

Much has been written about BIM and its promise and many conferences and presentations have promoted its wider use, however, its full potential has yet to be realised.

There are many exciting technical developments both in hardware and software which, perhaps, blind us to the fact that at its core BIM is fundamentally centred on information about the assets we plan, design, build and operate.

There are many information users across the life cycle of an asset, and each tends to focus upon their individual viewpoints and information requirements to carry out their own function.

Hence, BIM has become very discipline/task centred and siloed in specific tools and systems be they for design, construction, or operational management.

The true power of information is realized when we start to join up those tasks into a process and systematically capture, create, edit and use data across the asset life cycle at each intervention point.

This paper proposes that Asset Information Management (AIM) is core to our industry's digital engineering future and that terms like CAD, BIM and GIS are at best a subset of AIM and most likely in fact redundant.

In this paper, we expand on that proposition and review a Systems Engineering approach to asset information.

2. BIM IN PERSPECTIVE

2.1 Historical Context

Building Information Modelling (BIM) has its origins back in the 1970s when the late Chuck Eastman published his paper "The use of Computers Instead of Drawings" [1] in which he described a computer programme that would be able to perform parametric design and 3D representations.

He called it Building Description System (BDS), a "single integrated database for visual and quantitative analysis" stating that this theory in practice could cut design costs while making the construction process more efficient.

This idea was extended in the 1980s when Robert Aish published his paper "Building Modelling: The Key to Integrated Construction CAD" [2].

He proposed that traditional representation of design information such as drawings, perspective views and non-graphic attribute data developed in separate systems and processes will be integrated into a CAD system capable of handling multiple representations all related to a single 3D model thus encouraging consistency and coordination of design information across multi-disciplinary teams.

Since that time developments in technology and software have made those proposals more practically feasible and the concept of information modelling has evolved to include what today is termed 'Digital Twins' that represent virtual models, properties and characteristics of physical assets.

During that evolution process, it has become clear BIM is bigger and more diverse than many originally imagined and is much more a process of capturing, creating, editing, updating and communicating information about our assets throughout their life.

2.2 BIM beyond 3D

It is perhaps not surprising that early applications of BIM concentrated on tools to produce virtual 3D design models.

Software systems concentrated on the production of design information and its coordination across all the various domains involved in the design process often automating existing processes and producing the documents common in the design and construction world.

This has unfortunately led to many seeing BIM as software products sold by vendors and mostly concentrating on 3D graphical construction and visualisations.

BIM turns out not to be a software application but an information-based process that integrates the life cycle of the assets we create and manage adding value as we interact and intervene with those assets.

Of course, being able to virtually construct an asset in 3D has many benefits and to be able to locate, contextualise and understand those assets in a 3D context is extremely valuable to planners, designers, constructors, and operators.

Similarly, being able to communicate with the owners and users visually is a key benefit.

2.2.1 Information-Rich Objects

Simply put, BIM breaks assets into discrete objects and stores information about those objects.

That information may include the unique identity, geometry and position of the object but also what type of object it is, what it is connected to, what system or assembly it is part of and perhaps how it is loaded and how it behaves under load.

Figure 1 illustrates those examples.

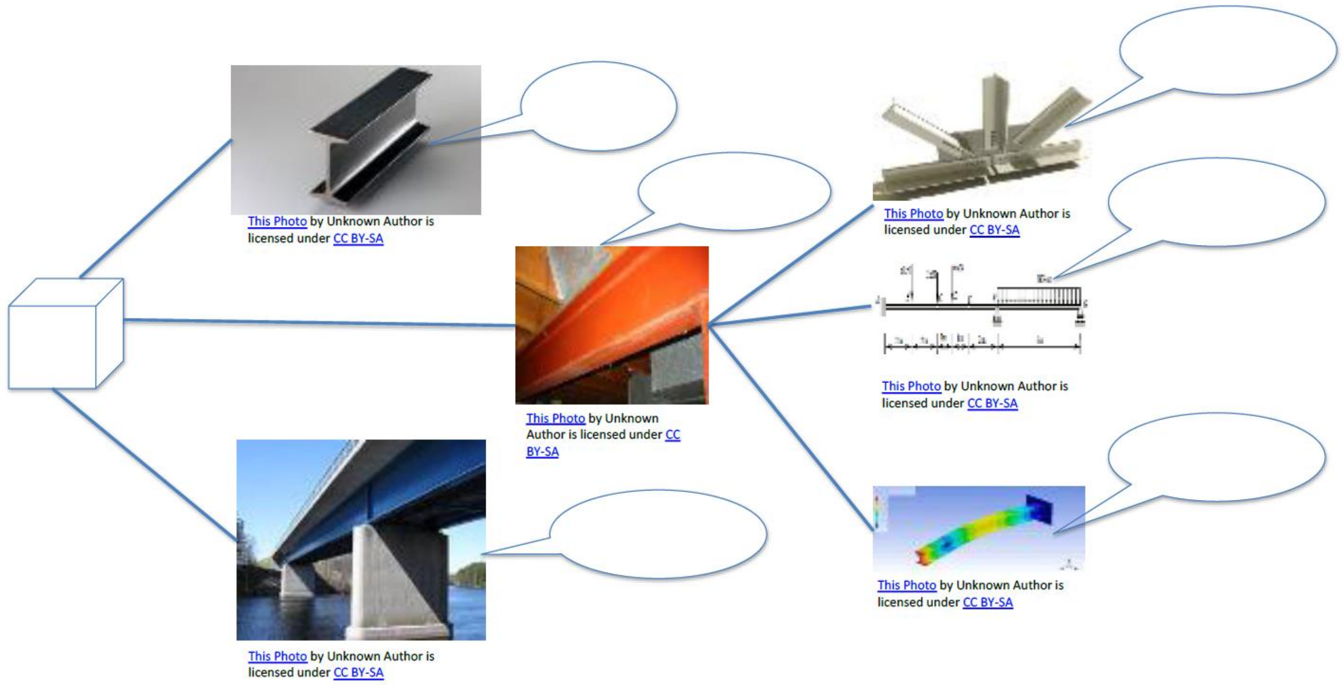


Figure 1: Example BIM Asset Information

Figure 2 below illustrates diagrammatically some model information that might be held about an asset/object.

Critically this includes the type of asset, relationships to other assets, assemblies and systems and temporal information.

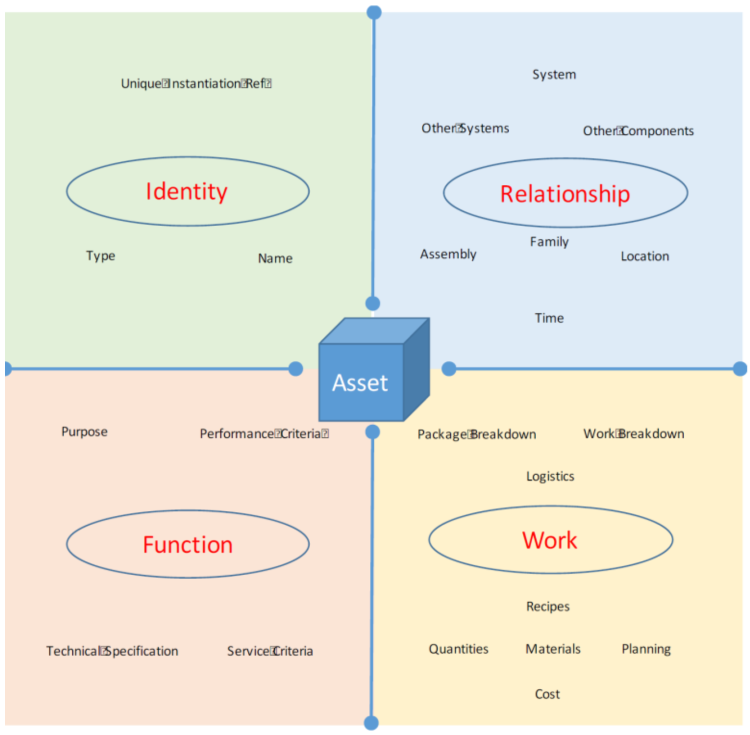


Figure 2: Typical Model Information for an Asset

Of course, information held in the model extends beyond those examples and would include physical properties (dimensions, etc.) of the asset/object and metadata such as accuracy and provenance.

It is not our purpose in this paper to go into the intricacies of modelling but rather to highlight that modelling is essentially a virtual representation of an asset which can be created, edited, interrogated and used as a basis for further tasks, calculation and simulation.

