e-mosty

NEGRELLI VIADUCT BIM TAMKAL AND SISIT BRIDGES

ISSUE 04/2020 December

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Front Cover: Negrelli Viaduct Reconstruction, Prague, Czech Republic

Photo Credit: HOCHTIEF

Back Cover: Tamkal Bridge, Kenya Photo Credit: Jeff Hennessey

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Contact: info@professional-english.cz

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Dear Readers

*The first article of this issue provides an overview of the reconstruction of the **Negrelli Viaduct in Prague, Czech Republic**. It was prepared by Linda Černá Vydrová from Hochtief. The Negrelli Viaduct is a railway bridge in Prague, Czech Republic, that connects two major railway stations in the city. The main reason for the viaduct reconstruction was the poor technical condition of the arch structures.*

*In the next article, **BIM Application for expert design tasks** using Allplan Bridge is described. In the article, Johann Stampler and Gregor Strekelj of ALLPLAN Infrastructure focus on prerequisites for advance applications, structural analysis, and structural design and assessment. The article is accompanied with an advertisement and PR article prepared by ALLPLAN as they are our high-esteemed partner.*

*In the last article of this issue, we bring information on the **current opening of two bridges which have been rebuilt by Bridging the Gap Africa**. In 2019 and early 2020, flooding and mudslides devastated the African region and nearly all of the 60 bridges BtGA had built were washed away or severely damaged. In 2020, thanks to collaboration and support from the communities and the generous donations of supporters around the world, BtGA has rebuilt two flood ravaged bridges, repaired several other damaged bridges, and is assessing and planning for additional bridge schemes moving forward.*

*I would like to thank all authors and companies involved for their cooperation; **Ken Wheeler** and **Richard Cooke** for reviewing this issue. I would also like to **thank our partners for their continuous support**.*

Due to the current situation we have postponed publication of two articles originally planned for this December edition to next year.

On the following pages you can find our Editorial Plan for 2021 for both magazines. Almost all issues are already full which is great as e-mosty and e-maritime will keep going despite the unfavourable conditions and situation.

Apart from that, we will also feature projects in which our partners participate. We are happy to show and share their achievements.

With our other magazine, e-maritime, we go on focussing on maritime construction projects, design and construction of ports and docks. We welcome cooperation with you and your company as well.

On the next page please also find information on how you can directly support me and especially e-mosty magazine.

Thank you all for fantastic cooperation and I wish you a Happy and Prosperous New Year.

Magdaléna Sobotková

Chief Editor

CROWDFUNDING for e-mosty (and e-maritime) magazines

For almost 6 years I have kept e-mosty magazine going with Open Access.

We all do our best to show bridge projects from the whole world, especially their design and construction, operation, and maintenance. We aim to share technical and informative content with everyone worldwide.

I have been giving it a lot of energy, time, and money. Unfortunately, me and my company have been affected by the current pandemic situation with the business in 2020 almost zero.

I would like to keep e-mosty magazine going as it is; for 2021 it is almost full, with numbers of readers, subscribers, and followers increasing every day.

We go on promoting conferences and charities. We are always happy to support any other projects, especially within the bridge community.

Please help me keep it going, still with open access, and overcome this difficult period.

With your support things will be much easier for me.

Thank you.

Magda Sobotková

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We are happy to provide media support for important
bridge conferences, educational activities, charitable
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Our Editorial Board comprises bridge engineers
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RECONSTRUCTION OF NEGRELLI VIADUCT, PRAGUE, CZECH REPUBLIC

Linda Černá Vydrová

Hochtief CZ a. s., Division Traffic Infrastructure

Figure 1: Aerial View of the Northern part of the construction site

INTRODUCTION

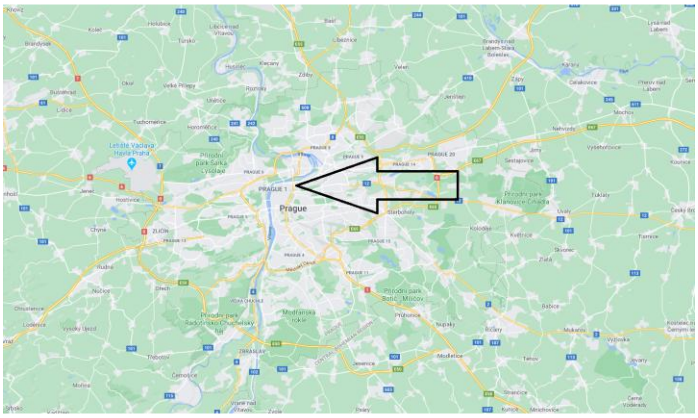
The Negrelli Viaduct is a railway bridge in Prague, Czech Republic, that connects two major railway stations in the city.

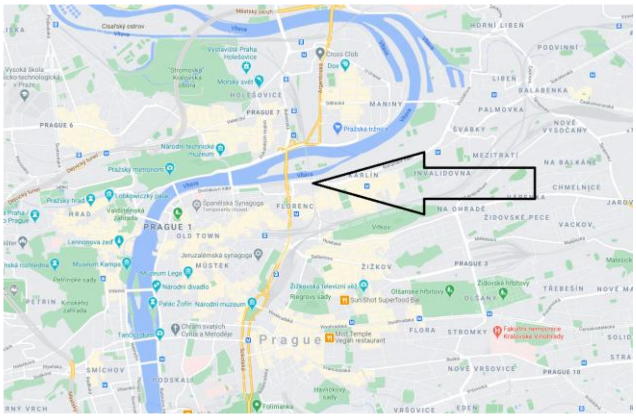
It is historically the first railway bridge over the River Vltava in Prague and now the second oldest Prague Bridge over this river.

It is also the longest railway bridge and the third longest bridge in the Czech Republic. The Negrelli Viaduct was declared a Czech cultural monument in 1964.

The current reconstruction (2017 – 2020) addressed comprehensively the unsatisfactory condition of the bridge structure, track structure, interlocking system, signalling and heavy current installations and traction lines and it has ensured compliance with the obligatory parameters of the upgraded railway line.

The project included, in particular, removal of additional incorporated structures and annexes, increasing the load-bearing capacity of both the subsoil under the piers and the piers themselves; when a failure affecting the load-bearing capacity of the arches was identified, these arches were completely reconstructed.





Figures 2 and 3: Location of the bridge in Prague   Source: Google maps

New modern railroad switches were installed in the yard, acoustic treatment was applied to the rails and anti-vibration mats under the ballast bed were installed.

The railway bed was reconstructed and a new track structure was installed. The obsolete mechanical devices were replaced with modern electronic interlocking system and signalling installation, so the impact of the human factor was reduced significantly and the safety of operation was increased.

BASIC INFORMATION ABOUT THE PROJECT

The Negrelli Viaduct is located on the railway route segment Praha Masarykovo nádraží – Praha Bubny, which is a part of the railway lines Praha Masaryk Railway Station – Děčín City and Praha Masaryk Railway Station Hrabovka – Praha Masaryk Railway Station Karlín.

The viaduct was first commissioned in 1850. In 1875, it was supplemented with the so-called connecting viaduct for the line Hrabovka – Karlín. In total, Negrelli Viaduct consists of 15 separate bridge structures.

Both sections of the railway line mentioned above are a part of the national railway system. The owner is the Czech Republic represented by the Railway Infrastructure Administration (SŽDC s. o.); the operator of the rail transport is the Czech Railways company (ČD a. s.).

The bridge and the block post no. 249 are registered on the State List of Immovable Heritage.

The source of EU funding was from the Connecting Europe Facility programme (CEF), the national co-funding was provided by the State Fund for Transport Infrastructure. The general designer is SUDOP PRAHA a. s.

The viaduct reconstruction was performed by a joint venture of HOCHTIEF CZ a. s. (Division Traffic Infrastructure), STRABAG Rail a. s. and AVERS, spol. s.r.o. (Ltd.).

The construction activities were carried out during complete closure of traffic on the viaduct from April 2017 to May 2020. The finishing works will extend until December 2020.

The reconstruction of Negrelli Viaduct was closely connected with the planned project "Upgrade of Railway Line Praha – Kladno" because the reconstruction will enable its execution.

FROM CONSTRUCTION TO RECONSTRUCTION

In 1841, the Court Chamber presented a proposal to Emperor Ferdinand to build six railway lines running from Vienna to the centres of the Austro-Hungarian monarchy. A route connecting Vienna with Prague, continuing to Dresden was proposed to be among the first ones.

For this purpose, the Imperial-Royal General Directorate of the State Railways was established in Vienna in 1842.

Ing. Jan Perner, a Czech patriot, was charged with a task to manage the Prague-Dresden railway line; sadly, he died as a result of an accident in the Choceň tunnel just before the start of the construction.

Figure 4: View of the Viaduct in 19th Century. Source: Wikipedia

And so Alois Negrelli, a pioneer of traffic infrastructure projects, an Austrian engineer of Italian origin, after whom the viaduct bears its name, was appointed the Chief Inspector.

Up to 3,000 workers of various nationalities participated in the construction, which took place from 1846 to 1849 and the construction costs amounted to one and a half million Gulden.

Steam lifting cranes and steam pile drivers were utilized to a greater extent for the first time during the construction; these were used to ram oak poles under future bridge piers.

87 arches were built of sandstone masonry (or granite masonry in the case of flat arches over both branches of the Vltava River).

