McElhanney | CANADIAN CONSULTING engineer | ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA / ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS | CANADA

KISMET CONNECTION

World's longest extradosed bridge

Prepared for the Canadian Consulting Engineering Awards 2018

Submitted by McElhanney Consulting Services Ltd.

Category H International

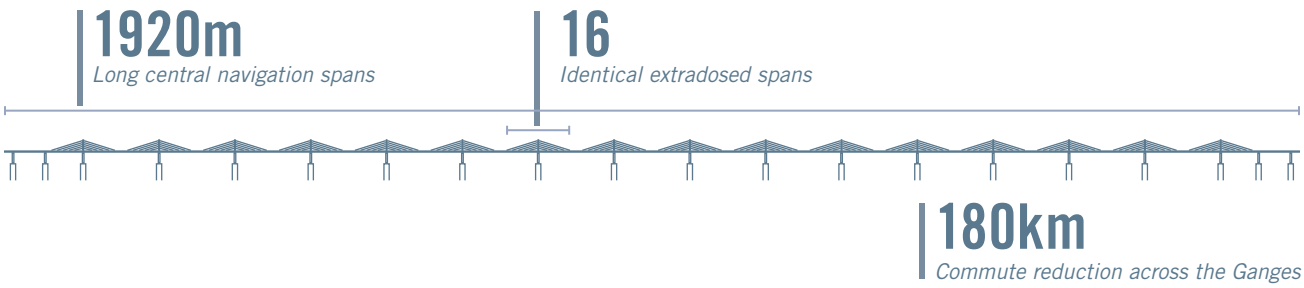
TAB 3

Project Description

VEER KUNWAR SINGH BRIDGE

Q.11 SOCIAL AND/OR ECONOMIC BENEFITS

India's state of Bihar was in desperate need of another crossing along the mighty Ganges River, as only four two-lane road bridges existed along the 400km stretch of water that divides the state, and those bridges were already severely strained, underserving Northern Bihar's isolated communities. Bihar is India's second most populous state, located in the north bordering Nepal. Bihar is also the poorest state, with a GDP per capita of $680US compared to India's overall GDP of $1,860US. The construction of a new four-lane bridge was one of the key commitments Chief Minister Nitish Kumar made to the people in 2010; however, the procurement process stretched on until 2013, when the $160 million US design-build project was finally awarded. After award, the owner directed the contractor to reduce the construction duration by one year while improving the iconic appeal of the bridge. The contractor engaged McElhanney, who quickly responded and delivered a value-engineered, extradosed design for the new Veer Kunwar Singh Bridge that combined precast segmental with cable-stayed technology and achieved the owner's goals as described in *Q.15.*



Since opening on June 11th, 2017, the Veer Kunwar Singh Bridge – the world's longest extra-dosed bridge – has been critical in supporting the region's economic initiatives, as it reduces the commute to cross the Ganges River by 180km. Now, some of the most underpriviledged communities in the north are accessing educational, business, and cultural opportunities in the more developed city of Patna to the south, which used to take five hours to drive to and now takes just one. The new four-lane bridge augments transport capacity across the river within the state by 60%, resulting in drastic improvements to traffic congestion.

McElhanney's Dr. Brook Robazza, who spent several months on-site, was invited by a family living in a nearby slum for a meal one evening. They prepared a simple, yet the most expensive meal they could afford as a thank-you, the father explained, because the new bridge would mean his children could pursue educational opportunities in Patna. The people of Northern Bihar had been deprived access to opportunities for generations and continue to live in poor conditions without basic infrastructure that most of the rest of the world takes for granted. According to the father, this bridge is the "kismet (destiny or fate) connection" that gives him hope that his children can have the opportunities to leave the poor slums to become engineers like Dr. Robazza.

The two children Dr. Robazza met during his dinner with a local family.

A segment of the bridge being lifted during from the ground during the dry season.

The first extradosed span during the balanced cantilevering process.

Q.12 TECHNOLOGY TRANSFER

This was the contractor's first extradosed bridge. It is only the third extradosed highway bridge in India.

