Markgraaff Pedestrian Bridge: view to stadium

FINALIST – Technical Excellence Category

Markgraaff Pedestrian Bridge

KEY PLAYERS

Client
Mangaung Local Municipality

Main consultants
Vela VKE Consulting Engineers
GAPP Architects

Main contractor
HSH Construction

Main sub-contractor
GEAR Steel

INTRODUCTION

The Markgraaff Pedestrian Bridge in Bloemfontein is visible confirmation that steel can be used to create a unique and innovative structure that is functional and aesthetically pleasing, despite a limited budget. Combining technical expertise and creative thinking, the project team constructed a slender steel bridge of individual character, which displays standard sections, and complements its surrounding environment. Positioned at the gateway to the Bloemfontein CBD, the unbraced steel network arches of the 31 m long main span have become a point of proud reference for the client and the community alike.

The attractive bridge is an important link for pedestrians walking from public transport nodes towards Bloemfontein's stadium and commercial centres. The bridge also completes the Selbourne pedestrian route, which in turn forms part of the rejuvenation of the Bloemfontein CBD. The rejuvenation particularly includes making the CBD more user-friendly for pedestrians.

DESIGN DEVELOPMENT

The final developed length of the structure, including the approach ramps and back-spans, was 152 m. On the eastern side the back-spans are 30 m long and consist of a continuous composite steel and concrete section that is supported by steel Y-shaped piers at 7.5 m intervals. On the western side the back-spans are 22.5 m long and supported at similar intervals.

The main span is 31 m long and is a structural steel-tied arch with a 3.5 m wide concrete deck slab. Situated in the midst of the 152 m long structure it was important to visually connect the arch to the approaches. A solution where the arch appeared to flow out of the approach spans was developed.

Arch bridges are often dramatic structures. When they spring from steep slopes to span a cutting or gorge, an arch bridge makes immediate sense to an observer. The flow of forces into solid ground is visible and direct. When supported on low abutments an arch can be read as a single elegant entity spanning across a gap. However, an arch placed on high piers in the midst of multiple approach spans can appear somewhat stranded. It was therefore important to the design team to visually connect the arch to the back-spans.

Given the poor founding conditions, a tied arch was considered the most economical structural form, and a way of visually expressing the flow of the arch into the back-spans had to be found. Exploring the opportunities around this concept led to the innovative idea of the bifurcation of the arch.

The bifurcation of the arch as it approaches the deck visually softens the transition between the back-spans and the main span. The concept also has structural advantages, as the bifurcating section helps reduce the effective length of the arch. This is important when considering the lateral buckling of the element. An added visual benefit of extending the arch below the deck is that the arch appears shallower in elevation.

The conceptual design also developed the idea of connecting the various sections of the bridge with a single visual thread. A composite structure was chosen on the back-spans, because it allows a 150 mm concrete deck slab to run the total length of the bridge. On the approach spans the slab acts compositely with steel I-beams to achieve the required stiffness. Across the main span the slab spans the short distances between the steel I-beams supported by the arch hangers.

The concrete deck slab therefore becomes the connecting thread that creates visual continuity across the differing sections of the bridge. Following this language, the deck edge section is also expressed in the abutments. This is considered a positive feature of the bridge, as the changing sections of the bridge appear related and in harmony. The bifurcating sections of the arch and back-span columns also follow this theme.


View along deck edge; note inclined arches

DETAILED DESIGN AND TECHNICAL CHALLENGES

With a conventional tied arch, the arches typically lean towards each other and are braced against lateral buckling by transverse elements. In this case the arches lean outwards and are un-braced. The main work of the arch is done via a set of in-plane high-tensile steel hangers. These hangers are not vertical, but run diagonally in a truss arrangement. This is the typical configuration of a network arch and helps to reduce the bending moments in the arch. This fact helped limit the diameter of the arch to 273 mm, which was the maximum size of circular hollow section (CHS) that could be rolled locally.

Out-of-plane stainless steel cables connect the arch to the deck's CHS curving edge member. When stressed, these cables provide the necessary stability to the arch and restrain it from buckling laterally. The variation in materials between the in-plane and out-of-plane hangers visually differentiates the different roles of each hanger.

The detailing of the connection points for the out-of-plane hangers presented a geometric challenge. This was because all the cables intersected the main arch and the curving deck beam at different angles. The simple answer came from the stainless steel connectors used to stay the mast of a yacht. These connectors can pivot transversely, accommodating the small out-of-plane angles. The fabrication of the cleats at deck level was therefore simplified, as no complicated setting out was needed. The cleat plates were just sized to accommodate the bending stresses and fatigue actions that resulted.

The connection of the in-plane hangers to the main arch is achieved using a connection plate that runs parallel to the arch section. This arrangement was preferred for aesthetic reasons. In the end the plate was made continuous to simplify the appearance of the structure.