Eight arches (over the Vltava River) have a clearance of 25.3m; the other ones are of 6.39 – 10.75m clearance.

The viaduct piers were built of broken marlite stone placed on mortar; the face work of sandstone. In case of the arches over the Vltava River, the face side of the piers was built of granite blocks.

A part of the arches and piers from Za Poříčskou branou Street towards the Bus Station Florenc was built of brick masonry, the so-called Clinker bricks that are exposed to excessive heat during the firing process and more weather resistant.

Some arches and piers are of brickwork masonry only, at some places combined with sandstone (frontage walls and front strip of the arch as well as front face of the piers).

The so-called connecting viaduct for the route Hrabovka – Karlín was built in 1875 (shortly after demolition of the city walls) of brick masonry for both the arches and piers and with two steel truss bridges.

Once completed, the viaduct was 1,110m long, which made it unique worldwide; many similar bridges were still being built of timber at that time.

The builders did a respectable job; the bridge withstood floods, the ravages of time and the increasing load from train units.

The viaduct layout was modified in various ways during the 20th century. A part of the viaduct at its beginning located at the current bus station was replaced probably in 1932 with a single-span slab with concreted beams ensuring passageway of the former coal line.

In the 1950s, the original truss bridge over Pernerova Street was replaced by a steel structure with composite reinforced concrete slab.

A part of the arches – at the intersections with Křižíkova and Bubenské nábřeží Streets – was replaced by other structures a little later due to insufficient width and height for traffic in the city.

A part of the viaduct over Křižíkova Street was replaced by a load-bearing structure of precast beams of pre-stressed concrete from 1954 to 1956.

It was the first implementation of this type of structure on the railway line in our country. In 1981, the arches over Bubenské nábřeží Street were replaced by a two span superstructure of pre-stressed KT beams.

Based on partially preserved archival documentation, some arches were re-masoned using new sandstone blocks from the 1930s to 1950s or the front face of the piers and frontage walls was completely replaced.

The quality of the original sandstone used was very diverse and it was probably already necessary to replace the worn stones.

At that time, some of the brick and sandstone arches were replaced with reinforced concrete arches on the original bridge piers.

PURPOSE OF THE RECONSTRUCTION

The main reason for the viaduct reconstruction was the poor technical condition of the arch structures.

Due to drainage failures with subsequent leakage of water into the structure, the arches showed a number of failures and rehabilitation of masonry or replacement of masonry elements was required.

It was necessary to replace and restore the viaduct drainage system and to reinforce selected foundations of the piers and masonry by grouting.

In some cases, due to the extent of damage to the masonry, it was necessary to completely dismantle the arches, replace the worn stones with new ones and to re-mason the arches, sometimes together with the piers.

The aim of the project was to ensure compliance with the mandatory parameters of the upgraded railway line.

In particular, GC loading gauge, D4 track load class, modification of geometric parameters of the track eliminating local speed restrictions, ensuring sufficient track capacity, compliance with noise and vibration limits, replacement of unsatisfactory structures and facilities.

The reconstruction of the railway bed and the new track structure resulting in quiet and smooth rides can already be appreciated by the passengers.

BRIEF DESCRIPTION OF THE RECONSTRUCTION

Comprehensive photogrammetric survey of the structure was an important basis for the reconstruction design (the side face of the bridge and soffits).

As a result, the exact shape of the arches' structures and location of joints between stones (digitally) was obtained; at the same time, the condition of the structures and location of cracks was documented.

The possibility of evaluating the depth of defects of the individual stones compared to the arch level proved to be useful, which was obtained from the photogrammetric survey using the digital model of the structure surface.

As a part of extension of the photogrammetric survey, each stone in the bridge structure was marked with a unique code, so its position was recorded and its dimensions and potential defects (cracks and depth of vents of the stone surface) detailed.

The photogrammetry was also the basis for a detailed restoration survey. This was performed visually and it was the basis for determination of the method of rehabilitation and cleaning of each masonry element.

Even though the surveys were extensive, it was not possible to rule out the possibility of replacing the stones and re-building the arches, once the surface stone layers were removed, exposing the actual condition of the insides of the arches.

The viaduct was reconstructed along its entire length, i.e. 1,413m. All 100 arches were repaired - 8 of which span two branches of the Vltava River, 5 bridge structures cross roads, 2 bridge structures, which were fully replaced and 14 arches were completely re-built pursuant, see Figures 5 and 6.

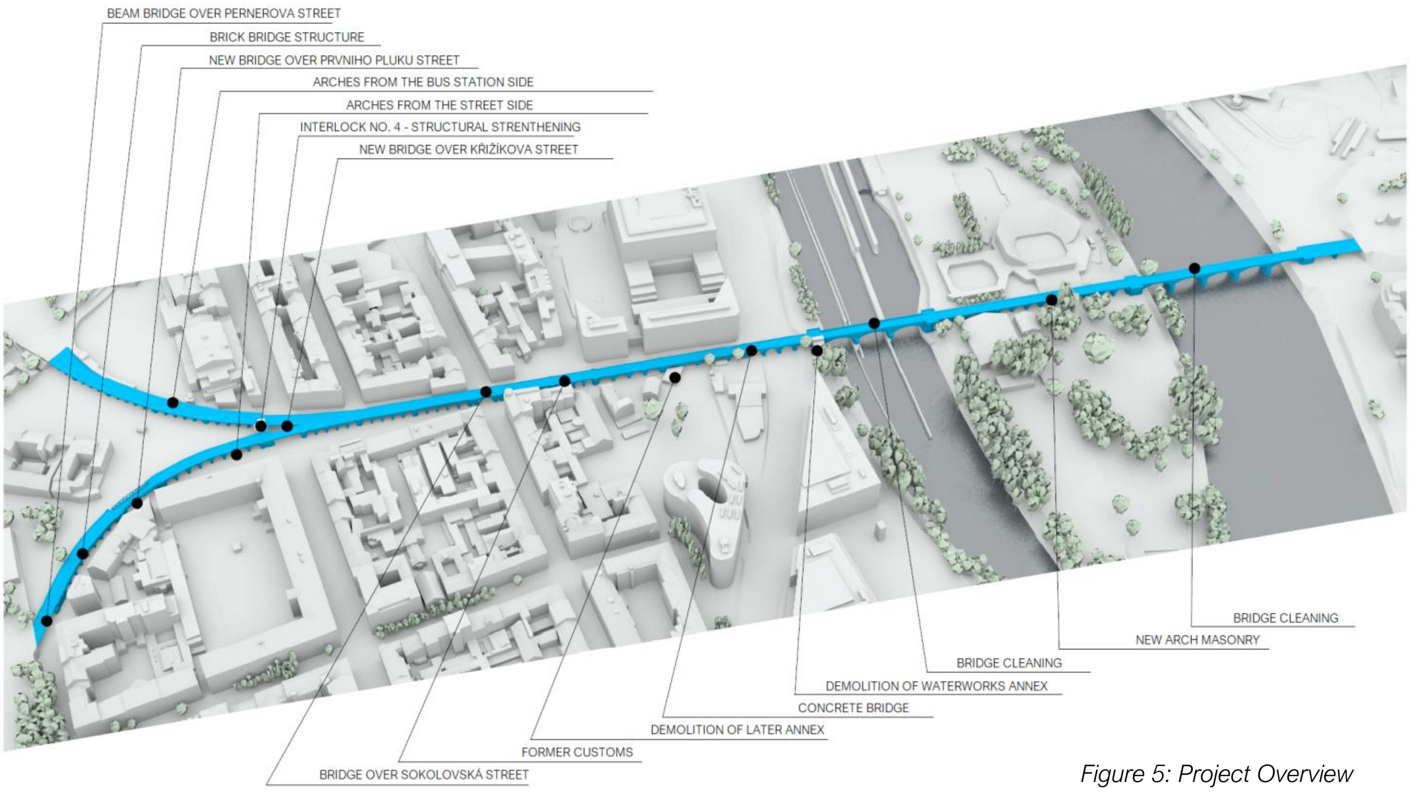


Figure 5: Project Overview

Figure 6: Project situation   Credit: SUDOP
(Click on the image to see the drawing in full)

When dismantling the arches and building them again, a maximum emphasis was put on re-use of suitable stones. Their suitability was based on an additional survey conducted by non-destructive methods.

As the viaduct is a state immovable heritage monument, almost a third of the total volume of the works performed consisted of restoration surveys and detailed diagnostics of the individual masonry elements which formed the basis for the next steps in the rehabilitation works.

At the beginning of the reconstruction, additional structures and annexes which had been incorporated into the viaduct were removed.

Brick infill walls that closed the bridge openings, gates, built-in floors and other structures, annexed garages, workshops and a restaurant near Křižíkova Street were demolished.

The commencement of the construction activities from the bridge deck level started with removal of track ballast and traction lines on the viaduct.

Contrary to the assumptions in the design documents, spread footings at some locations were not discovered.

These had been replaced with gravel layers, which had to be re-sorted (large pieces were taken out) to minimise the risk of concentrated loadings to the arch from passage of machinery across the viaduct.

Where large voids were identified inside the piers under the face side masonry, low-pressure grouting was applied to the pier cores using boreholes from the viaduct deck level at a spacing of approximately 700mm; these were filled with clay-cement grouting mixture and rebar was inserted.

