220 kV transpower NZ North Auckland and Northland (NAAN) project - Design validation of thermo-mechanical behaviour

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This paper is based on work that was motivated by the challenges associated with the installation of approximately 18 km of new 220 kV underground cable circuits between Albany & Hobson Substations in Auckland New Zealand, which included:

- Design, manufacture & install the 220 kV 2,500mm² & 1,600mm² copper enamelled (CuE) cables & accessories.
- Determine the thermo-mechanical characteristics of the 220 kV cable.
- Design & verify the snaking arrangement designed to restrain the 220 kV cables before entering the joint bay and to establish the forces imposed onto the joints by longitudinal thermal expansion of the cables.
- Design of special clamping arrangement in the joint bays and substation basements.
- Design & verify the cable installation arrangement / support structure on the 1.4 km long Auckland Harbour Bridge (AHB) to cater for both horizontal and vertical bridge movements, which included design of the dilatation mechanism at the expansion joints and verification of the mechanical behaviour of cable when subjected to simulated thermo-mechanical and seismic movement, and bridge vibration.
- Install the 220 kV cables & associated optical fibre cables in a single pull without joints on the constantly vibrating bridge structure.

The paper describes how the mechanical and thermo-mechanical behaviour of the 220 kV cables were experimentally evaluated. Tests include axial, flexural and torsional stiffness and thermal expansion. The paper also describes the evaluation of the performance of the cable snaking arrangement, the joint restraint system as well as those of the dilatation mechanism that was designed to cope with the relative movement caused by thermal expansion. The dilatation mechanism was also designed to accommodate bridge motion due to seismic activity. Issues relating to traffic-induced bridge vibration on the dilatation span are also discussed.

Full-size prototypes of the cable restraining systems for joints were commissioned to verify the level of transmitted longitudinal force to the joint due to thermal expansion. The effectiveness of the joint restraint systems was established as a function of time and applied force.

A full-size prototype of the dilatation structure was commissioned to include a computer-controlled hydraulic actuator to mimic the relative (longitudinal) motion between the bridge and the cables due to thermal expansion and seismic activity. The restraining forces were experimentally established and cyclic endurance tests that simulated some 80 years' daily expansion / contraction as well as seismic motion was undertaken. The effect of the cyclic loads on the cable was evaluated by monitoring cable curvature and longitudinal force. Cable curvature, which was measured optically, was used to predict strain in the aluminium sheath which was used as the primary design limit for establish cable path.

The vibration characteristics (namely resonant frequencies and self-damping) of the prototype dilatation span were established and the ambient vibration characteristics of the bridge were monitored to determine if resonance was likely to occur and if additional damping was required to minimise the possibility of fatigue failure of the cable. Finally, the vibratory response of the dilatation span in-situ was monitored for three months to confirm that additional damping was not necessary.