A quick look at the typical model information for an asset/component shown in Figure 2 confirms that not only does a model hold more than just a 3D representation of that asset but together with properties it can represent much more including how it relates to other assets/components, what type of thing it is, what its function is and its designed performance and technical specification.

It follows that model information extends across all the stages of an asset's life and reaches down to its smallest components.

2.3 BIM is not a Single Database

Despite some early work suggesting that all information should be held in a single database, it has become more useful to understand that several separate but related models might be combined as if they were one for interrogation and use in a process known as “Federation”.

Additionally, assets within those models could be linked to other databases for further information.

2.3.1 Asset Data Connection

In this approach, a unique asset can be related to other databases.

This might add construction sequencing from project plans, a cost database or a condition database, or output from sensors using the unique id as a key.

In fact, the power of BIM lies in the fact that only essential model information is held in the model and other information is held separately but linked. Figure 3 below illustrates that linking.

BIM therefore provides not only a geometric 3D design model but a platform for capturing and managing information about assets throughout their life in connected and linked databases.

It provides a context for information beyond what has been modelled and connects to diverse information which might include links to cost databases, scheduling tools, planning approvals, on-site tests, results of condition surveys and live information from local sensors and observations.

Hence BIM models become the hub and the link to all asset information.

2.3.2 Federated Models

Whilst it might seem attractive to hold information in one single model it soon becomes cumbersome and complex, especially with infrastructure assets which would have to model so many interdependencies it would soon become huge and unmanageable.

The concept of bringing together models based on the same standards and the same location fundamentals has gained popularity and is now the accepted way of working across many domains, disciplines and stakeholders.

Using this approach, it is possible to overlay/ federate survey models, road alignment models, bridge models and many others and utilise them as if they were one.

The key to the success of this federation is the use of strong open standards.

Such standards are emerging and developing rapidly not least buildingSmart’s IFC standard for interoperability which now includes most of the elements required to model infrastructure in its version 4.3 making it able to cover most of the built environment.

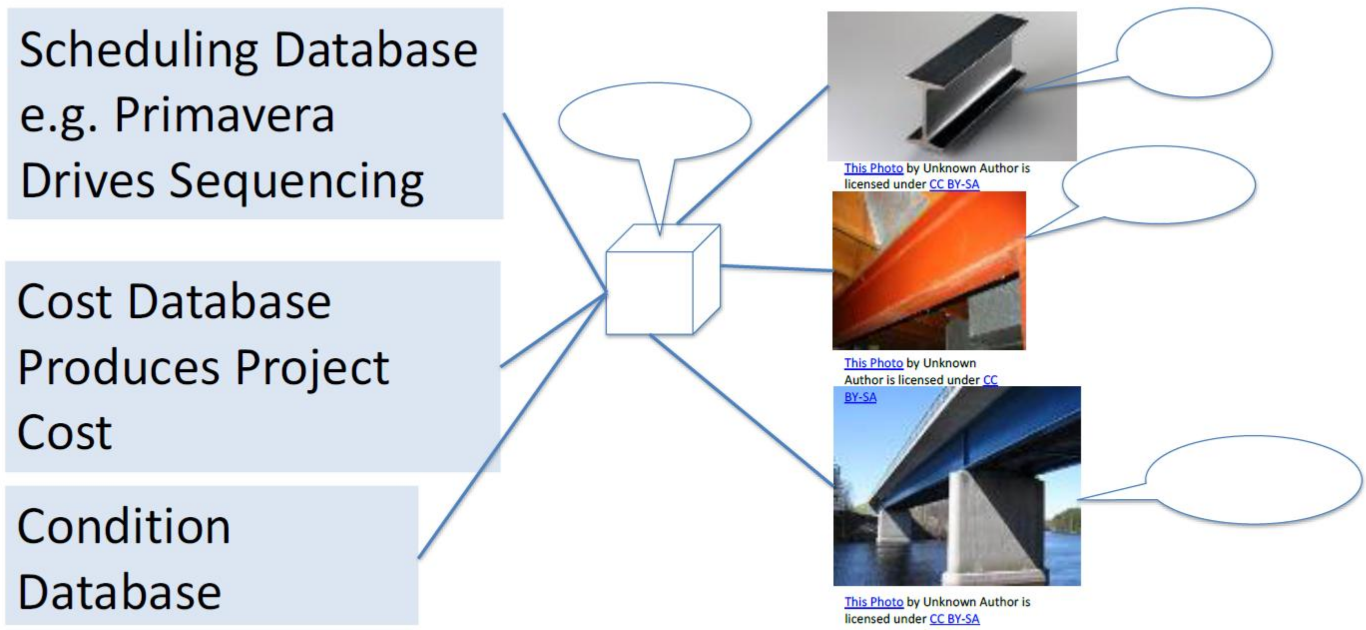


Figure 3: Linking Assets to other data

2.4 BIM Fragmentation

The built and natural environment involves many specialists and stakeholders, even the design process has many domain experts that create and use information related to their tasks and interests.

Similarly, the construction process involves even more domains stretching from work packaging through project scheduling, logistics and eventual handover to operational management.

Once handed over, a broad range of tasks and interventions take place within the operational lifetime of an asset.

Hence how you see BIM and its usefulness depends on your specific viewpoint, the tasks you are responsible for and your interests.

An architect for instance might be interested in spatial planning and visual representation whereas a structural engineer specific properties of elements that support structural analysis and fabrication detailing.

Software developers have over many years developed specific tools to handle specific domain interests and hence the results are a series of “task” oriented limited BIM models and fragmented information.

Not only that but each domain approach has tended to automate existing practices rather than take advantage of the information continuity that BIM offers.

Finith Jernigan in his book “BIG BIM little bim” [3] demonstrates the need for an integrated process approach to BIM linking each task in all the steps required to procure and operate an asset.

The consequence of this fragmentation is that many perceive BIM as just a design tool rather than the asset information tool that it really has the capability of becoming.

So, a culture has evolved that has broken the life cycle of an asset down into silos of information and thinking.

So, we have Design BIM tools, Construction BIM and Asset BIM. Furthermore, the industry has broken down the information chain into areas of specific expertise, organisational structures and professional institutions.

Things like planning, project management, design, quantity surveying, construction, and asset management have developed their own processes and methods which they are reluctant to change.

And BIM provides the mechanism to join up information across all these tasks and offer continuity across the life cycle of our assets be they planned, or physical.

2.5 Life Cycle Information

At the heart of BIM is information about assets that are being planned, designed, constructed and operationally managed.

BIM information is a continuous process of capture, creation, editing and using throughout an asset’s lifecycle.

Each step along the way represents an intervention with that asset and the resulting information becomes held an accumulation of knowledge.

BIM information is therefore progressive and not task-limited.

That progressive nature of BIM information joins up the natural life cycle of an asset.

Figure 4 below summarises the information lifecycle stages.

Figure 4: Natural Lifecycle of Asset Information

These are:

- Information required to plan management of existing assets and new potential projects.
- Information required to design, build and deliver an asset.
- Information required, used and captured during the operational management of an asset.

2.5.1 Intervention Triggered BIM

The BIM process joins the dots between these stages and integrates that life cycle in a continuous loop. As discussed earlier, BIM application has, to date, concentrated on the "New Project" aspects of that life cycle.

However, most of our projects fit into or are interventions with existing assets and hence the starting point of the cycle is more sensibly viewed as "Asset Information Management".

Taking that view, an asset and its information begin at its conception and planning not after it has been built. Each intervention during that asset life cycle triggers the capture, creation and recording of information about an asset system, assembly, and component.

Interventions include not just the design and construction of new assets but any task associated - be it socio-economic, legal process, planning, design, construction, inspection, repair, refurbishment, repurposing or demolition.

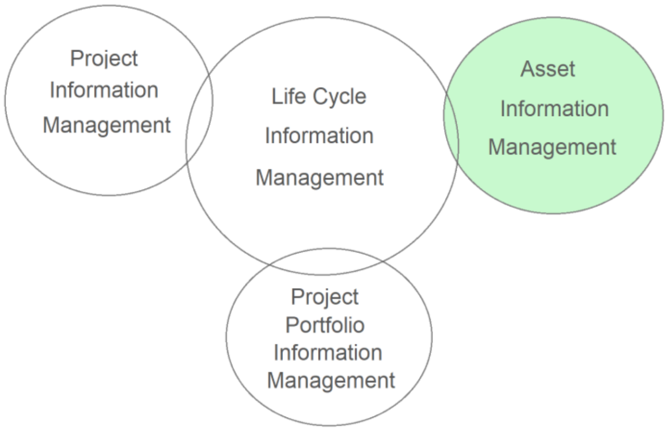


Figure 5: Integrating the Information Life Cycle

Based on ARC Advisory Group

BIM becomes the integrator of information across the life cycle and captures tracks and follows each asset and asset component through its life.