SP Singla, from India, relied on significant technology transfer from McElhanney's experts in segmental and cable-stayed systems, development of critical means and methods of erection, and geometry control to ensure the cantilever tips met within tolerance at closure. They gained know-how that can be used on other bridge projects.

McElhanney's Principal Bridge Engineer, David Jeakle, provided expertise in streamlining the casting yard operations and accelerating construction through opening multiple work-fronts. With ample staging areas available at the project site, McElhanney advised the contractor to use a simpler long-line casting method, which was also more cost-effective. Superstructure segments, which varied in weight from 87-95 tonnes, were cast on long-line beds of 120m, one on each side of the river. This simplified camber and geometry control sped up construction by allowing multiple cantilevers to be cast simultaneously. The team considered the common solution of an overhead truss gantry but did not selected it for the segment erection primarily because it did not allow for work on multiple cantilevers simultaneously. Instead, custom-designed small gantries mounted on cantilever tips hoisted the girder segments at several work fronts, again saving time from parallel scheduling of activities.

McElhanney used WhatsApp (an instant messaging phone app) to communicate with crews at each site, providing them with support in real time for cable stressing and geometric corrections to keep pace with the rapid schedule.

The 4.4km bridge opened after four years of construction – one of the fastest completion periods for similar bridges anywhere in the world.

Q.13 ENVIRONMENTAL BENEFITS

Throughout the design and erection stages, the design team and contractor considered environmental impacts, sustainability, and long-term maintenance when proposing solutions. Most of the construction aggregates – approximately 150,000m^3 – were sourced locally from the river flood plains. A total of 1,448 segments for the entire superstructure were constructed in the on-site pre-cast yard, eliminating transportation disruptions and emissions from hauling these massive segments in the constricted network of roads leading up to the site. A sizable portion of the labour force – estimated to be 750 workers in total – came from neighboring villages and towns, invigorating the local economy.

Changing the superstructure to pre-cast from cast-in-place significantly reduced casting operations over the river, meaning that debris entering the river ecology was greatly reduced, and balanced cantilevering eliminated the need for falsework bents in the riverbed. The transition between monsoon and dry seasons creates swampy and low water level stretches of the river, too shallow to allow operation of tug boats. The team used a unique solution of excavator-driven barges to claw into the river bed to pull itself forward, propelling the barge forward, eliminating the need for temporary trestle structures in the river bed.

McElhanney designed the substructures as state-of-the-art, twin, thin-walled bladed piers connected integrally to the superstructure, eliminating bearings at all locations to reduce long-term maintenance costs. The integral design also means that the substructures participate with the superstructure in carrying traffic loads, making the system more structurally efficient and reducing overall material consumption.

The Veer Kunwar Singh Bridge opened June 11, 2017, drastically reducing the commute between the Northern and Southern Bihar, India.

Shaken, not stirred: The partially erected bridge withstood the 2015 Nepal earthquakes.

Q.14 COMPLEXITY & EXTRAORDINARY CONDITIONS OVERCOME

The combination of two structural systems (cable-stayed and girder) makes extradosed bridges relatively complex to analyze due to competing load paths. As the foundations were already being installed based on the original bridge design by another firm, the new superstructure needed to be compatible with the locations and capacity of the pre-built caissons. The design also had to balance the conflicting requirements generated from accommodating thermal movements on a long bridge in an active seismic region. Therefore, McElhanney designed the new substructure as twin, thin-walled bladed piers connected integrally to the superstructure. McElhanney carefully tuned the piers through iterative analysis and design detailing to offer longitudinal flexibility for movements and adequate seismic strength at the same time.

The bridge experienced a real-life seismic load test when earthquake tremors hit nearby Nepal on April 25th and again on May 12th, 2015. At that stage, the structure was in a vulnerable state; the superstructure cantilevers were only 60% complete and not connected at mid-span. Dr. Robazza was in the on-site office during the seismic events,"I ran outside to see wide-scale panic as people were fleeing the buildings. Site vehicles were rolling and bouncing about, and the bridge's pylons were shaking back and forth about one meter in each direction," he recounted.

Despite the vulnerability of the bridge at this stage of construction, McElhanney's close inspections showed that the structure was shaken but not damaged. The pier blades behaved as per the analysis with negligible and repairable cracking.

