Auckland Harbour Bridge truss assessment and strengthening design for a major refurbishment project.

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Abstract: Design of the Auckland Harbour Truss Bridge commenced in September 1951 by Freeman, Fox and Partners in London where the original team of structural engineers and draughtsman led by a chief engineer designed the 1.02 km long steel truss bridge using entirely manual methods in approximately 18 months. To meet the aspirations and budget of the New Zealand Government and Auckland Harbour Bridge Authority the engineers delivered a design optimised for minimum material use with bespoke design of individual structural members. Spans 1 and 3 are mirrored, Span 2 is symmetric about its central panel point and the bridge is longitudinally symmetric, but the symmetry ends there. Spans 1 to 3 are longitudinally restrained at the northern anchorage, and Spans 4 to 7 at the southern anchorage. Spans 1 to 3 are wider than Spans 4 to 7 and the bridge depth varies along the full length of the bridge from 7.5m deep at the southern anchorage increasing to a maximum of 28.1m at Piers 1 and 2. Loading is also asymmetric. As a result, the form and arrangement of truss members and connections vary at every panel point on the bridge outside these symmetries.

Today, New Zealand demands increasingly more of this critical asset despite its age and the durability challenges inherent to all historic steel structures located in a marine environment. Since the bridge was completed in 1959 eccentric superimposed dead loads were added in the form of major watermains, 220 kVA power cables, the AJ Hacket Bungy Pod, maintenance walkways and other infrastructure. Vehicle mass limits have significantly increased, and bridge specific live load models have been developed to understand current and future demand on the structure. A combination of the wind loading requirements from AASHTO LRFD, BD37/01 and its successor, CS454 rev 1 and AS/NZS 1170.2 are now used in assessment of the bridge. The original designers adopted uniform wind pressure of 30 lb/sq ft on the basis that gusts exceeding 60 mph (26 m/s) were uncommon with the maximum recorded gust being 73 mph (32 m/s). Now these standards require a ULS base wind speed of 56 m/s (201 km/hr) in any direction, at an elevation of 40m above sea level. This yields a base wind pressure of 2.6 kPa or 54 lb/sq ft, 1.8 times the designer's allowance.

Now, to support major maintenance of the bridge corrosion protection coating, substantial new gravity and wind loads will be applied in the form of large containment structures to enable environmentally safe coating removal without requiring traffic restrictions. A typical containment structure (designed by SRG Ltd and NAL Ltd) is shown in Figure 1 designed to encapsulate one truss panel at a time. The additional demands imposed by these structures must be considered at every location where containment will be installed, in combination with all other assessment load combinations for detailed assessment of every member and connection.

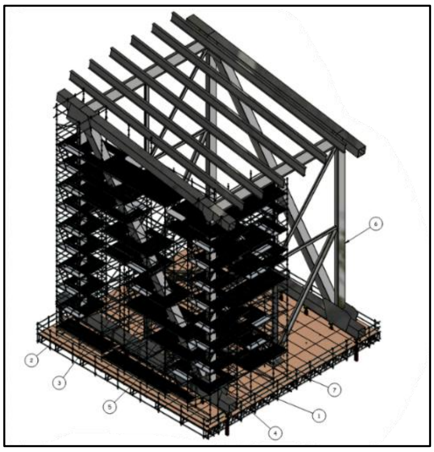

Figure 1 Typical Containment Structure

Working with the NZ Transport Agency and Auckland System Management Alliance, Beca engineers completed a comprehensive assessment of the bridge and designed strengthening where needed to support containment - the most detailed and refined assessment of this structure completed by Beca in 30 years of working on the AHB. This work included:

- Development of the Auckland Harbour Truss Bridge assessment standard and strengthening design basis with the NZ Transport Agency.
- Building new digital tools for rapid detailed assessment of all primary and secondary members. Each new tool processes over 700,000 individual data points.
- Physical wind tunnel testing of models of the containment structure and bridge.
- Assessment of all primary and secondary members and connections in accordance with the NZ Transport Agency Bridge Manual, AASHTO LRFD, AASHTO MBE, BS5400, BD37/01 as appropriate for built-up truss members.
- Refined assessment methods with increasing complexity to get the most out of the existing structures without intervention where possible.
- Non-linear Finite Element modeling of primary connections as required.
- Design of strengthening for 12 chord members, 8 diagonal members, 24 post members, and 15 cross frame (secondary bracing) members and 24 primary connections.

The presentation highlights some of the complex challenges, opportunities and innovative solutions developed to enable a major refurbishment programme of the AHB.