If we can capture and store information at each intervention with an asset, we can build a record that is invaluable to each stakeholder in the stage-by-stage process.

Our information handover at each intervention becomes an addition to the model.

Figure 6 illustrates the flow of that information between these stages.

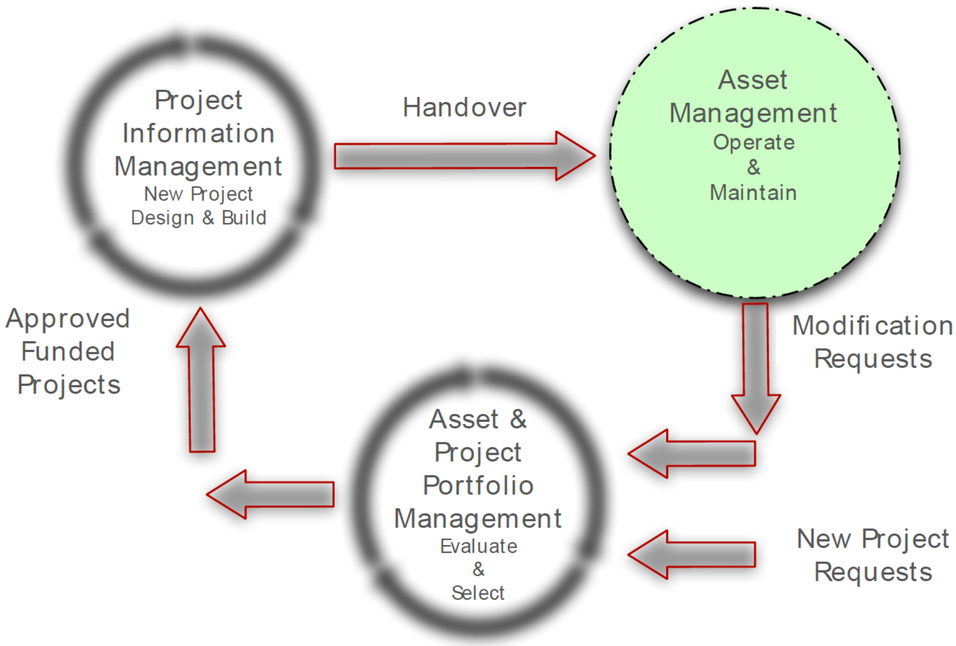


Figure 6: Life Cycle Information Flow. Based on ARC Advisory Group

At a high level, these can be summarised as follows:

- Existing Asset Information
  - Information held about existing assets and their history and condition.
- Output from existing assets
  - Their ongoing condition, state of repair, operational performance, continuing suitability of utilisation, potential risks, and mitigation requirements.
  - Drawn from operational management indicates needs for repair, updating modification or replacing all or parts of the current asset.

Social and political requirements from time to time indicate requirements for an entirely new asset to be considered.

Those requirements for replacement or refurbishment or new assets need to be considered against the entire portfolio of assets and budget availability of an organisation.

Output from that planning process is then requirements for a new project which needs to be delivered through a detailed designed process and physical construction.

This sets off a project that during its fulfilment creates design and construction information.

Once delivered, information captured from the planning design and construction process needs to be handed over to manage the operation of the new or updated asset.

2.6 Asset-Centric Information

When BIM is expressed in these terms, it becomes asset-centric recording information about individual assets components, the assemblies, systems, and infrastructure they form part of rather than a single model created for a single task or function.

It becomes the process and recording results of all the interventions that have taken place during the history of that asset from concept through procurement to operation, repurposing and demolition.

2.6.1 Process-Led Asset Information and BIM

Being a joined-up process capturing and tracking information through the life of assets has now been recognised as the core of modern BIM.

The introduction of the ISO 19650 series of standards “Organisation and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling” defines the process through the life cycle and defines information requirements and resulting information models.

Parts 1, 2 and 3 [4] cover the concepts and the whole life cycle of information.

These standards are centred on setting out and fulfilling information requirements in a coordinated and collaborative process joining up all the players through all the stages in the life cycle.

At the core of the standards is the principle that BIM information delivery includes “Asset Information Requirements” and follows that through design, construction and asset management.

The process follows, validates, and verifies each piece of information as it progresses signing it off and providing its provenance, thus, making information both relevant and trustworthy, with a known history and quality.

Furthermore, if the principles are followed at each intervention, the information is up-to-date and traceable.

2.6.2 Progressive Asset DNA

Information following the life cycle process records the DNA of each asset.

Figure 7 shows the evolution of asset information through that DNA chain.

At each stage of the asset's life fulfilled information requirements are recorded and progressively develop their DNA.

Each stage inherits information from previous stages and adds its own.

- Portfolio planning business and performance outcome requirements created and collected, and business plans developed, involving both technical and social interaction.

- Concept Development & Master planning - developing potential solutions and alternatives, interacting with public bodies, interacting with the public, gaining planning approval, statutory public inquiries, government approval, etc.

  Building high-level geometric models with functional and performance specifications requirements for the desired outcomes.

  All gather and produce information that will be required downstream in the life cycle and may prove invaluable when revisiting designs or answering operational questions.

  This may include, amongst others, contractual obligations that are needed to achieve outcomes such as accommodation works, land purchase agreements, statutory obligations, and environmental mitigations.

- Detail design develops the final geometric model for construction together with the underlying analysis of performance, and the resulting technical specification for each component to fulfil the performance requirement outcomes.

- Construction – fulfils the performance and technical requirements of building the physical asset.

  The information included may include the details of the materials and processes involved in construction, the products used in fabrication and assembly, any changes made to design during construction (as built representation) and any circumstances that may have an impact on operational performance.

- Handover - acceptance testing and commissioning information.

- Operational management – maintains the functional performance of the asset.

  Collecting information from, condition surveys, feedback from built-in sensors, performance monitoring, risk assessments, mitigations, operational maintenance, refurbishment, etc.

  Using information from previous interventions.

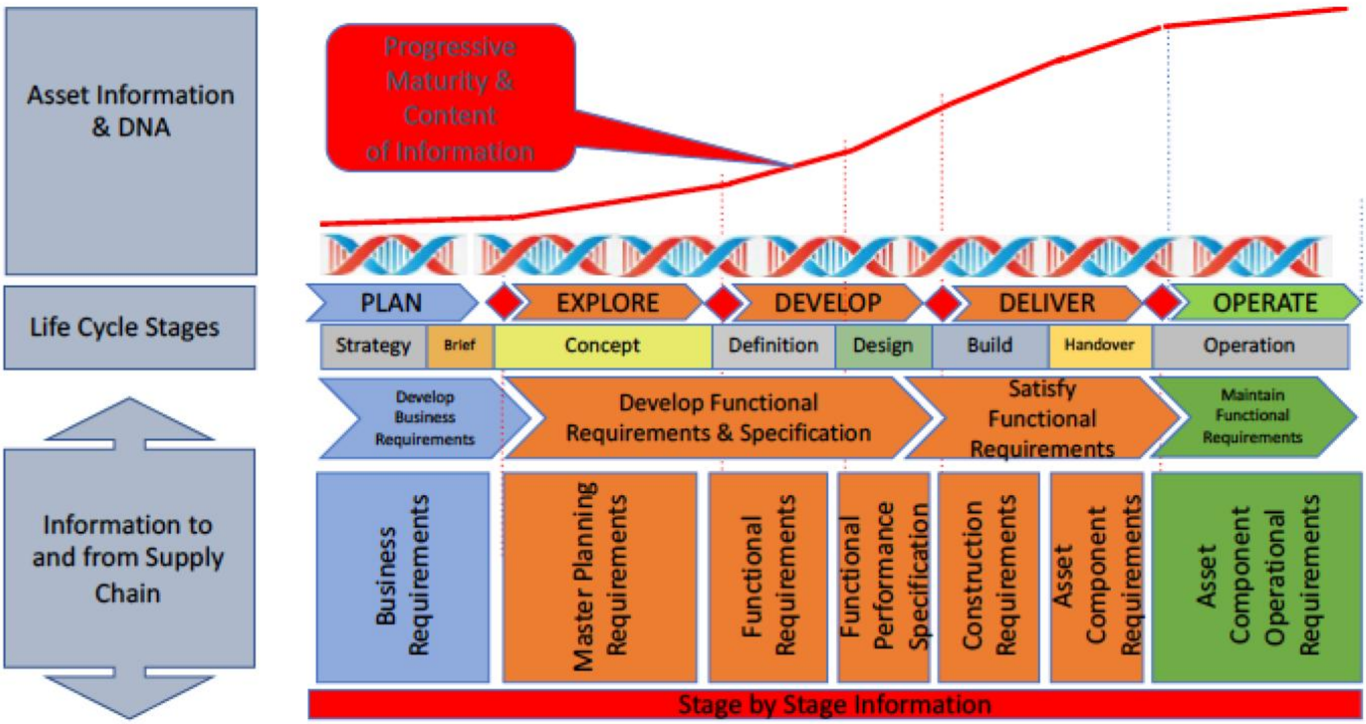


Figure 7: Asset DNA in Life Cycle

2.6.3 A Systems Approach to Asset Information

This integrated approach to information through the life cycle underpins a "Systems Engineering" delivery of projects and services.