Q.15 MEETING OWNER'S NEEDS

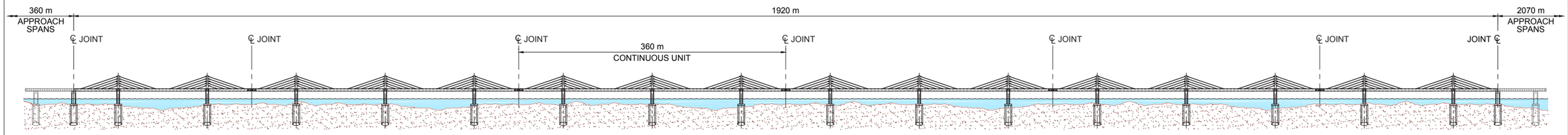
The client's main goal was to reduce the project duration by 12 months to honour time commitments made to the public, while making a stronger aesthetic statement to be symbolic of the government's developmental initiatives at a minimal increase to the as-bid project cost.

The original as-bid concept utilized a cast-in-place, variable-depth, segmental, box girder superstructure in the central 1,920m-long navigation spans, while the flanking approach spans were a constant-depth pre-cast box girder system *(see sketch)*. McElhanney inventively strengthened the constant depth pre-cast box girder of the approach spans with external cables to double the length required for the navigation spans. Through pre-casting the constant-depth segments in the nearby casting yard, the desired time savings were achieved.

For construction efficiency, the team configured the bridge with intentional repetition in component geometry and details. The stay cables were arranged in a parallel "harp" pattern so that the same saddle type and details could be used at all anchorage locations. Pier blades and pylon geometry was kept uniform to facilitate easier forming. The result is a harmonious structure that boasts simplicity – "the ultimate sophistication," as Leonardo da Vinci has said. The team achieved the re-design in a fast-tracked schedule of five months and within budget. The government covered the 10% cost increase as a small price premium for the time savings and enhanced aesthetics. In a reference letter, the SP Singla project manager said: "McElhanney engineers reduced cost surplus to minimum. McElhanney provided our team immense technological support…we cannot imagine completing this project without your assistance."

The Veer Kunwar Singh Bridge is an iconic bridge, uplifting the living standard for some of the world's poorest people.