Grounding micropiles were installed from the same level to selected piers that will reduce the impact of stray voltage on the viaduct deck structure with the electrified railway line.

The backfill to the arches was excavated and the arches were exposed, surveyed and rehabilitated from the underside.

Together with the commencement of the works to the viaduct deck, the side faces of the arches and piers were cleaned from the existing surface level.

The masonry of the arches and piers was cleaned with hot steam and jetted by high pressure water with feldspar, so that the appearance of the bridge has almost been restored to the condition in which it was built.

Cleaning of the masonry surface was necessary to conduct the detailed additional diagnostics of the masonry elements and determine the extent of replacement.

Figures 7 and 8: View of granite bridge pier footings in sheet pile cofferdams – Bridge 14-14

Figure 9: Underpinning of brick arches with falsework – Hrabovka

Figure 10: Sandstone arches with falsework – main line

At the same time, on the basis of statics assessment, the subsoil of the piers was required to be reinforced by jet grouting.

The substructure was rehabilitated as well. For this purpose, double sheet pile cofferdams were built in one section of the Vltava River bed.

Based on the identified findings, rehabilitation works to pier shafts in another section were performed by divers.

Within the reconstruction of the Negrelli Viaduct, only three new bridge structures were designed: over Prvního Pluku Street, Křižíkova Street and over the former coal line at the beginning of the viaduct, which is currently an impassable opening. These new bridges replace existing structures which are unsuitable for current use.

ARCH BRIDGES

In order to ensure stability and keep the shape of the arches when removing the arch backfill, falsework was installed that remained in the place until the time of re-filling with backfill of gap-graded concrete.

After installing the falsework under the arches, the original railings and ledges were demolished and the arch backfill was gradually removed, followed by mechanical cleaning treatment.

Then, the levelling screed was applied on the entire inner surface to serve as a base under the new waterproofing system.

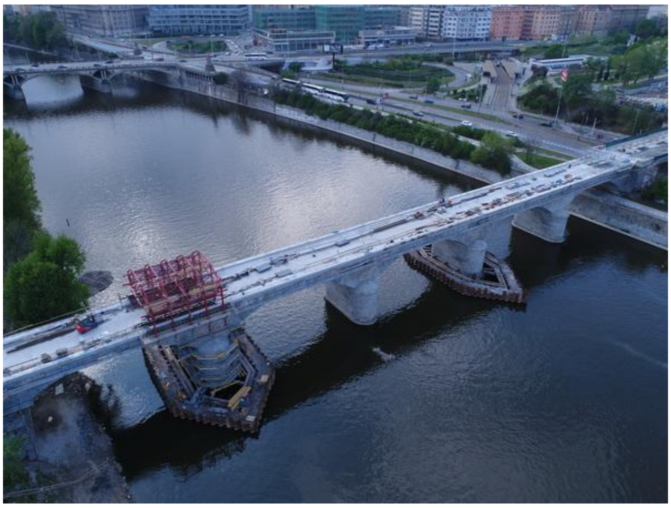


Figure 11: Traveller and sheet pile cofferdams

Figure 12: Bridge 14 – 12 above the navigation lock

Figure 13: Uncovered concrete vaults

Figure 14: Dismantled brick vaults on falsework

The screed smoothed out major bumps on the arch upper surface. Particular attention was given to the material properties of the screed, in particular low shrinkage values and potential for cracking when applied on the uneven upper surface of the existing arch.

Its quality corresponded to at least to C 25/30 X0 concrete. Alternatively, instead of the cement-based screed, shotcrete of the appropriate quality was used, specifically at SO 14-12 and SO 14-14 (bridge structures over the Vltava River) mainly because of simpler processing, transport to the top of the arch and alignment of granite stones that were sticking out.

As it was not possible to re-use the material of the original backfill, it was necessary to choose a suitable new backfill.

The decisive factor was to ensure the drainage properties specified by voids of 20 – 25% and to maintain bulk density and compression strength.

For these reasons, gap-graded concrete was chosen, which was placed in layers with a maximum thickness of 300mm.

The next layer could be applied once the previous layer reached the required strength in order to reduce pressure of the fresh mixture on the parapets.

Compaction was achieved by treading and hand rollers, so that the drainage properties of the entire backfill would not be disabled.

Figure 15: Uncovered sandstone vaults

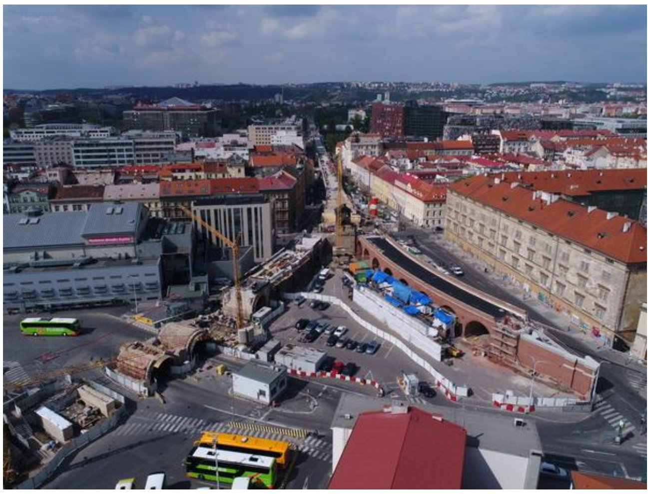


Figure 16: On the left masonry works on the bridge

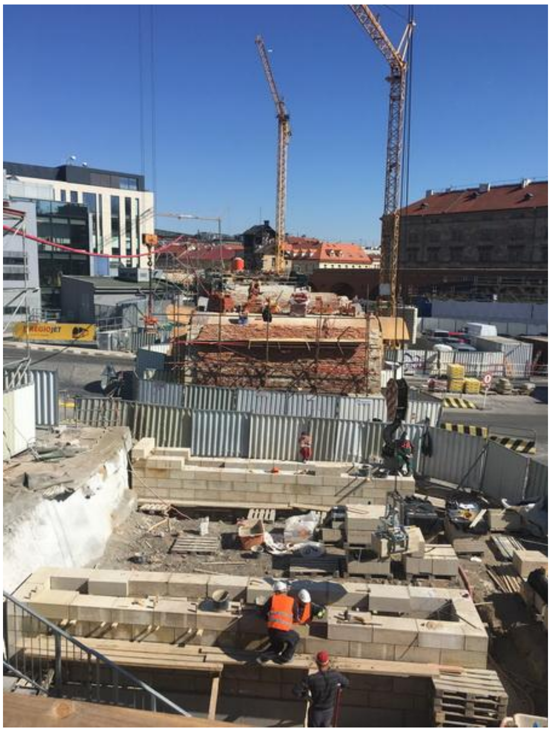


Figure 17: Masonry works on new piers of Bridge 14-06

At the level of the demolished viaduct parapets, reinforced concrete dovetail bearing blocks were placed symmetrically to the axis of the piers, which were anchored to the original parapets using glued rebar spikes.

The sides were covered with anchored cladding of the original sandstone blocks. The stones were anchored into the bearing blocks from the side using rebar spikes placed into drilled holes filled with high-strength non-shrinking filler.

The bearing blocks are supported on both sides by monolithic blocks of lightly reinforced concrete. These blocks as well as the bearing blocks were anchored using rebar spikes glued into the parapets.

Reinforced concrete spread footings of C 30/37-XC4+XF3 concrete with a mixture of polypropylene fibres were installed on the bearing blocks on dovetails.

The individual footing slabs were extended above the arch crown. The slope of the slab was secured both in the transverse and longitudinal direction to the drainage, located on the axis of the pier and discharging to a stainless steel drainage system extending through the parapets into downpipes on the outside of the piers.

Prior to the start of concreting works, templates with a suitable pattern were placed on the inside of the future slab form to achieve a relief of a continuous concrete surface imitating the surface of rough stone according to the architectural design.

Figure 18: Bridge parapets

Reinforced concrete ledges were then installed on the spread footings that were cast in shorter sections to avoid occurrence of shrinkage cracks.

A waterproofing system comprising of double asphalt melted strips placed on the reinforced concrete spread footing followed by a protective

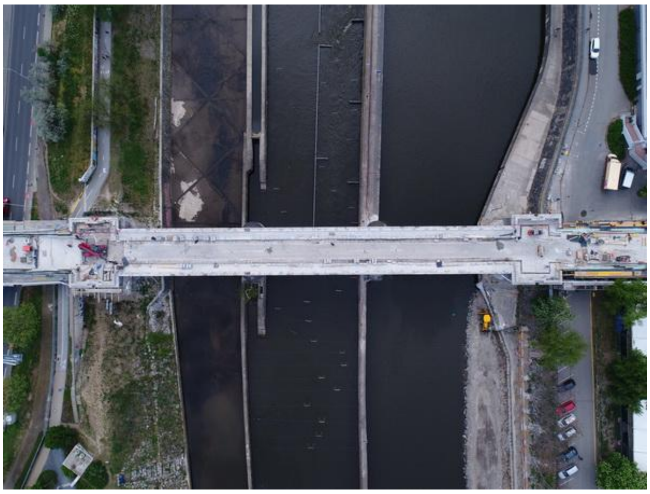


Figure 19: Aerial View of Bridge 14-12 during deck concreting

layer of mastic asphalt and anti-vibration mats of natural rubber.

In October 2019, spreading of the ballast to lay the tracks in the Bubny – Hrabovka section commenced.