Systems engineering and thinking have proved very effective in many project-based industries but until recently have not been used in infrastructure project delivery.

The UK Institution of Civil Engineers 2020 report "A Systems Approach to Infrastructure Delivery" [5] reviews how such systems thinking can be used in complex infrastructure.

Critically it defines the digital elements of this cyber-physical asset, in the form of a BIM process or digital twin, which can be the basis for designing and testing a robust delivery and commissioning plan.

A project's digital outputs can also become the basis for maintaining and upgrading the operational assets, creating a 'golden loop' of information. It describes the data/information systematically defined and captured as the oil of projects whether they be for new assets, refurbishment of existing or operational maintenance of current assets.

2.6.4 Information Life Cycle Entry Point

By historical connecting BIM to the design and construction stages of our assets, we have limited its potential power, utilisation, and benefits.

By using our modelled BIM objects as the key to linking information across the whole life cycle we bring to bear temporal context to asset information.

Asset life cycle information held within a BIM model context is a continuous creation, capture and management process.

If we use that context across the life cycle, all our interventions with assets become BIM information entry points. So, the information we capture and create can occur at any point in that cycle.

Using this approach, we add information as it is created or captured to our BIM model.

Most of our assets are already built and are under management so information captured during condition surveys and operational maintenance becomes an intervention point, information capture is not limited to when we design and build it.

Jackson in his technical report for buildingSMART International "Infrastructure Asset Managers BIM Requirements" [6] states that asset managers require data collected in a continuous process throughout the life asset cycle rather than exchanges between software applications or single drops/exchanges of information at the completion of projects.

Implying that information begins its life at the conception of an asset and not when the asset is built and handed over for operation.

In most organisations, new projects and what is seen as capital expenditure (CAPEX) are handled separately from operational expenditure (OPEX).

This is reflected in the organisation's management structure and the consequent systems and processes for controlling and monitoring its assets.

Figure 8 attempts to show that information about our assets is captured throughout time and can be broken down into the many interventions with our asset portfolio.

The key to joining up this process is relating information to our BIM models as a progressive continuous process and setting up the management structures that support this Total Expenditure management approach.

In such an integrated approach assets can be located, seen in 3D, understand what they are related to, seen in a time context, what they are planned and designed to do, what is their current condition, whether they have deteriorated, how are they performing and managing intervention projects.

2.7 Benefits of Systematic Life Cycle BIM Approach

Taking this life cycle approach to information and linking it to identified assets in an open standard way enables the establishment of a 'digital twin' version of our assets and gives us the capability of querying and using the information in context at each stage.

At any stage we can ask any question about our asset, its location, planning, dependencies, design, delivery project, simulate any scenario & monitor its performance.

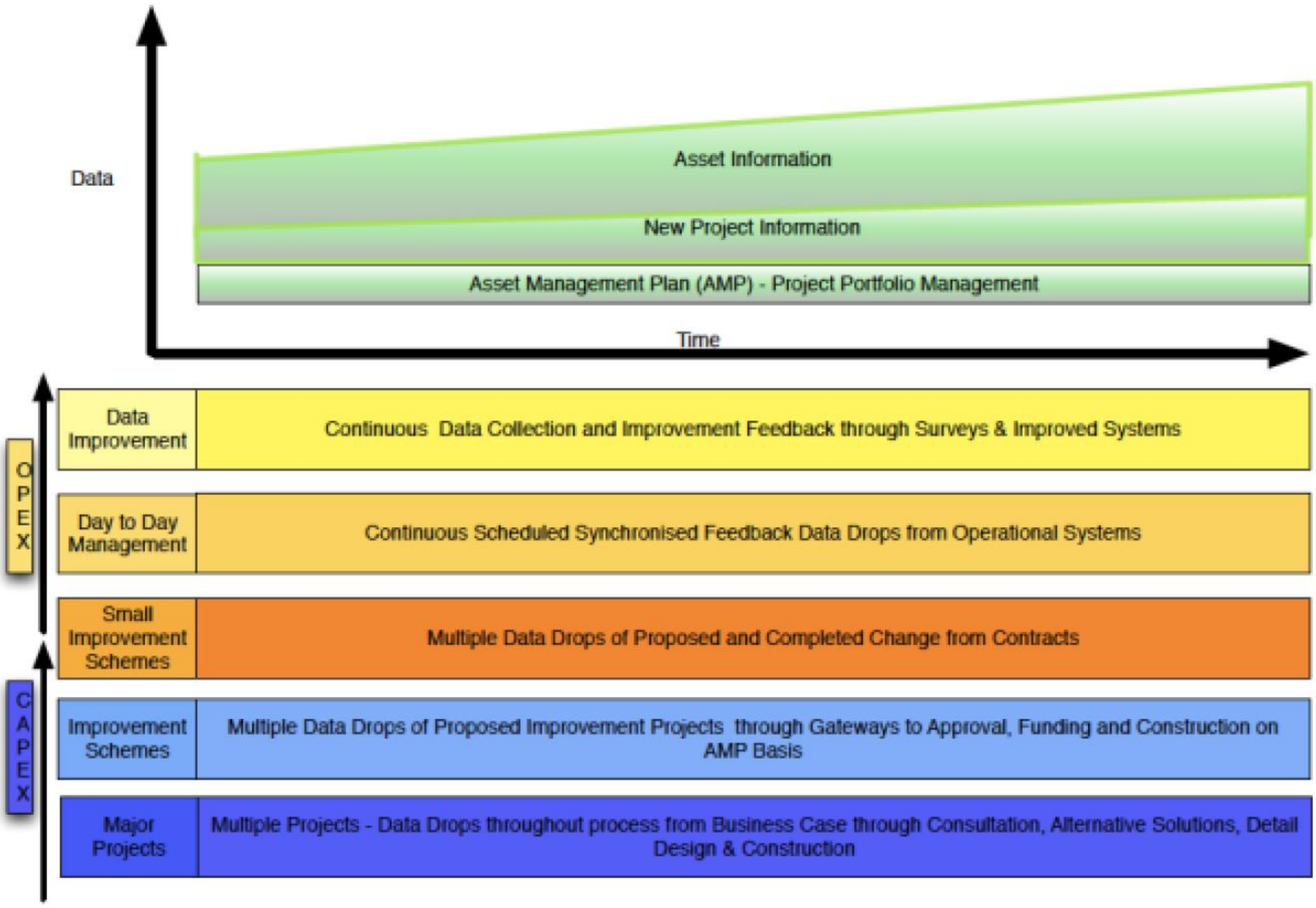


Figure 8: Total Asset Information Continuity

2.7.1 Operational Management Benefits

Significantly the longest and most important stage of an asset's life and over time probably the costliest.

Not surprisingly then significant benefits accrue from using a systematic BIM approach at this stage of the life cycle.

Having access to the DNA of our asset is invaluable in many operational scenarios. Imagine we have a failed bridge support bearing that needs replacement; without the DNA we might look up what the original product used was from as-built drawings or schedules and find that a similar one is no longer manufactured.

With the DNA evidence, we can query the design performance characteristics, we might even refer to original structural analysis results to understand the design envelope.

We can read its technical specification requirements, see its location, view it geometrically in its context and understand the issues in replacing it or selecting a new bearing using the original design purpose and parameters.

