Second Sir Leo Hielscher Bridge handles growth boom

Charles Francis Adams said, “No one ever attains very eminent success by simply doing what is required; it is the amount and excellence of what is over and above the required that determines the greatness of ultimate distinction.”

Nothing better describes the all-encompassing effort and degree to which the $2.12 billion (A) Gateway Upgrade Project succeeds as a project of ultimate distinction.

Everyone wants a long, purposeful life. But structures are measured on a different scale, as they should be. Their purpose, value and aesthetic worth are judged along with their longevity. Yet even by these standards, Queensland Motorways’ Gateway Upgrade Project and its featured element—the second Sir Leo Hielscher Bridge—are extraordinary. Designed to last for 300 years and delivered six months ahead of schedule, the Gateway Upgrade Project is a Queensland government initiative and an essential element in the growing success of the state of Queensland.

“Population growth in southeast Queensland has been so dramatic, the impact of the mining boom so profound, that not only is the original bridge at capacity, but the connecting motorways need to be moved to foster a new economic development zone around the airport and port,” explained journalist Sean Parnell in an article in the national newspaper The Australian.

“The $2.12 billion Gateway Upgrade Project is the largest bridge and road development in the state’s history, cutting a 24-km swath through bayside suburbs and adding six lanes of traffic capacity on that north-south route. Perhaps more importantly, more than 6,000 jobs will be sustained during the life of the project, injecting some $450 million in wages and salaries into the local economy.”

The third most populous Australian state, Queensland is the second-largest state in terms of area. With a booming economy dominated by agriculture, tourism and the natural resource industry, the state’s population and economy...
are centered in South East Queensland. Critical to supporting South East Queensland’s rapidly growing population and economic might, the Gateway Upgrade Project will reduce congestion and provide better access to and from the Port of Brisbane, Brisbane Airport and the Eagle Farm Industrial area, and between the Gold and Sunshine coasts, two considerable tourist and commercial regions. It is a key link powering the Queensland economy. But the project’s value is matched by its scope.

In addition to the construction of the second Sir Leo Hielscher Bridge (a six-lane bridge with an added feature, a pedestrian and cycle path) and the refurbishment of the existing bridge, there are 30 new or widened bridges of various configurations and types, 16 km of upgraded motorway constructed under traffic of 100,000 vehicles per day, 7 km of new motorway to the north, eight new or upgraded interchanges (including a new route to the Brisbane Airport) and an urban and landscape design that includes iconic terrain waves at the north and south approaches to both bridges. This is not a small endeavor. But it is not just the project’s size or intrinsic value to the region that impresses.

**Lasting for centuries**

The signature element of the Gateway Upgrade Project is the second Sir Leo Hielscher Bridge, and possibly its most striking feature is its longevity. The new bridge was designed and built for a service life of 300 years. A remarkable achievement in its own right, the 300-year life span concept was far from designer or political vanity. In fact, it was a most practical aim. Designing for a very long service life offers considerable economic and community benefits, maximizing the return on the community’s infrastructure investment.

Standing 64.5 m above the Brisbane River at its highest point—mirroring the existing bridge only 50 m upstream—the new 1,627-m bridge sports a twin box-girder system. The 260-m balanced cantilever main span and the 130-m side spans were cast in situ and at height from the two main river piers. The approach spans were constructed using a segmental match-casting method, where precast concrete segments were lifted into place to form the bridge deck. In total, construction of the bridge took three years—six months less than originally designated. But aside from the typical engineering challenges faced by the project team, the 300-year life span presented its own unique hurdles.

Some believe that designing for such a long life span increases cost considerably. It doesn’t. Designing for a 300-year service life compared to a 100-year service life does not represent an order-of-magnitude increase in material consumption, embodied energy, CO₂ emissions or cost. Given this bridge’s considerable importance to the Queensland transportation network and economy, a long life span—at least 100 years—is a virtual necessity. So, is a 300-year service life a better value?

Yes, it is. In fact, a study exploring the economics of service life for civil infrastructure by J.M. Fenwich and P. Rotolone (“Risk Management to Ensure Long-Term Performance in Civil Infrastructure,” 2003) concluded that the initial cost for a structure designed for a very long service life affords substantial economic and community benefits. Replacing infrastructure in an urban area is very expensive, especially when handling traffic is part of the equation. When all costs are factored in, communities can save a lot of money by replacing infrastructure less often. Also, a structure designed for a very long service life will have lower annual maintenance costs. But in addition to delaying replacement and minimizing maintenance costs, a longer service life also tends to reflect more sustainable structural engineering.

**Enhanced by design**

In the case of the Sir Leo Hielscher Bridge—and particularly given the size and importance of the bridge to the Queensland transportation network—designing for a very long service life provides Queensland Motorways with the best whole-of-life value. But how exactly does one design for a 300-year service life?

The Sir Leo Hielscher Bridge is a prestressed and reinforced concrete bridge exposed to a broad range of environmental conditions. These include a tidal/splash zone (where the main-span piers are located in the Brisbane River, which is essentially seawater); permanently submerged foundations; high chloride and acid sulphate potential soil in places; and exposure to the air. As a result, the durability of the concrete that makes up
the bridge elements is the major factor in achieving a long service life.

To design effectively for these conditions, the project team had to explore outside the current codes, evaluate environmental loading and establish materials performance over a long period. That required extrapolation of current knowledge of climate and material properties as well as the extrapolation of material deterioration models.