A new steel railing was progressively installed on the ledges. The visual appearance of the railing corresponds to the original one from 1936 and is one of the unifying architectural elements.

The railing pattern was designed and approved specifically for the reconstruction of the Negrelli Viaduct.

Originally, many types of steel and stone railings were installed on the bridge corresponding to the time when the new bridge ledges were constructed.

BEAM BRIDGES

SO 14-01, beam bridge over Pernerova Street

The existing superstructure of the bridge over Pernerova Street was temporarily raised by 2.5m on a steel structure supported at the sides of the abutments by framed steel props.

The steel members were cleaned and the protective coating was renewed. The existing bearing blocks were demolished, the bearings were dismantled and refurbished and the abutments were reinforced using micro piles drilled from the top of the abutments.

Once the works were completed, the superstructure was lowered back on the modified substructure.

Figure 20: Assembly of formwork for new concrete arch

The weight of the lifted structure was approximately 220t.

Under the new track configuration, the superstructure was moved transversely and longitudinally by several centimetres and lowered onto new bearings placed on newly concreted bearing blocks.

All activities were performed while maintaining car traffic under the bridge.

SO 14-03, bridge over Prvního Pluku Street

The existing superstructures of the bridge over Prvního Pluku Street – separate superstructures for each track weighing over 170t – were dismantled in February 2018.

The original stone and partly concrete bearing blocks of the bridge abutments were demolished subsequently.

Grids of micropiles were subsequently installed (these were drilled through the existing shaft of the abutment into the subsoil under the footing). New bearing blocks for the new bridge structure were then concreted on the pile grids.

The new steel superstructure was installed in May 2019. Unlike the original bridge, the new superstructure is single-track only.

Figure 21: Application of antivibration mats before laying ballast - Hrabovka

The new bridge superstructure consists of two trusses with parabolic upper chords and a deck supporting a ballast bed.

The deck was designed as an orthotropic deck with transverse stiffeners. The weight of the steel used is 169t and the structure span is 34.8m. The whole structure contains 388 welds with a total length of more than 256m.

SO 14-05, bridge over the former coal line

The original superstructure of the bridge over the former coal line of concreted beams was demolished and it replaced by a new superstructure of composite steel beams, with bearing blocks anchored into the existing substructure.

In 2019, the new deck with the ledges was concreted, the transition area was filled with gap-graded concrete and ballast and then the protective insulation layers of asphalt mastic were applied.

The anti-vibration mats and safety rails were installed in 2020.

SO 14-07, bridge over Křižíkova Street

The bridge over Křižíkova Street (SO 14-07) was the first railway bridge in the Czech Republic where prestressed concrete was used.

The original three arches of the Negrelli Viaduct were replaced with a bridge of prestressed concrete with a span of 29.73m because of the ever-increasing car traffic and insufficient capacity of the viaduct at this location.

These were two double-track bridges carrying tracks running in opposite arches towards Masarykovo nádraží and Libeň.

The demolished bridges had been in operation for 63 years.

The demolition of the bridge superstructures was followed by demolition of the bridge abutments and rehabilitation works.

Figure 22: Post-tensioned concrete girder from 1955

Figure 23: Cutting girders during demolition of Bridge 14-07

Figure 24: Removal of original bridge girders – Křižíkova Street

Figure 25: Removed bridge – Křižíkova Street

In mid-2019, seven steel beams weighing 15.3 – 21.4t were installed that form the future superstructure, which was designed as a composite steel deck.

Before the girders were installed, the subsoil of the designed abutments was massively reinforced with combined elements of deep foundation jet grouted columns and reinforced steel pipe micro piles fixed in new reinforced concrete foundation strips.

The architectural design had envisaged that the concrete abutments would be covered with machine-cut sandstone identical to the sandstone used at the other parts of the bridge.

SO 14-15, bridge over Bubenské nábřeží Street

The works in the area of Bubenské nábřeží Street started in 2019. It is a double-track bridge of two spans with a superstructure consisting of precast prestressed KT beams.

The work was preceded by a survey based on which the scope of rehabilitation work was determined.

The rehabilitation included reprofiling of concrete elements, restoration of waterproofing layer, restoration of protective coating on the railings and bearings, restoration of bridge drainage system and modification of the transition area towards Bubny, while maintaining the substructure and superstructure of KT beams.

CONCLUSION

The viaduct's location was frequently criticised by the end of the 19th century, when this railway project became an obstacle to the road traffic as the city progressed.

It was also considered an unwelcome encroachment on the city area. It was said that the entire route should had been located much further east.

However, at the time of the construction, the cheap rural land was the most suitable one for the railway line, which had an impact on the viaduct's existing route.

The designer was not originally recognised as well. This is apparent from the bridge name, which for a hundred years was generally referred to as the "Viaduct of the State Railway Company", and later as the "Railway Viaduct from Karlín to Holešovice".

The constructor's name does not appear in the name until the 1950s.

Even today, Prague citizens perceive the structure hideous and disagreeable, complicating the road traffic flow despite all reconstruction and provision of additional clearance.

Few people are aware not only of the bridge structure's age, but also of its true beauty.

Last but not least, the reconstruction should preserve this important cultural monument of transport infrastructure.

Video 1: Installation of bridge beams for a bridge over Křižíkova Street

Click on the image to watch the video

Video 2: Aerial View of the reconstruction in April 2019

Click on the image to watch the video

References:

http://www.rekonstrukce-negrelliho-viaduktu.cz/ (Czech only)

http://www.hochtief.cz/en/our-projects/reference-projects/transport-and-pipeline/prague-reconstruction-of-negrelli-s-viaduct

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BIM APPLICATION FOR EXPERT DESIGN TASKS USING *ALLPLAN BRIDGE*

Dipl. Ing. Johann Stampler and Dipl. Ing. Gregor Strekelj, ALLPLAN Infrastructure

INTRODUCTION

Traditionally, BIM technology aims at providing a digital twin of structures mainly for data management and visualization purposes.

However, limiting the BIM scope to architectural tasks is a severe limitation of the methodology because many different participants are involved in the planning and construction process, having a range of quite differing requirements.

In bridge design and construction we are often faced with the fact that, apart from geometrical design, coordination work and construction management, many sophisticated tasks are required which are performed by experts in different specialist areas.

Structural analyses require, for instance, experienced bridge engineers and often additional help from experts addressing special problems like geotechnical and foundation issues, prestressing, or earthquake engineering.

Therefore, the vision of the BIM process becoming a fully integrated planning procedure, including detailed structural analyses and assessment, and being accessible to all different parties collaborating in a project, has exceptional significance.

In this context, the BIM tool Allplan Bridge claims to extend the applicability of the BIM methodology and provides in addition structural analysis and strength assessment functionality.

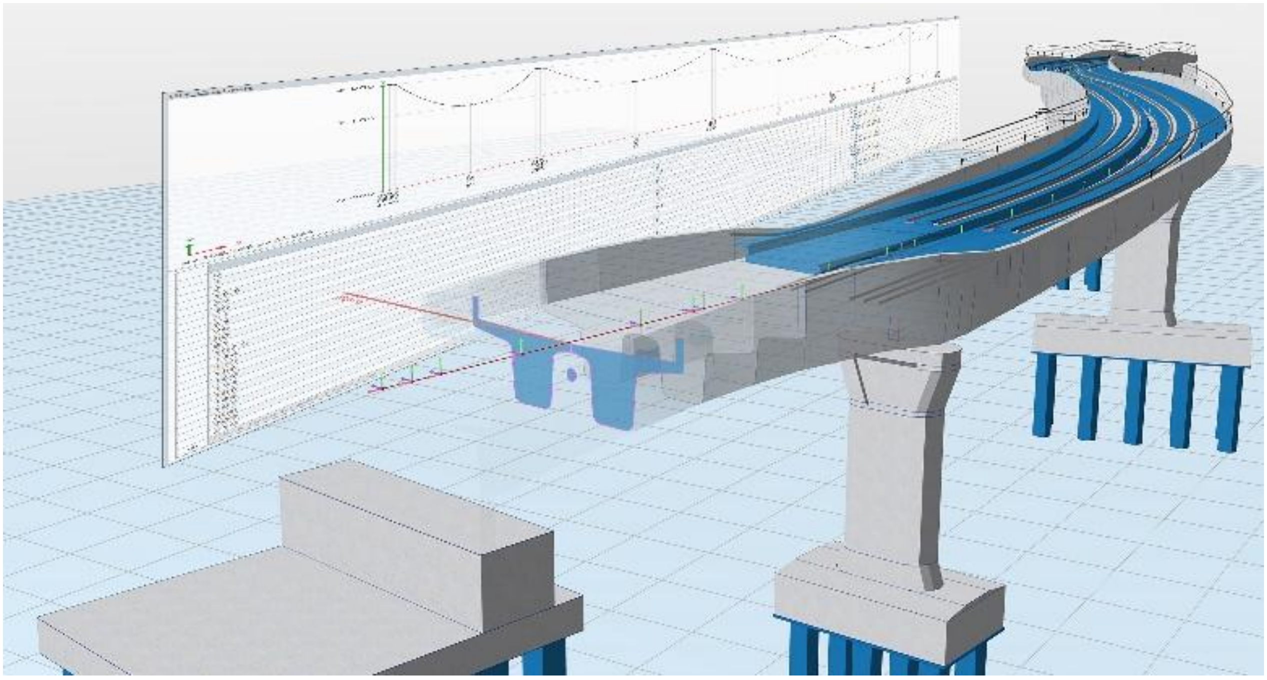

Figure 1: Parametric model description

PREREQUISITES FOR ADVANCED APPLICATIONS

An essential prerequisite for the step to integrate structural analysis functionality is that the architectural BIM model has an intelligent data structure allowing automatic derivation of a suitable structural analysis model from the geometric model.