Additionally, we might look at inspection history and locate/identify other similar bearings in our asset portfolio that may need attention.

Of course, we could use traditional asset management systems and tools to do this accessing information captured from the as-built survey, handover drawings and schedules that have been manually input into the system.

How much better would that be if we could use information related to location, geometry, and asset DNA captured from life cycle intervention information presented in a standard BIM format.

2.7.2 Planning And Procurement Benefits

Many of the benefits at these stages have been defined elsewhere so we will not go into them in detail.

There are of course all the well-versed ones of clash avoidance, visualization, project management controls, logistical controls, prefabrication, and collaboration across all parties involved.

However, beyond those immediate benefits, they also include the ability to record each decision made during the planning, design and construction process and the information that supports those decisions.

With such information, the stakeholders in the process can look back and retrieve that information if revised design decisions need to be made due to a change of circumstances or if a redesign requires access to all the underlying parameters.

But perhaps most importantly it can be seen what other systems and decisions might be impacted by a change.

3. CONCLUSION

Taken together this systematic holistic approach to information capture and creation provides the basis for revolutionising our approach to asset planning, procurement, and operation.

It breaks down the silos of information that historic disciplines have built into a more systematic integrated view of the delivery of infrastructure service.

Objections are often proposed to this approach concentrating on the fact that no BIM model exists for most of our assets as they are already built and that most asset management is based on retrospective surveys.

Whilst this is no doubt true it should not stop us from adopting a reverse engineering approach by defining BIM objects at the point of the survey of existing assets using BIM modelling methods.

By defining ‘Open BIM objects’ at that stage and attaching information we will gradually build a retrofitted BIM model of our existing assets.

To achieve an integrated approach our approach to asset management philosophy will need to change to a more total view of information using BIM objects/assets as the base of information.

It is also necessary to set up organisational structures that recognise that the BIM ‘Digital Twin’ is central to planning procuring, delivering, and managing our assets.

By doing so we will enable a systematic, holistic, life cycle understanding of assets, and BIM information can become for life and not just for the individual tasks we encounter en route.

BIM technology and open standards exist to support this approach it is now up to industry and asset owners to recognise that all asset information can be linked to BIM models rather than building siloed management and process structures.

It will take some radical changes to do that but until we do the full potential of the digital engineering revolution will not be realised.

4. REFERENCES

[1] Eastman, C., 1975: “The Use of Computers Instead of Drawings”, AIA Journal, March, Volume 63, Number 3, pp 46-50

[2] Aish, R. (1986): ‘Building Modelling: The Key to Integrated Construction CAD’, CIB 5th International Symposium on the Use of Computers for Environmental Engineering Related to Buildings, 7 - 9 July

[3] Finith Jernigan: Big BIM little bim: 4Site Press, ISBN 978-0-9795699-0-6

[4] “Organisation and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling” Parts 1, 2 & 3: ISO Standards

[5] “A Systems Approach to Infrastructure Delivery”: ICE.org

[6] Jackson P.M: “Infrastructure Asset Managers BIM Requirements”: bSI Asset Report 18-01-09-AM -TR1010

DATA DRIVEN BIM MODELS IN BRIDGES

Eetu Partala, Sweco Structures Ltd, Finland

ABSTRACT

Design automation tools are rarely used in the context of existing structures. The methods of modelling can also be harnessed to create digital twins of structures with the help of data from structural health management systems.

With 10 pilot bridges, the workflow was studied and key parameters for the modelling specified. Semi-automated modelling process made it possible to create models from bridges that were designed and built before the BIM era.

Keywords: bridges, BIM, structural health management, SHM, data-driven design

Reference: Partala, Eetu: *Data Driven BIM Models in Bridges.* IABSE Symposium Prague 2022. Proceedings ISBN: 978-3-85748-183-3

1. INTRODUCTION

The knowledge and tools in the field of design automation have developed rapidly during the last years. With the developing technologies, digital twins can be produced even from the structures that have been designed and built before the digital era.

In the project case, the national structural health management system (SHMS) was utilized to create a digital twin of bridges.

Several bridges were randomly selected as pilot cases from the SHMS of the Finnish Transport Infrastructure Agency. The goal was to determine the required parameters for automated digital twin creation.

Bridge models studied in this case contained only a limited amount of data and cannot therefore be considered as building information models (BIM). These models are considered geometry models which are to be enriched with the data from the SHMS database.

The goal of the research was to discover the workflow and required minimum parameters to create a bridge model from the database without any manual work.

2. INITIAL DATA

2.1 Data from the structural management system

The data for the models were exported from the national registry of bridges and infrastructure in Finland.

Instead of a browser interface, data was exported in JSON (JavaScript Object Notion) format, which is a useful open file standard for information exchange.

This format will gather the bridge information into easily understandable attribute pairs and groups. With the help of data hierarchy, a certain part of the bridge and its attributes can easily be found.

2.2 Open data interfaces

In this research, several different open data services and interfaces were utilized.

The goal was to supplement the data from SHMS with open data and to connect the structures more accurately to roads and surroundings.

Most of the open data services used can be categorized into, WMS (Web Map Service) or direct download WFS (Web Feature Service) platforms.

WMS is primarily subjected into map browsing and WFS for the direct server download, upload and editing.

2.3 Open data sources

Sources of the open data were national databases for roads, streets, maps and land surveys. Most of the information needed for the bridge site modelling required a combination of data from different data sources and services.

The use cases for the data available are virtually endless and post-processing is key for data management.

2.3.1 Roads

Information on roads and streets was in different formats with attribute data in one and geometry in another service.

The common aspect to open data is standardisation which is at the core of automated information post-processing.

Geometry information was imported in ESRI Shape format, which can comprise points, lines or polygons. Information is geo-referenced.

The road geometries were utilized to position the bridge into the right location and to work as visual quality control for the SHMS coordinate information.

2.3.2 Bridge surroundings

The national land survey agency of Finland provides open-format laser scanning data from all of Finland. Cities and towns can provide more accurate data, but they often cover only small areas.

The nationwide database of land surveying will provide point cloud data which is constantly updated in the cycles of 5 to 10 years.

The point cloud and road information was supplemented by OpenStreetMaps (OSM), which is an open collaboration project of map information.

OSM is excluded from the BIM but will work as a reference in the models. Maps are a visual and effective tool for quality control of the otherwise automated process.

All the services are open to everyone and free for use.

2.3.3 Data standardisation and processing

Information sources for roads, maps, and structures are many. Also, they all have different quality standards and interfaces for users to operate.

In this research, WFS data was processed with QGIS software, which made it possible to combine all the required data sources and support the bridge site geometry models. The ESRI Shape format files and the bridge data were post-processed with Python programming language.

Methods of data exchange became a more integral part of the project; it is all about how different data sources can be used without compromises in information quality. An example of varying accuracy levels is presented in the figure below.

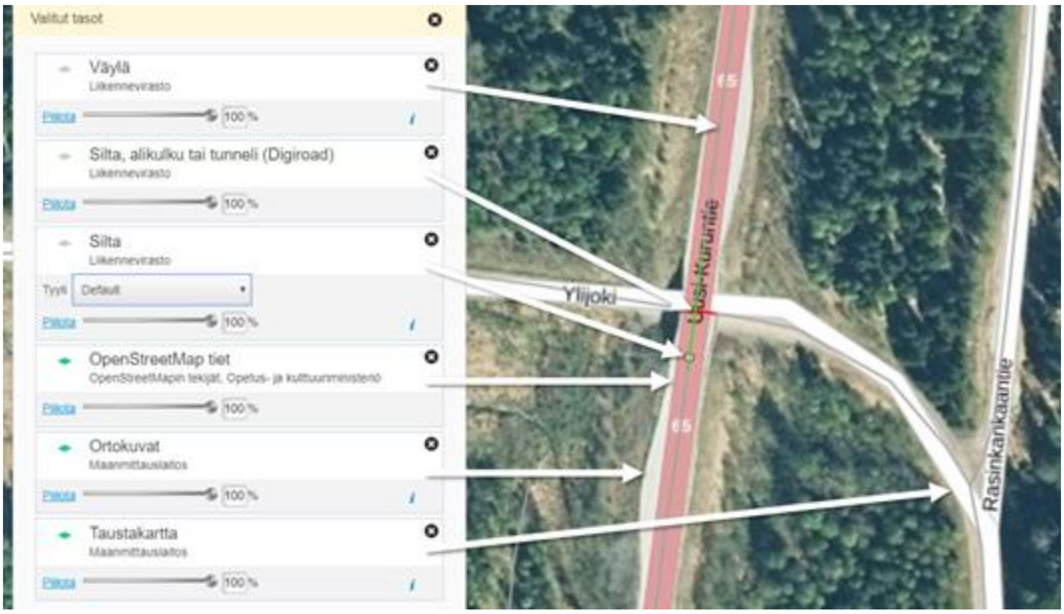


Figure 1: Overlayed data sources

The reasons for this are many. The attribute definitions are in some cases different, accuracy levels might vary and coordinate systems can differ.