The project scope and technical requirements (PSTR) specified that the bridge have a 300-year design life, with some replaceable subitems having design lives ranging from 20 years to 100 years. In addition, several other requirements were mandated by the PSTR to ensure a minimum level of durability. These include a minimum B2 exposure classification, minimum 40 MPa concrete strength, minimum 20% fly ash, electrical connectivity of reinforcement in concrete piles, pile caps and piers for possible future installation of cathodic protection, and mix requirements for concrete in potential acid sulphate soil.

Going beyond the deemed-to-comply approach of the codes, the project team chose a process that took a first-principles and deterministic approach to modeling the environmental influences and material performance. But rather than just adopting mean values of the governing parameters, the team chose to overlay an understanding or assumption of their variation using known or assumed coefficients of variation. Similar to the ACI Life365 deterministic methodology, it did, however, also incorporate the probabilistic components of "DuraCrete," a European research project on the probabilistic performance-based durability design of concrete structures.

Evaluating the exposure environments for aggressivity toward concrete deterioration, the project team included corrosion factors caused by chloride ingress or carbonation, sulphate attack, microbiological attack and degradation resulting from acid sulphate soil exposure. Other forms of deterioration and durability risks were considered as well, such as alkali-aggregate reaction and thermal cracking. But the design team's primary concerns were chloride ingress and carbonation.

In terms of chloride ingress, pile caps in the Brisbane River's tidal/splash zone presented the greatest concern. With a chloride concentration up to 18,000 ppm, the Brisbane River is similar to seawater. Modeling chloride ingress versus depth of cover and factoring in a time-weighted average diffusion coefficient, a concrete mix for pile caps was proposed of a 50 MPa-grade ternary blend consisting of 30% fly ash and 21% blast furnace slag. The total cementitious content was 560 kg/cu meter, and the maximum water/cementitious material ratio was 0.32. In addition to improving chloride and sulphate resistance, the use of fly ash and slag had the added benefits of reducing heat of hydration and greenhouse-gas emissions of the concrete compared with a 100% cement mix.

Another potential risk, particularly for concrete exposed to atmospheric conditions, is carbonation. Of primary concern for superstructure elements, carbonation reduces concrete pH. When concrete pH levels dip below a certain threshold, the concrete's protective passive iron oxide layer loses stability, as well as its protective properties. If concrete becomes carbonated to the depth of reinforcements, corrosion can occur.

Many factors, though, contribute to concrete carbonation, including CO₂, concentration, the concrete's moisture content and diffusivity of hardened cement paste. In turn, diffusivity depends largely on concrete mix design, extent of curing, pore size and distribution within the concrete and connectivity of pores. Also, the presence of cracks permits local ingress of CO₂, and can result in carbonation and subsequent corrosion. Using high-quality concrete and sufficient depth of cover can reduce carbonation.

To address this, the project team chose concrete mix designs of 40 and 50 MPa with 25% fly ash. The maximum water/cementitious material ratios of the S40 and S50 concretes were 0.46 and 0.4, respectively, and the minimum total cementitious contents were 450 and 390 kg/cu meter, respectively. The fly ash was required to provide protection against alkali-aggregate reaction.

For exterior surfaces of superstructure elements, the project team also proposed 55-mm cover to prevent premature carbonation and corrosion. Thicker cover was not practical or beneficial, as the superstructure consists of relatively slender elements. Additional cover would only have resulted in wider crack widths under load and would have reduced durability.

Though the project team also addressed other deterioration mechanisms, a similar philosophy prevailed in every case. Key to that philosophy, though, was a global necessary control applied by the construction team to realize the design durability assumptions. After testing trial mixes and achieving the desired results, focus turned to ensuring the correct thickness of high-quality cover concrete.
Achieving the correct thickness of cover concrete was critically important for several reasons. First, the design had to ensure that the detailing was practical enough to prevent reinforcement corrosion. But the construction also needed to ensure that the requisite cover would be achieved, the concrete compaction would achieve a good layer of dense cover concrete and the concrete would be sufficiently cured to prevent any early-age cracking or incomplete hydration. To that end, the contractor undertook an extensive education campaign with the theme “3 Cs” (compaction, cover, curing) to encourage worker commitment to the 300-year life span goal.

Without doubt, the concrete was a decisive element to this project. So much so, in fact, that the project team had to create its own precast manufacturing facility to deliver enough concrete parts for the project. But successful bridges and infrastructure projects are not made by concrete alone. Considerable effort also went into the aesthetics of the project.

As previously mentioned, the bridge also houses an iconic land art treatment at the north and south approaches. “Terrain Waves” is a landscape treatment that weaves ribbons of predominantly native vegetation into the surrounding environment and integrates curvilinear noise walls that reflect the character of various local precincts. Detailed treatment of a series of nodes and interchanges along the motorway also features quintessential Brisbane vegetation—hoop pines, jacarandas and figs—to reinforce local character and enrich the experience of motorway users.

Distinct honor

Everyone wants a long, purposeful life. But structures are measured on a different scale. Along with its longevity, a structure’s purpose, value and aesthetic worth are judged as well. And even by these standards, the Gateway Upgrade Project and its featured element—the second Leo Hielscher Bridge—are extraordinary.

“No one ever attains very eminent success by simply doing what is required; it is the amount and excellence of what is over and above the required that determines the greatness of ultimate distinction.” Queensland Motorways and the Gateway Upgrade Project team went well beyond the required, creating a project that is a triumph of distinction.

Connal, M.Eng Sci., B.E., F.I.E.Aust, and Berndt, Ph.D., B.Sc., F.I.E.Aust, are senior project engineers at AECOM. Commissioned by the Leighton Abigroup Joint Venture, AECOM and SMEC provided principal design, with input from Cardno, Aas-Jakobsen and Coffey. In addition, AECOM provided urban and landscape design for the project.

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