This is done by including relevant analysis parameters in the dataset.

A key-point in this context is a parametric model description, which allows for easy modifications by changing few relevant parameters.

Typically, these parameters are hierarchically structured, i.e. subordinate values are automatically adjusted when superordinate values have been modified.

STRUCTURAL ANALYSIS

Analytical Model

The detailed geometry data of arbitrary 3D bodies is not suitable for structural analyses and simplifications must be made to allow strength analyses in accordance with accepted design rules.

This task is typically performed by structural engineers, considering the statically relevant relationships, and the required accuracy of the analysis results, i.e. planning work is mostly done on two separate tracks - architectural designs and geometric modelling in the sense of a BIM procedure on the one hand - and, separately, the creation of the structural analysis model by the specialized bridge engineer.

A considerable improvement can be achieved by avoiding this double modelling work and allowing for automatic creation of a relevant structural computation model from the parametrically described architectural model.

This functionality is provided in Allplan Bridge, but the user always keeps control over the created model and may make adjustments to the used numerical model from the fully automatically created proposal.

The architectural and structural models are completely interlinked within the BIM software, i.e. any modification in the geometry is immediately considered in the structural model.

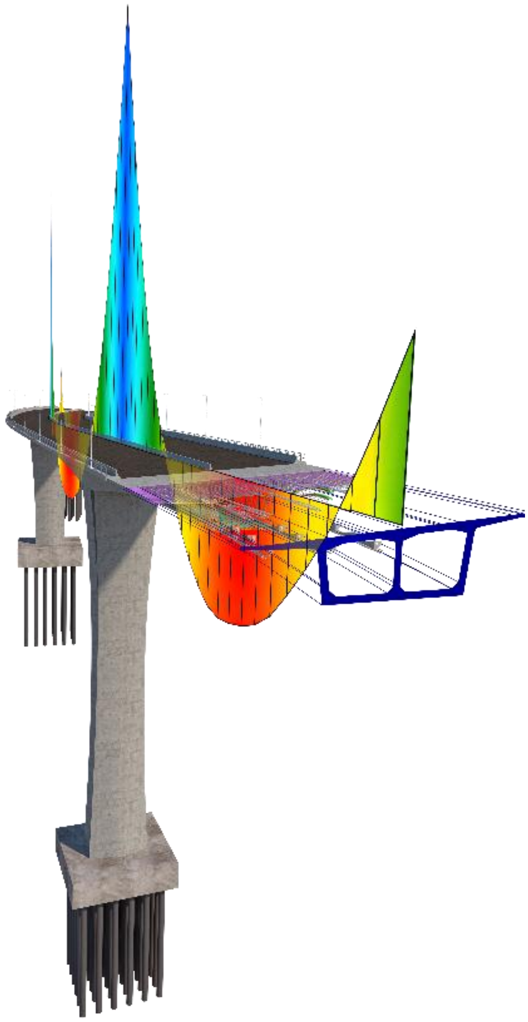

Figure 2: The analytical is derived from the geometrical model

Simulation of the Construction Process

In bridge engineering, not only the final structure but also the construction process governs the load bearing behaviour.

Therefore, the description of the construction process in the BIM model is automatically transferred into the analysis model as a timeline for performing the necessary static calculations in an automated process.

By simulating the construction process, stresses due to stage by stage erection are taken into account as well as time-dependent behavior due to creep and shrinkage.

For prestressed concrete bridges, expert tasks like designing the tendon geometry and tensioning schedule to minimize prestressing losses are also included.

Loading Conditions and Combinations

Apart from loadings like self-weight, prestressing or creep and shrinkage, which are automatically considered in the construction simulation analysis, we have to take into account different effects arising during the service life, which often require special expert knowledge.

Traffic loads and earthquake impacts are representative here. Intelligent functionality directly supporting these analysis tasks in the BIM process is of high importance.

Traffic loading is essential for nearly all bridges and detecting the worst case in accordance with national design rules is a sophisticated task.

The respective functionality in Allplan Bridge is based on the evaluation of lane-related influence lines.

Notional lanes along the bridge surface are defined in the bridge model in addition to the actual geometry data of the structure.

For getting the worst influence of traffic loading on a certain lane, load patterns (called load trains) as required by the design code are automatically placed along the lane in the relevant position.

The extreme values resulting from different load trains and on different lanes of a lane set are superimposed.

Combining the results of different possible lane sets gives the final traffic load envelope containing the relevant extreme values.

Special expert knowledge is also required for bridges in regions where major earthquakes can occur.

A dynamic analysis is usually performed considering the effects of such events. In this context the modal analysis method has turned out to be the appropriate method for determining the relevant structural response and this method has therefore been included in the software.

First step in the calculation process is the determination of the relevant natural modes dependent on the structural stiffness and active masses.

The contribution to excitation by the individual modes is governed by the frequency content of the earthquake and determined from the response spectra specified in the design codes.

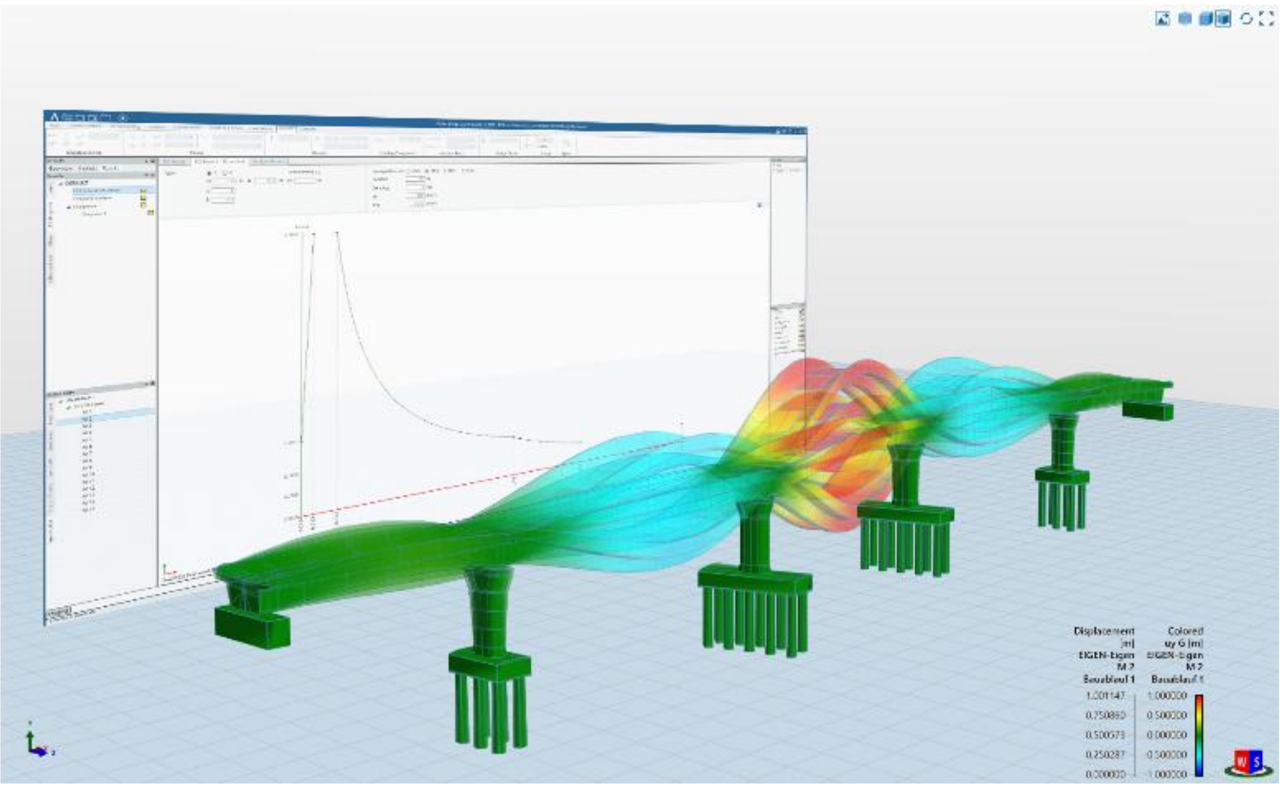

Figure 3: Earthquake analysis is based on the multi-mode Response Spectrum Method

STRUCTURAL DESIGN AND ASSESSMENT

Once the structural analysis has been performed and critical result values (displacements, internal forces) have been calculated, checks in accordance with the relevant design code must be made for the serviceability limit state (SLS) as well as for the ultimate limit state (ULS).

Prestressed concrete bridges are characterised by many erection and service stages in which the structure must be analysed and checked. The construction history and the effects of creep and shrinkage cause stress redistribution both on cross-sectional, and structural levels.

The stress state immediately after completion of the construction is called the initial stress state for the determination of the ultimate resistance in flexure, fatigue checks and serviceability checks.