3. PILOT CASES

Ten bridges of the same type were randomly selected for the project cases.

Different information levels, bridge dimensions and ownership histories were used as drivers to establish the most diverse pilot case group possible.

3.1 Parameter definitions and research methods

The automatization was studied with software called Rhinoceros 3D and its visual coding language Grasshopper.

The imported data were processed with Python and modelling software was used to build the BIM representation of the bridge site.

Only the most important information such as part names, locations and dimensions were collected from the bridge site to avoid unwanted errors in the process.

Data iteration appeared as a tedious task, especially if the data were gathered during the last decades in the form of different SHM systems and purposes. For example, a pile can be located in a different data structure than others.

Also, the data hierarchy has no maximum depth or order, which makes it more challenging to develop automation in the workflow. The approach for modelling is very straightforward and often used in the modelling of new structures.

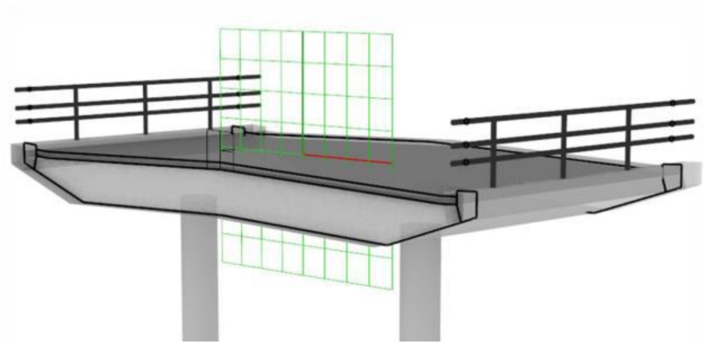


Figure 2. Bridge deck cross-section as an example of a local bridge modelling plane

The data from roads and bridge locations were used to create the main axis and cross-section planes for the structure.

With the help of these local coordinate systems, the whole bridge modelling could be split into phases – the bridge parts to be exact.

The SHM developer worked closely with the automatization development team to create an output that would meet the needs of modelling as good as possible.

Python code was used to organise the non-uniform data and to pick the required parameter for each of the bridge parts.

3.2 Study results

The full research report included all the required modelling parameters for a bridge of this type. The list of minimum parameters was supplemented with detailed verification of the data.

Successful use of data from the SHMS is a combination of data integrity and standardisation. A four-level system was used to rate the quality of the data, see the table below.

Level	Data Content
3	Sufficient – All data required
2	Good – Only geometry or material information needs to be supplemented
1	Poor – The required information needs to be picked manually from the documents
0	No data – Required data not available

The average data level rating of a single bridge varied from 1.3 to 2.0. In practice, none of the bridges had the level of information that would make the automated process possible on a reliable quality level.

In most cases some adjustments were required; for example, the cross-section width and height could have gone the other way around, resulting in poor results in the modelling phase.

Nevertheless, these small supplements are minor compared to the time spent on minor modelling methods.

The most critical factor is the non-uniform data, faulty data items and even the lack of data in some cases. In an ideal case, the process could be considered fully automated, but then all the data items need to fulfil the requirements.

Positioning the structure to the exact location is difficult because the bridge may not have survey information available or the georeferenced data from different data sources can also be conflicting.

From a modelling perspective, the geometry should not have tolerance, but in the real world, it is virtually impossible to have as accurate models as with the new structures.

In some cases, the accuracy level was in meters, which is not enough for a digital twin but will serve the bridge inspector sufficiently.

Bridge geometry can be considered as an assembly containing different parts that will connect each other by rules created in the modelling algorithm. If even just one of the dimensions is faulty, the whole algorithm might crash.

The reliability of automated modelling is good as the bridge part geometry accuracy. If information is missing, it has a direct effect on the result. The automated process leaves no room for manual interpretation and it is efficient only when the information is correct.

Figure 3: Bridge site of a pilot bridge. Google street view on top and view from the model below

4. CONCLUSION

With the methods of data-based and automatized workflows bridge models can be produced efficiently and quickly.

Nevertheless, only a few of the structural health management systems are built to support modelling or provide information that is useful without post-processing. In some cases, information required for the modelling is missing or it can be faulty.

The 10 pilot concrete slab bridges provided enough information to recognise the vital information required for the modelling of existing structures. These requirements are recurring with many other bridge types as well.

Therefore, the same workflows can be easily translated into most of the bridge types. The information and data standardisation level is the key factor in automated model production.

Geometry and information models can be automatized, but only partially. With non-standardised data, an SHMS professional has to verify, fulfil and modify the data content.

With more uniform data flows, efficiency can be improved markedly and ambiguousness equivalently minimised.

Data content development and standardisation would make it possible to have bridge models generated automatically.

Virtually all of the currently in use software can be extended and add-ins for the automated model creation be included.

Workflow for the existing structures is the same as that in the design of new structures, only in the opposite direction.

Database items are now being mined from the IFC files automatically. With existing structures, the database is being used as an input for the model with the same tools.

Automatically generated models can be a major help in the work of a bridge inspector when the remark could be straight applied to the digital twin.

This would improve the level of quality in inspections and provide an understandable and visual platform for structural health management.

IABSE SYMPOSIUM PRAGUE 2022 “CHALLENGES FOR EXISTING AND ONCOMING STRUCTURES”

František Wald, Chair of the Scientific Committee;
Pavel Ryjáček, Chair of the Organising Committee;
Czech Technical University in Prague, Czechia

From 25th to 27th May 2022, 363 structural engineers participated in the IABSE Symposium Prague 2022 with the overall theme “Challenges for existing and oncoming structures”.

This Symposium was organized by the Czech National Group of IABSE in Prague. 222 speakers from 37 countries lectured in 178 presentations.

All the current Challenges for structural engineers, the entry of computer science into the entire construction process, new materials, great design solutions for bridges and civil engineering, energy, transportation, globalization and anti-globalization issues were discussed.

Important sub-themes of the Conference were presented by Keynote Speakers discussing the following topics:

Manfred Curbach from Technical University Dresden, Germany, presented how Carbon Concrete may help in the climate-neutral building industry.

The increasing use of carbon concrete makes it essential to know the relevant material properties, especially the behaviour under tensile loading.

The test recommendation for the determination of material properties under tensile loading of textile-reinforced concrete, which was developed in a joint research project of TU Dresden, RWTH Aachen and MFPA Leipzig, was presented.

Eugen Brühwiler from the Swiss Federal Institute of Technology Lausanne, Switzerland, explained that Structural UHPFRC stands for Ultra-High-Performance Fibre Reinforced Cementitious Composite material which is complemented by reinforcing and prestressing steel to enhance the resistance and durability of structural elements.

Applications show that Structural UHPFR has made proved its status as novel building material and technology to enhance bridges and structures in general.

UHPFRC also contributes to lowering the environmental impact of structures and thus improving sustainability. UHPFRC is at the beginning of a new construction era: the post-concrete era.

Marco Di Prisco from Politecnico di Milano, Italy, presented the lecture *The bridges in Italy: how to manage the infrastructural heritage guaranteeing safety and sustainability*.

He presented that the collapse risk is a factor associated to the construction of any structure or infrastructure and that maintenance and monitoring are actions aimed at reducing this risk, but they cannot reduce it to zero.

Frantisek Wald from Czech Technical University in Prague, Czechia, demonstrated that connection modelling and analysis are both vital parts of the design *of* steel structures.

He introduced the stakeholders for designing steel structures and their joints.

A comparison and impact of three different levels of BIM implementation were demonstrated in practical case studies.

Zdeněk P. Bažant from McCormick Institute, USA, discussed the lifetimes of concrete structures, which have been inadequate, and that structural failures are far too common, especially in the case of large structures of novel designs.

He appointed the main aspect of the randomness of loads such as those from traffic, environment and random vibrations and discussed the uncertainty in material properties, the role of corrosive agents, and failure mechanics.