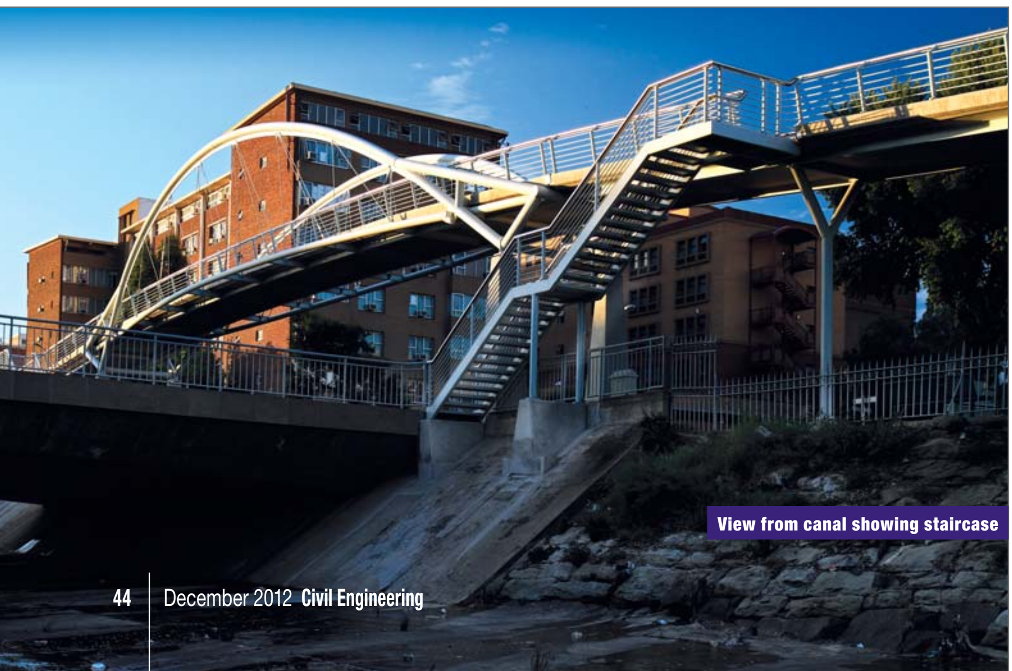
A further technical challenge was the client requirement that pedestrians should be able to access the bridge via staircases on either side of Markgraaff Street. Integrating these staircases onto the limited sidewalk area caused unwanted visual clutter. The dramatic solution where they cantilever over the canal retained the sidewalk functionality and preserved the view of the main elevation of the bridge.

CONNECTIONS AND MATERIALS

In the detailed design, the CHS connections were designed using EN 1993-1-8:2005 Eurocode 3: Design of Steel Structures Part 1-8: Design of Joints. This code provides a comprehensive approach for the design of T and K joints.

Although the use of castings was investigated for the bifurcating section, a fabricated solution was preferred. Castings are not commonly used in South Africa and their procurement presented problems in terms of the project delivery. Robust detailing was seen as a pragmatic alternative. The section was designed with full penetration welds and detailed in such a way that the welders could access both sides of the plate using stick welding.

Stainless steel connectors; note array of stress bars and cables



View from canal showing staircase

The final product shows that, with careful sequencing and detailing, innovative structural connections are possible using welded structural steel.

CONSTRUCTION

To keep the costs down the bridge was built from standard CHS and I-beams. The only exception was the transverse element that connects the arch and the deck ties. Here a 20 mm thick, 275 mm diameter steel pipe was sourced from the mining industry. This inexpensive product resisted the in-plane shear forces without the need of additional stiffening plates. Although there were elements with double curvature, all elements were bent to a single radius that was fitted to the 3D geometry.

The bridge itself was fabricated in a yard 180 km from Bloemfontein and the components transported to site. The arch was constructed in its entirety before being split at its midpoint and transported as an abnormal load. It was then erected onto temporary supports and reconnected. In adopting this approach the dimensional accuracy of the structure was assured and the support points aligned perfectly onto the concrete piers.

As the steel construction of the bridge took place separately from the concrete abutments and piers, quality and accuracy of construction had to be managed very carefully by the engineers. This implied regular surveys and on-site inspections. The non-negotiable 2010 FIFA deadline at the time, combined with the import of critical structural members from Australia, posed a managerial challenge for the engineers.

CONCLUSION

During the 2010 World Cup, the Markgraaff Pedestrian Bridge successfully provided access for thousands of spectators commuting to and from the soccer matches.

Through the use of technology and material from the civil engineering industry, as well as from other industries (shipping and mining), it was possible to adopt a design process where the structural requirements of the bridge were balanced with the aesthetic opportunities. This allowed the project team to create a bridge of individual character that is materially efficient and uses standard sections. The final product, completed within budget (R11 700 000), showcases the versatility of structural steel and the innovative structural connection details that can be developed. □