The calculation of the flexural resistance requires numerical methods for the integration of the stress function over the part of the sectional area, and a non-linear analysis of the equilibrium equations of the cross-section. It means that the method is rather complex.

On the other hand, the work involved is compensated by the exactness and completeness of the solution.

For shear resistance of concrete members, the Eurocode requirement is based on a variable-angle truss model.

Certain adaptations or interpretations of Eurocode provisions are needed for prestressed concrete design with respect to (i) the relationship between the shear strength and flexural lever arm, and to (ii) the calculation of tensile force in the longitudinal reinforcement due to shear.

For the case of SLS checks (stress limitation, crack width, decompression condition, deflection control), consideration of the initial stress state is more important than the ULS, because the initial stress state influences the results significantly.

In accordance with Eurocode, the serviceability conditions are often governing the cross-section design. The structure is subjected to the service load for most of its lifespan. Therefore, this check is very important and should not be ignored or replaced by a detailed assessment of the ultimate capacity of the structure.

Finally, it should be once more pointed out, that including intelligent functionality for tasks like structural analysis checks, as required in the design codes, can essentially improve the planning process and the effectiveness of the BIM method.

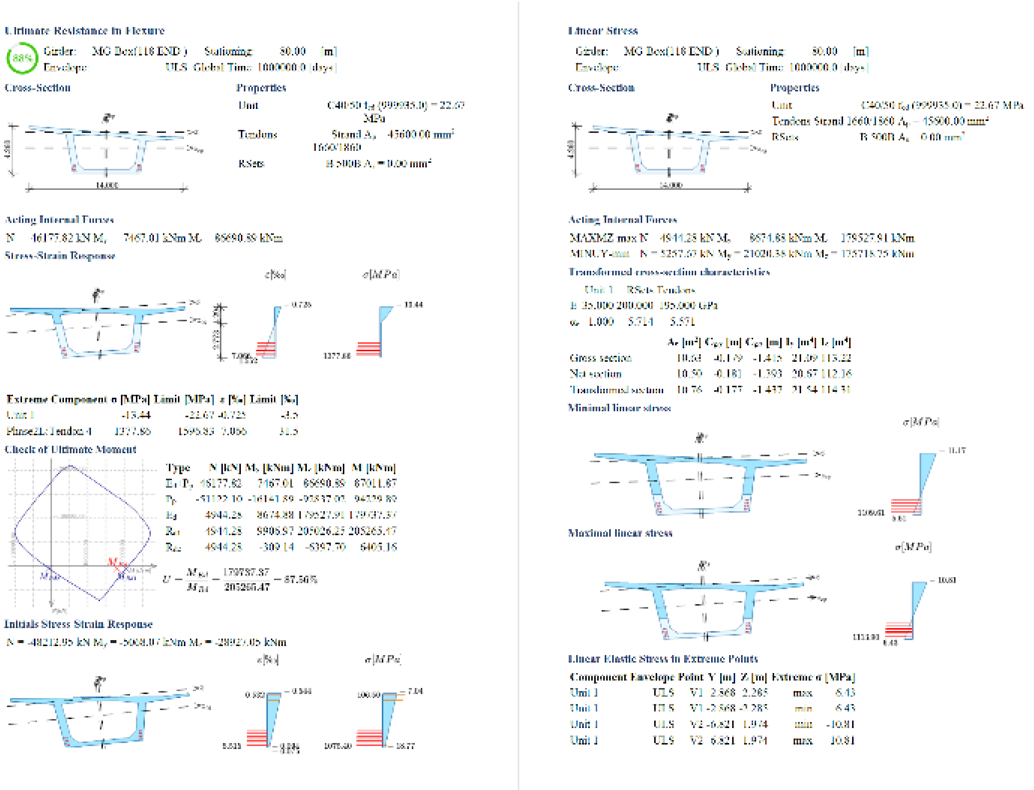

Figure 4: Detailed output of reinforcement design and code checking

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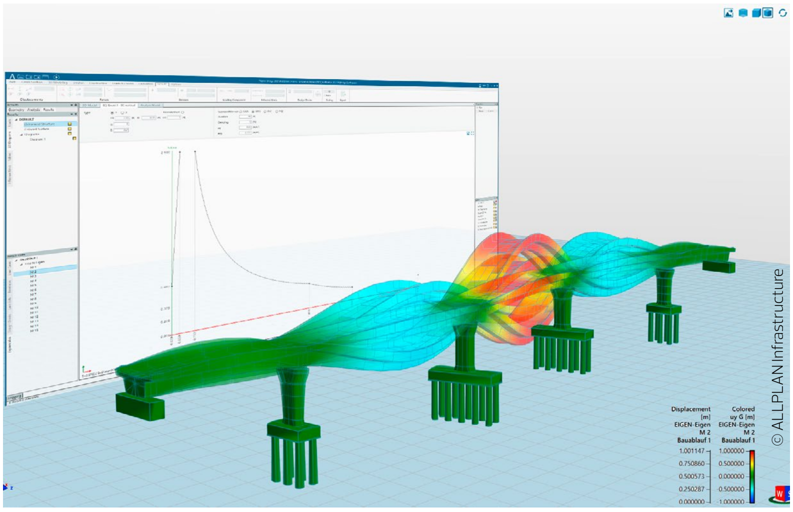
ALLPLAN BRIDGE 2021
MAPS COMPLETE BIM PROCESS FOR BRIDGE PROJECTS

Allplan Bridge 2021 enables bridge engineers to work with one single solution from the creation of a parametric 4D model to structural analysis, reinforcement design and detailing. In addition to improved modeling functionality and the consideration of earthquake effects, code-based design according to Eurocode is now available as a link between structural analysis, design and detailing. Allplan Bridge 2021 thus maps the complete BIM process in bridge projects – an innovation in the industry. This further improves the design process in terms of both time and quality.

With Allplan Bridge, a completely new platform has been created that is designed for the simplest possible operation and efficient workflows. By using a common bridge model for structural analysis and design instead of two separate ones, interdisciplinary cooperation is improved. The parametric model and the extensive automation of work steps drastically reduces the time required for processing, especially for design changes that were previously extremely time-consuming and error prone. Allplan Bridge is a new generation BIM solution that will change the way bridge projects are designed and executed.



NEW IN ALLPLAN BRIDGE 2021

Improved modeling

Allplan Bridge 2021 makes modeling even more precise and timesaving. For example, it is possible to interactively move stations and display the cross-section at any point along the structure. Furthermore, using a longitudinal eccentricity for the tendon point definition minimizes the necessary definition of stations.

Earthquake Load

Allplan Bridge 2021 uses the multi-mode Response Spectrum Method for evaluating the effects of seismic loading. The solution consists of two separate tasks in the calculation procedure, firstly the determination of the relevant natural modes of the structural system and secondly the evaluation of the response spectrum prescribed in the design code.

Code-Based Design

Once the global effects are calculated and the relevant envelopes have been created the user can perform code dependent design tasks to determine the required reinforcement content. After the reinforcement area has been calculated or manually specified, ULS and SLS checks can be performed according to EN code, and ULS flexural capacity checks also according to AASHTO LRFD.

Creep, Shrinkage and Relaxation for international markets

Particularly important for the construction stage analysis of prestressed and reinforced concrete structures is the correct consideration of the time-dependent effects. In Allplan Bridge the calculation of creep and shrinkage of concrete and relaxation of prestressing steel is code-compliant and now also available for Chinese and Korean Standard.

For more information, please visit:
allplan.com/bridge

ALLPLAN Infrastructure GmbH > Andreas-Hofer-Platz 17 > 8010 Graz > Austria > office@allplan-infra.com > allplan-infra.com

HOPE RISES WITH TWO NEW PEDESTRIAN BRIDGES IN FLOOD DEVASTATED WESTERN KENYA

Drew Deeter and Bobby Reese, MSCE, P.E

All Photos by Jeff Hennessey

Figure 1: Recently opened Tamkal Bridge

In 2019 and early 2020, flooding and mudslides devasted the African region with heavy death toll and infrastructure wiped out, cutting off access to life sustaining resources for more than 1 million people.

The seasonal rains in Western Kenya came early and with great ferocity in late 2019 and continued through May 2020.

Conservative estimates suggest that more than 400 people died and over 1 million were negatively impacted during this timeframe.

Bridging the Gap Africa (BtGA), a not-for-profit organization that had built more than 60 pedestrian bridges in Kenya over the past 20 plus years reported that nearly all of its bridges had been washed away or severely damaged due to the relentless waters.

These were bridges built for communities to provide safe passage across dangerous rivers where many people had been washed away or attacked by crocodiles and hippopotami.

BtGA founder Harmon Parker, who recently celebrated his 10-year anniversary of being nominated for the top 10 CNN Heroes Award in 2010 for his Kenyan Bridge Building efforts, used the tragic flooding as added motivation to fulfill the passionate organization's mission.

"We are here, on the ground," notes Parker. "We are well positioned to help rebuild and reconnect communities to the outside world – to schools, clinics, and even the food market."

And rebuild BtGA did. In 2020, with hands on collaboration from the communities they serve and the generous donations of supporters around the world, the organization has rebuilt two of the flood ravaged bridges, repaired several other damaged bridges, and is assessing and planning for additional bridge schemes moving forward.

The two new bridges are located in the communities of Tamkal and Sisit in a remote region of western Kenya. Both areas were devastated by the unprecedented flooding and loss of lives.