László Dunai from the Budapest University of Technology and Economics, Hungary, showed progress in the standardization of Finite Element Analysis in the design of steel structures.

He discussed the importance of uniform terminology, the definition of numerical simulation as an experimental work, and the numerical design calculations as a design procedure based on partial safety factors.

He showed the importance of validation as a comparison to experimental results and verification as a comparison model to model.

Benchmarking is important mainly for users. It allows one to check important steps and decisions in modelling.

The Symposium was based on themes of Keynote speakers to the challenges of existing and oncoming structures, materials, and technologies, summarizing the latest developments of structural engineering with respect to the advanced and new methods of design and analysis.

Scientists, experts, designers, contractors and all those who are interested in advances and problems related to civil engineering structures and bridges, numerical modelling, and advanced methods of design, contributed to the theme.

Papers were presented on a variety of methods to better understand our existing structures, including numerical simulation or field testing, automated assessment techniques, and material sampling, the use of sensors and digital twins.

Additionally, artificial intelligence, big data and neural networks were highlighted. Some papers addressed upgrading the seismic performance of structures. Life Cycle Costing techniques may help owners to improve their decisions for the benefit of society.

New, more sustainable materials, digital production and 3D printing were presented as well. Valuable information was given on how to reduce the environmental impact at the material level when producing new steel and concrete.

The advantages of timber as a sustainable building material were highlighted. Papers on innovative and lightweight structures showed how these concepts may contribute to sustainability.

Besides the resistance side, also the action side is important as shown in papers on developments in traffic loads for road and railway bridges and the consequences of these developments.

The reliability of our structures is a primary societal need: our structures need to be safe for the public and accidents should be prevented.

Many papers focused on enhancing the reliability of our more complex structures by 3D Structural analyses. Advanced finite element analyses assist the assessment of our existing structures, prolonging their lives. Finite element methods updating based on monitoring data is emerging.

Papers were also presented on wind dynamics of long-span bridges and high-rise structures.

The Symposium included several special sessions. They were focused on vibrant topics in bridge engineering, for example:

- *Bridge Management System and Building Information Modelling: Challenges and vision*
  This session included two separate sessions, which underlined the importance of BIM in modern bridge design and construction but missing in management systems. The papers also included the creation of digital twins through AI-based methods
- *The Storstrøm Bridge in Denmark – Challenges in Design and Construction*
  The session included papers, describing the process of the construction from tender requirements to reality, the design of the piers, superstructure and construction.

Other special sessions included:

- *Structural Steel Connection Design – Challenges and Vision*
- *Ultra-High-Performance Concrete is Ready to Revolutionize*
- *Membrane Structures – Recent Achievements in Practice and Standardization*
- *New European Standardization on Monitoring, Safety Assessment and Bridge Maintenance Design Assisted by Finite Element Analysis*

All the special sessions were considered to be very attractive for the participants.

This Symposium showed that structural engineers need to meet in person and online meetings cannot replace their quality. It was also shown how computer science, new materials and bold design solutions are changing design and construction practices around the world, and the benefits and limits of contemporary globalization.

VULNERABILITY TEST AND SPECTRAL ANALYSIS WITH SEMEX ENGCON - PROPOSAL OF PARTNERSHIP FOR A BRIDGE IN EU

The Team:

Kyle Rollins; Danilo Coppe; Roberto Tamagnini

SEMEX EngCon; KIMIA SpA

INTRODUCTION

We are looking for an owner or maintenance company that wants to collaborate in innovation for the vulnerability assessment of bridges and/or structures with an innovative method that uses the dynamic input of two blasts into soils before and after the retrofitting, and compute the Spectra at a node with high precision monitors (piezoelectric cells/geophones) that record vibrations with millimetre precision (10-3 mm).

ADVANTAGES:

- Vulnerability is defined in a scientific manner with measures and not with FEM analyses, that in many cases is very approximative (application of pseudo-static loads, disregard of soil liquefaction potential, cyclic mobility of soil is not easy to be implemented).
- The iron component of the structure is generally not visible (ex. Morandi suspension system of Genoa) and a visual inspection could fail the evaluation of Risk.

TEST PHASES:

- Step 1: Installation of SEMEX monitors on the nodes of the structures;
- Step 2: Blasting of micro charge into the soil;
- Step 3: Analysis of records by SEMEX and elaboration of Spectra with METRIS soft;
- Step 4: Intervention with composite material by KIMIA (carbon fibres or FRCM);
- Step 5: Basting of second micro charge into the soil with the same potential;
- Step 6: Analysis of second records by SEMEX on the same nodes and Spectral Analysis;
- Step 7: Definition of the absolute value of displacements, velocities and accelerations (with characteristic frequency);
- Step 8: Definition of IR Index of Risk reduction at the ratio of 1 – Acceleration Pre/Acceleration Post, with Acceleration Pre the acceleration of the unit mass before retrofitting and Acceleration Post the same quantity. Post intervention.

REFERENCES:

Academic: Prof. Kyle Rollins

https://scholar.google.com/citations?user=_KVZ8oMAAAAJ&hl=en

Research and Design: Eng. Roberto Tamagnini

https://scholar.google.com/citations?user=8Jzdgi8AAAAJ&hl=en&authuser=1

Contact: rob.tamag@gmail.com

INDUSTRIAL PARTNERS:

https://www.kimia.it

https://www.linkedin.com/company/semex-engcon-gmbh/

THE PARTICIPANTS

Professor Kyle Rollins, PhD.

Received his BS degree from Brigham Young University and his PhD from the University of California at Berkeley. After working as a geotechnical consultant, he joined the Civil Engineering faculty at BYU in 1987, following his father who was previously a geotechnical professor.

His research has involved geotechnical earthquake engineering, deep foundation performance, bridge abutment behaviour, collapsible soils and soil improvement techniques. He has supervised more than 130 graduate students and published over 190 papers. His work typically involves full-scale testing to evaluate and improve the performance of bridges and buildings.

The American Society of Civil Engineers has recognized his work with the Huber research award, the Wellington prize, and the Wallace Hayward Baker award. In 2009, he was the Cross-Canada Geotechnical lecturer for the Canadian Geotechnical Society. More recently, he received the Utah Governor's medal for science and technology and the Jorj Osterberg Award from the Deep Foundations Institute.

Danilo Coppe

Born in Milan in 1963 and in 1970 he moved to Parma. He graduated from the "Umberto Follador" Industrial Mining Institute in Agordo and attended the first experimental course in Geotechnics connected to the University of Padua. In 1989 he founded the Siag company, specialized in controlled demolitions with the use of explosives.

He executed the Morandi Genoa demolition. He graduated in Political Science with a criminological address at the University of Bologna where he currently teaches the Master of Forensic Chemical and Chemical-Toxicological Analysis.

Roberto Tamagnini, PhD, MSc., Eng.

Expert in Soils Modelling and Finite Element Theory for Three Phase Porous Materials. He worked in 4 European Universities and he has published 20 papers on gas dissociation and soil compaction due to liquid water flow in unsaturated soils.

He specialized in Phase transformation studying in Vienna the Theory of L. Boltzmann for the Kinetic of Gas.

SEMEX-EngCon

An ISO 9001certified company, designs, engineers and manufactures products and solutions for civil engineering, strong motion, and seismic vibration monitoring applications, including sensors, recorders, actuators and application software.

Our talented workforce and passion for innovation create excellent value for our customers by providing quality solutions and services.

KIMIA SpA

Was the first company in Italy to introduce composites in the structural field and among the very first to develop mortars and resins specifically designed for restoration. From the Trevi Fountain to the Milan Central Station, from the Royal Palace of Caserta to the Viaduct Italy, the most prestigious construction sites in our country tell our story and the very high quality of Kimia solutions better than any word.

Today we are one of the main and most acknowledged companies in the field and with our assistance network located throughout Italy, we offer constant design, technical and commercial support to professionals, both in the choice and in the use of our solutions.