SKETCH



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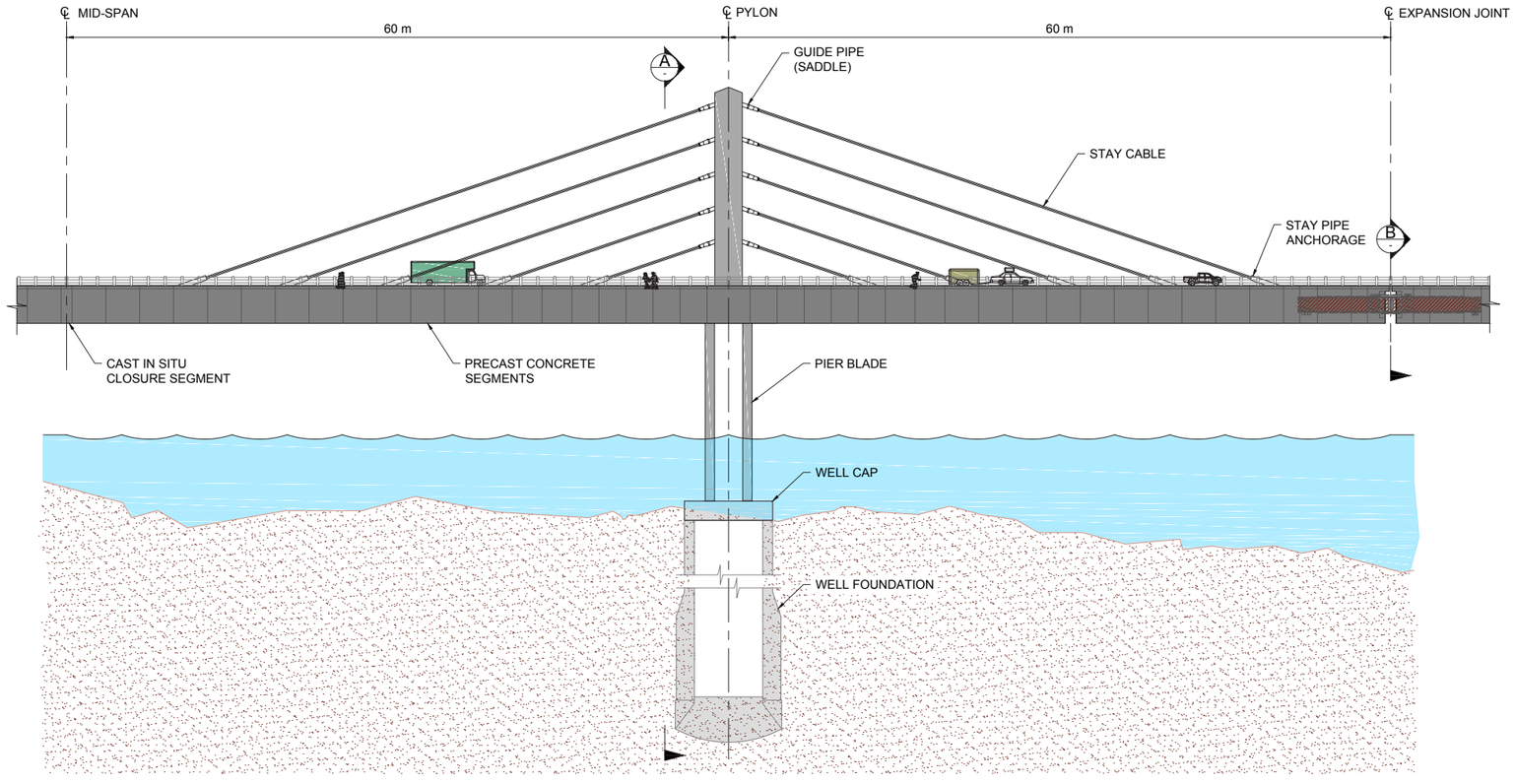

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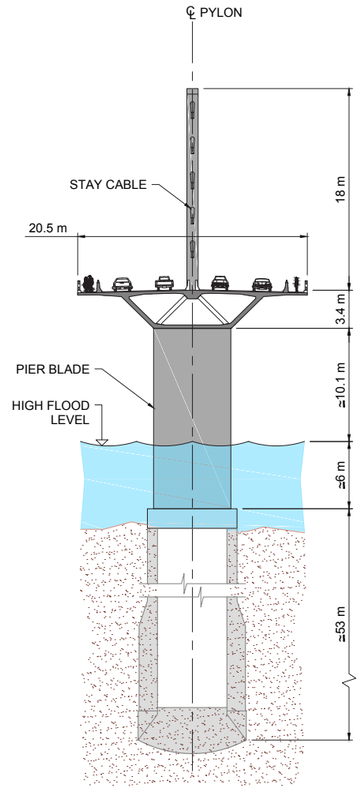

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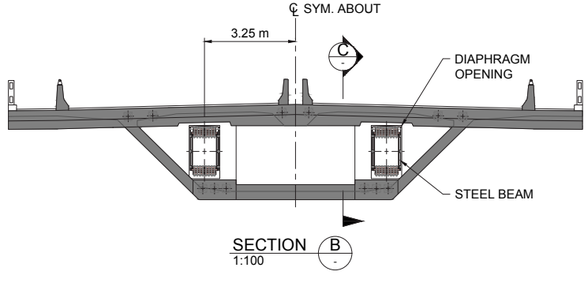

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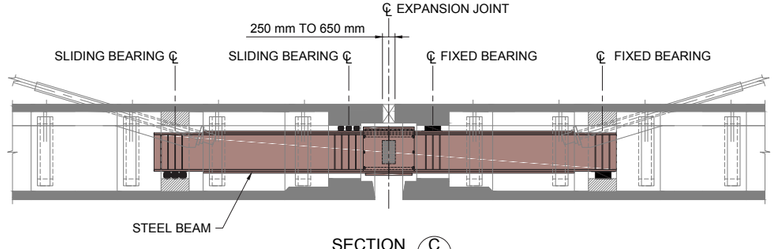

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