Figure 2: Temporary Bridge Constructed by the Community at Tamkal after the Flooding

All of the twelve existing foot bridges in this area were destroyed by the flooding, cutting of safe access to markets, education and healthcare.

Several more lives were lost in the following months, as individuals were forced to cross swollen rivers without the safety of the bridge crossings.

Once the waters subsided, BtGA's engineers Bobby Reese and Peris Kahindi along with others from the team wasted little time to travel to these isolated communities to assess the situation and help.

TAMKAL BRIDGE

BtGA's engineering team determined a 40 meter (131 feet) span suspension bridge was needed in Tamkal.

WSP Canada through the MMM Group donated engineering hours to BtGA and developed a short span suspension bridge design in 2013 that met the following criteria:

1) The various components had to have technically simple designs that can be easily fabricated by local metal workers.
2) The larger bridge components had to allow for easy transportation to remote bridge locations, and allow for easy field assembly.
3) Was in full compliance with the Canadian Highway Bridge Design Code.

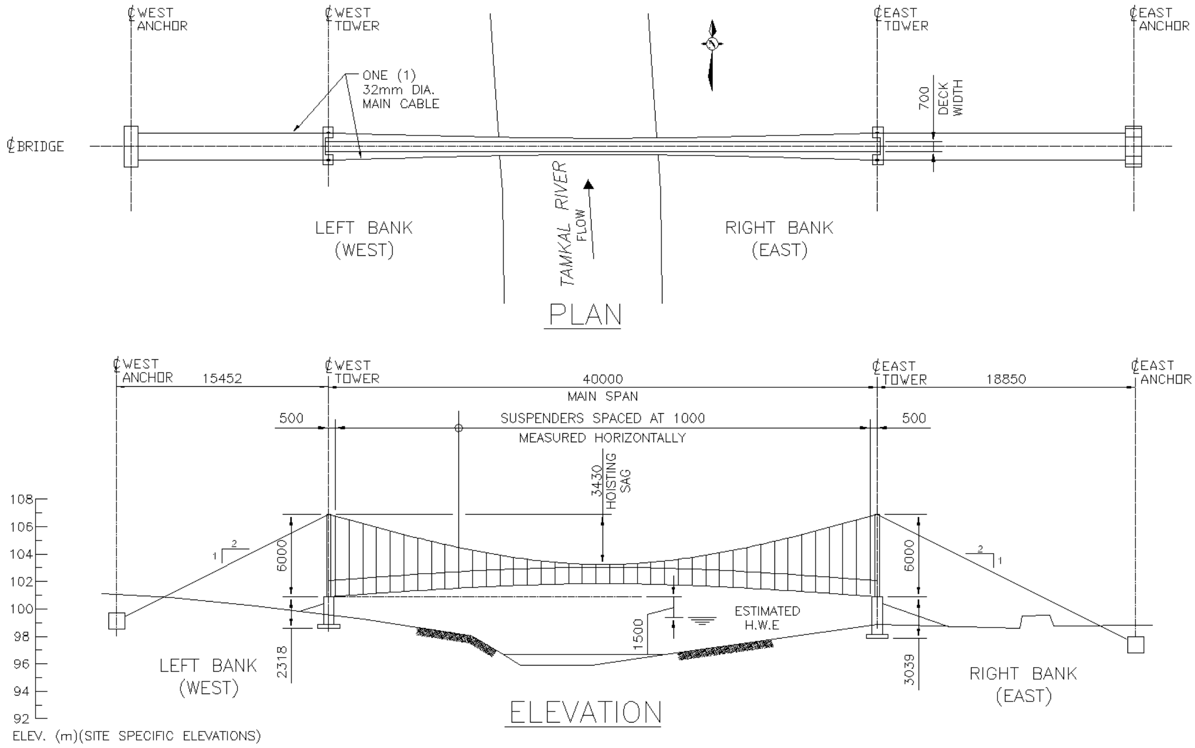


Figure 3: Plan and Elevation of the 40m Suspension Bridge at Tamkal

The Tamkal Bridge would be the seventh suspension bridge built by BtGA that utilized this design.

For fabrication of bridge components, BtGA relies on Patrick Macharia, a local Kenyan metal worker who has fabricated components for all six previous suspension bridges as well as countless "suspended" bridges.

He mostly works outside of his small workshop, laying components to be cut, welded, and painted on the bare ground. BtGA's goal is to build bridges that do not rely on the commercial steel fabricators located in Nairobi, the capital of Kenya, yet instead can be easily replicated by workers such as Macharia in Kenya's large informal sector.

Such workers can be found in almost any town throughout Kenya, however the limitations in manufacturing capabilities of these outside workers necessitates the importance that the short span suspension design does not rely on overly technical cutting or welding techniques.

In the final design, load paths are not reliant on weld strength at connections, and all cuts are made at right angles to allow for each to be hand cut by hacksaws or grinders.

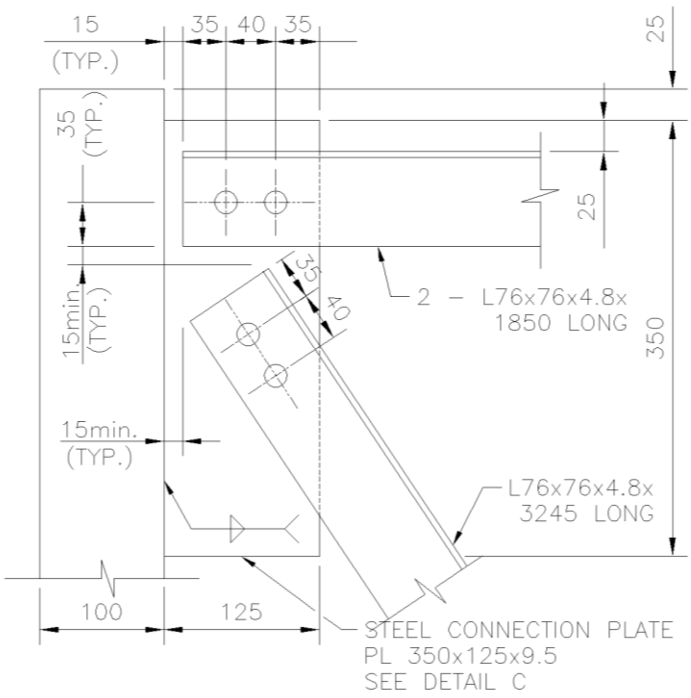


Figure 5: Connection Detail of RHS Columns and the Angle Bracing for the Tamkal Suspension Bridge

Figure 4: Preparing the Reinforcing and Formwork for the Tower Concrete Pour at Tamkal

Specific to Tamkal, all components were required to be small enough to be transported to the remote location.

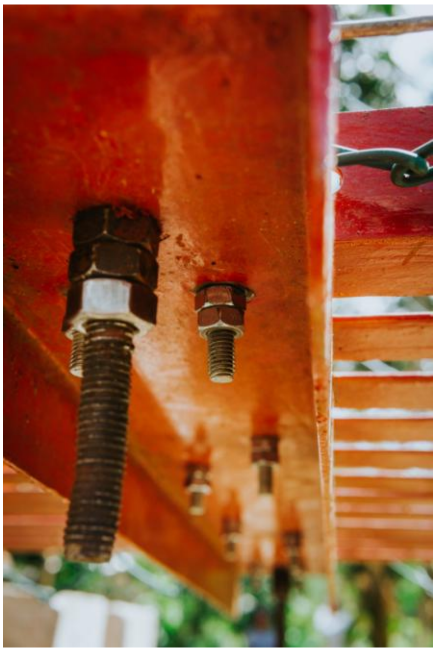
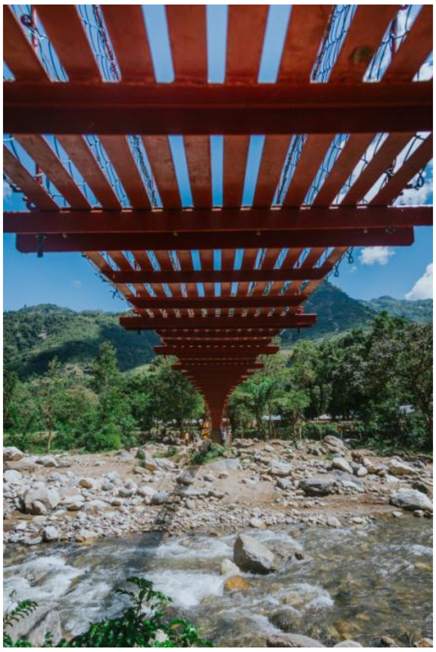
BtGA's work in isolated communities often means that adequate roads often do not reach bridge sites, and often bridge components must be carried and placed by hand.

Sometimes the components have to be carried across the river itself as there is only initial access to one side of the river for delivery.

Field welds are avoided except on non-structural components of the bridge.

The tower design relies on bolted connections of the RHS columns and the angle bracing, allowing each piece to be transported separately and then easily assembled on site.




Figures 6 – 12: Structural Details of the Complete Tamkal Bridge and its Opening Ceremony

SISIT BRIDGE

Due to the topography of the Sisit site, a “suspended” design was selected by BtGA engineers.

The steep river banks allowed sufficient freeboard to be achieved over the previous high water elevation by building up short steel towers on each river bank.