Helgeland Bridge, Norway

Photo : Jules van den Doel

AAS-JAKOBSEN

RÚBRICA **BRIDGES**®

We design and produce formwork equipment for **in-place casting of bridges**

N25 New Ross Bypass (Ireland)

rúbrica | engineering®

Intelligent construction methods for civil works

25 YEARS UNIQUE SOLUTIONS

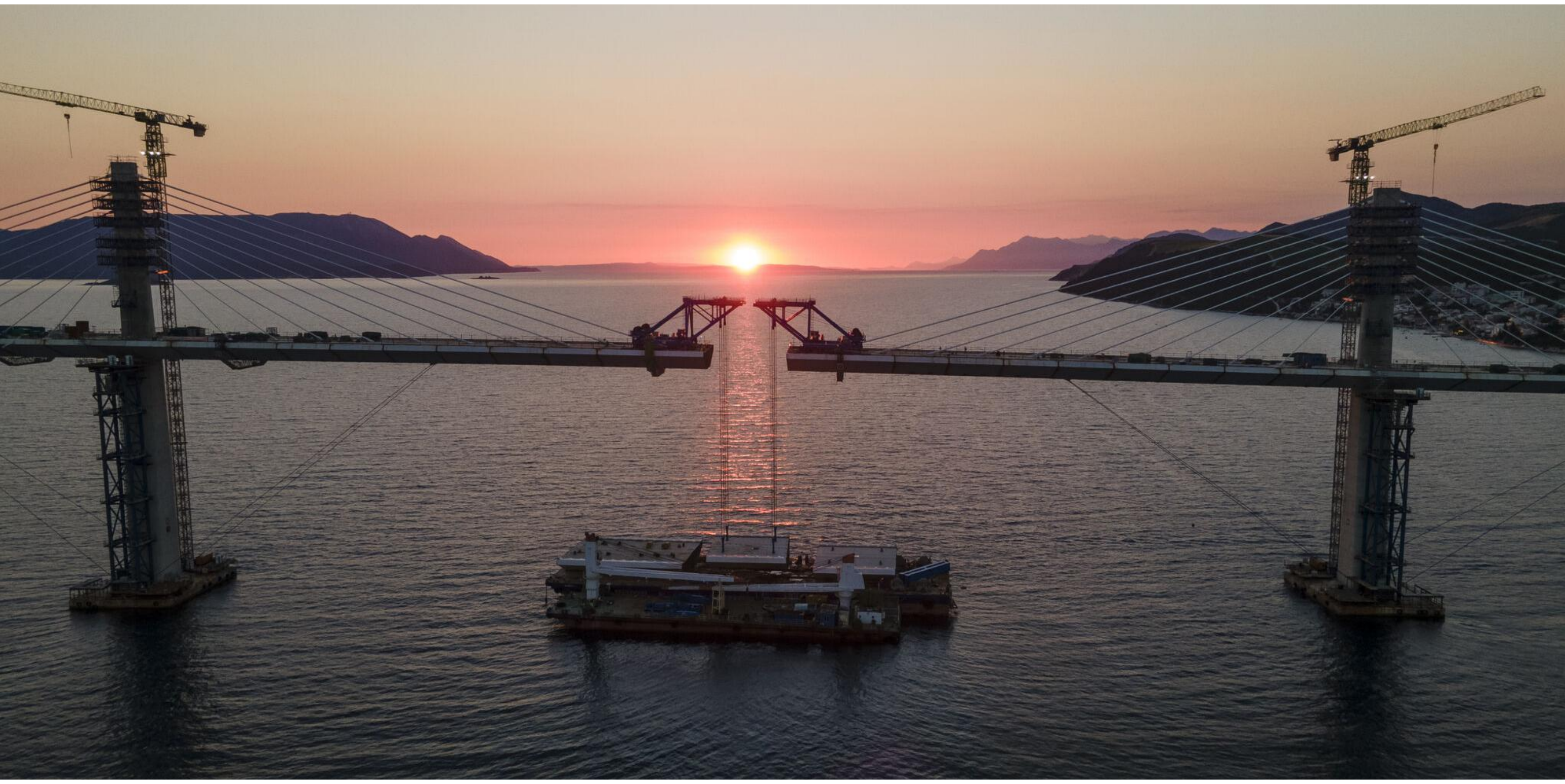
PELJEŠAC BRIDGE, CROATIA

Pipenbaher Consulting Engineers

PIPENBAHER INŽENIRJI d.o.o., Slovenia
www.pipenbaher-consulting.com

Pipenbaher Consulting Engineers / PIPENBAHER INŽENIRJI d. o. o.
Žolgarjeva ulica 4a, 2310 Slovenska Bistrica, Slovenia

We design bridges



Pelješac Bridge, Croatia

Conceptual/Preliminary/Final design
Joint Venture Faculty of Civil Engineering, University of Zagreb; Ponting; Pipenbaher Consulting Engineers

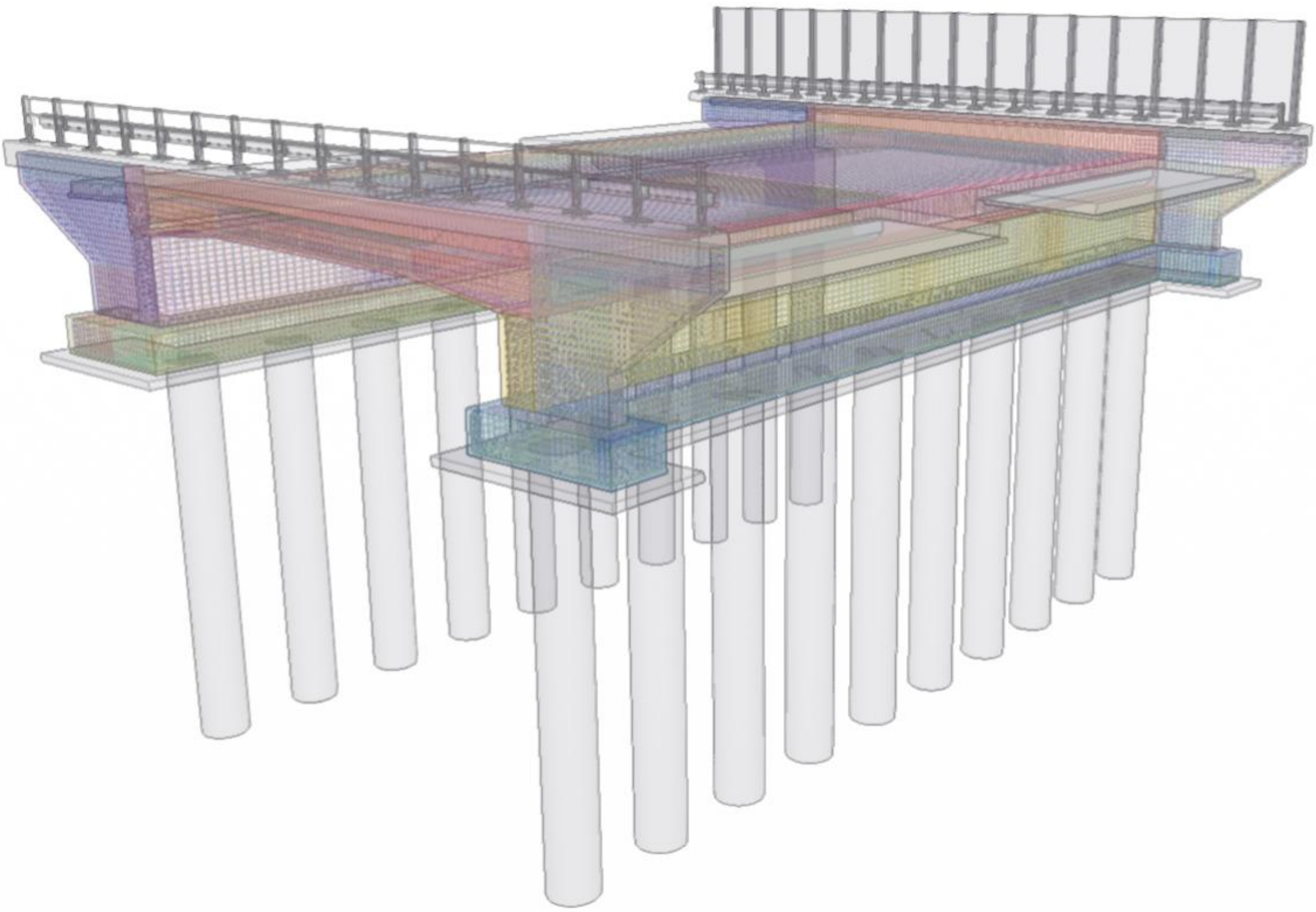
Ada Bridge over Sava in Belgrade, Serbia

Winning competition design/Preliminary/ICE for final and detailed design

Ponting inženirski biro d.o.o., Strossmayerjeva 28, 2000 Maribor, Slovenia

e-BrIM

ISSUE 03/2022 OCTOBER



International online peer-reviewed magazine about

BRIDGE INFORMATION MODELLING