The span length at this site was determined to be 53 meters (174 feet), over 10 meters (33 feet) longer than the previous bridge as flood waters had increased the bankfull width significantly at this site cutting away large sections of the riverbank.

Again the same criteria of design came into play at Sisit. However, with the shorter towers, the tower bracing could be welded to the RHS towers and still be light enough to be hand carried and placed on site.

CONSTRUCTION OF THE BRIDGES

Construction began in September 2020 with excavation of tower and anchor foundations. As is the model with all BtGA bridge schemes, the organization relied on the help of the communities that will eventually benefit from the bridges.

For both the Sisit and Tamkal bridges, teams of bridge crew members from the two communities were hired for the construction of the bridges.

In keeping with BtGA’s desire that bridge design and construction can easily be replicated in any community, excavations and concrete placement were all done by hand.

Large boulders found during excavation that were too large to remove manually, had to be heated by building a large fire in the excavated pit and left to burn overnight.

In the morning water was poured on the heated rock causing it to crack into smaller pieces that could be removed.

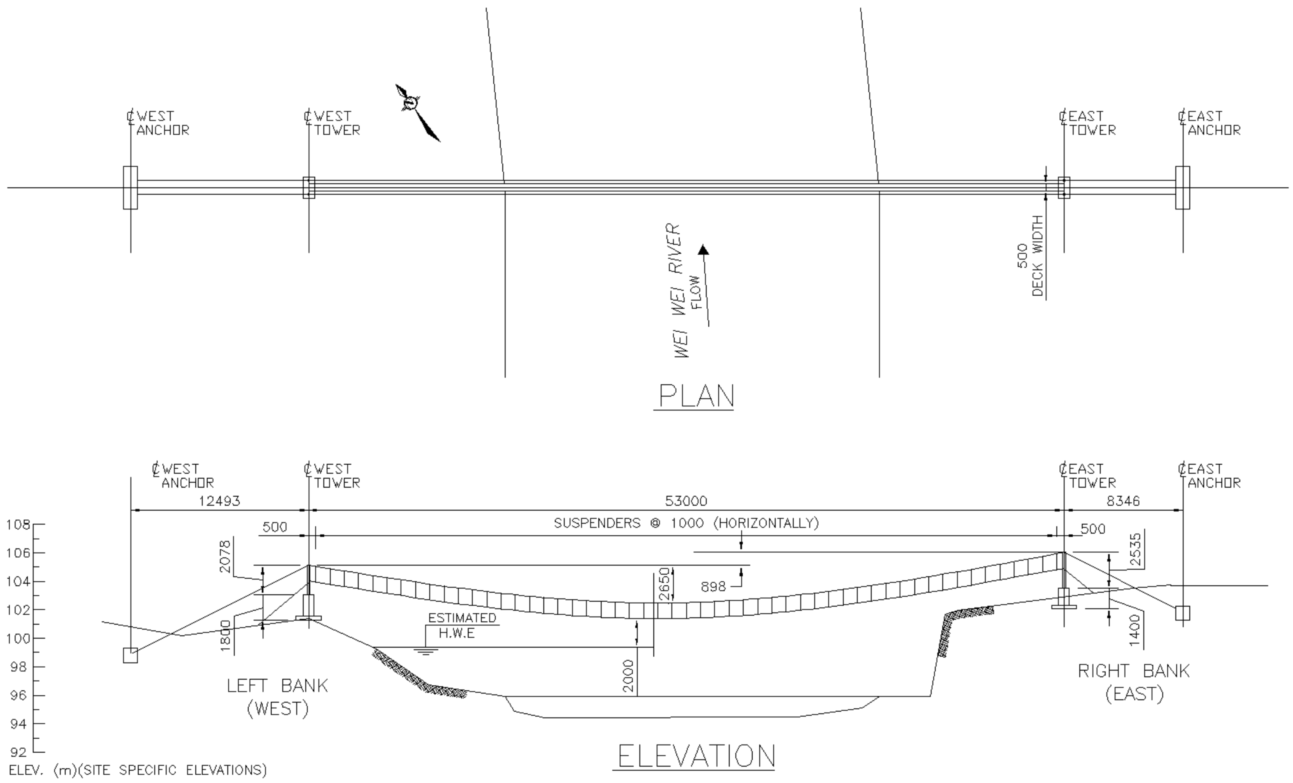


Figure 13: Plan and Elevation of the 53m Suspended Bridge at Sisit

Figure 14: Complete Sisit Bridge

Concrete was also poured manually. Bucket by bucket, over 28 cubic meters of concrete was poured between the two bridges.

Once the concrete work was completed and cured, the RHS towers were placed in their hinges and the tower bracings assembled, steel cables were placed onto the tower saddles and the towers were raised to stand vertically using a tirfor winch.

The sag was then set in each cable, again using the tirfor winch to raise the cables above the hoisting sag and then slowly "dropped" back down to the determined sag by letting the cable carefully slip by gravity through loosened wire rope grips.

Then the work of placing the deck components began. On the Tamkal Suspension Bridge, deck suspenders were placed and held in place with wire rope grips along the length of the cables.

The metal decking panels were then placed one by one spanning between each set of suspenders and their cross beams.

On the suspended bridge at Sisit, the deck was "launched" from one side and slowly pushed across the bridge span as deck panels and suspenders were added one by one.

IMPACT OF A BRIDGE

BtGA was able to see first-hand the impact of having a safe river crossing in these remote communities.

Within hours of completing the approach stairs at the Sisit Bridge, members of the community were lining up waiting to use the bridge.

Many were carrying produce; many were elderly, and of course many children were excited to just walk across the new bridge.

Before the bridge was completed the only option was to wade through the chest deep, flowing river. For many that was too risky and often impossible when there was rain higher up in the mountains.

"We see beauty in bridges," states BtGA's Country Manager Bobby Reese. "Beauty in not just the structure itself, but also in what that structure represents and can do for a community.

Bridges provide access – to education, medical care, and commerce – to connect people. It's inspiring to work alongside the people who are going to benefit from a new bridge. You can breathe their excitement and it motivates you to want to do more."

Without question, 2020 has been a challenging year, for some more than others, yet BtGA offers the communities they serve and the world at large a glimpse of hope and an opportunity to celebrate.

A celebration for the vibrant communities of Tamkal, Sisit, and others that now have access to safe river crossings.

Bridging the Gap plans to continue building foot bridges in nearby communities replacing more of the foot bridges that were lost last year.

To learn more about Bridging the Gap Africa and how to help the people impacted by the flooding in Kenya, visit bridgingthegapafrica.org.

BRIDGING THE GAP AFRICA
BUILDING BRIDGES & TRANSFORMING LIVES

← Figure 15: Carrying Produce across the New Sisit Bridge

Figure 16: People using the Tamkal Bridge

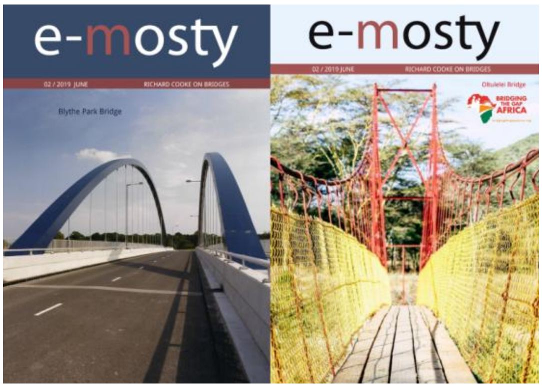
Figures 17 - 22: Structural Details of the complete Sisit Bridge and local people using it

You can watch short videos:
(Click on the image to play the video)

TAMKAL BRIDGE

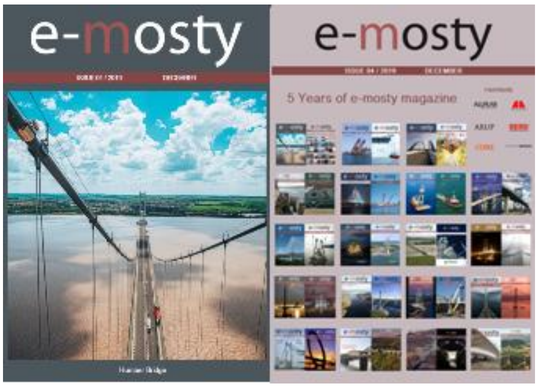
SISIT BRIDGE

You can read about BtGA in e-mosty:



A COMMUNITY APPROACH TO ENABLING SUSTAINABLE FOOTBRIDGES

Matthew Bowser, P.Eng., Débora Bowser, M.Sc.



HEAVY RAINS DEVASTATE WESTERN KENYA

Drew Deeter, DeeterUSA

Storda Bridge

AAS-JAKOBSEN

Triangle link - Storda and Bømla Bridges

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Naeem Hussain
naeem.hussain@arup.com
Global

Richard Hornby
richard.hornby@arup.com
UK, Middle East & Africa

Steve Kite
steve.kite@arup.com
East Asia

Deepak Jayaram
deepak.jayaram@arup.com
UK, Middle East, India and Africa

Peter Burnton
peter.burnton@arup.com
Australasia

Marcos Sanchez
marcos.sanchez@arup.com
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*Wyatt Brooks and Kevin Donovan - "Eliminating Uncertainty in Market Access: The Impact of New Bridges in Rural Nicaragua," 2017.

info@bridgestoprosperity.org
/bridgestoprosperity
@bridgestoprosperity
@b2p

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