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SEISMIC RESPONSE CATEGORISATION OF THE NEW ZEALAND BRIDGE STOCK

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INTRODUCTION

While essential to the delivery of emergency services and relief supplies, bridges represent the portion of the transportation network most susceptible to damage during an earthquake. The New Zealand bridge stock is especially exposed to this risk, with over half of the structures built before current capacity and ductility based design philosophies were put into practice [1]. Screening programs have been undertaken to identify bridges with seismically deficient detailing, but these programs were designed to prioritize the bridge retrofits necessary to maintain post-earthquake lifelines, rather than develop an overview of seismic performance for the New Zealand bridge stock as a whole [2].

A study was undertaken to categorise the New Zealand bridge stock and determine its overall seismic vulnerability. Bridges were categorised based upon several physical characteristics, and using New Zealand seismic hazard models, the hazard at each bridge location was defined.

BRIDGE STOCK SEISMIC CATEGORISATION

The NZTA Bridge Database System (BDS) was analysed to determine the distribution and prevalence of various bridge typologies throughout New Zealand. While state highways bridges do not represent the entire bridge stock, the categorisation of seismic performance was limited to these bridges as they comprise a significant portion of the road bridges in New Zealand. Additionally, bridges owned by city and district councils typically follow the design and construction methods used in state highway bridges.

Bridges from the BDS were categorised using the following criteria:

- Crossing type
- Number and length of spans
- Bearing type
- Foundation type
- Superstructure construction
- Pier type
- Year constructed

These criteria provided the most relevant indications of potential seismic response available in the BDS.

The crossing type influences the form of both the pier and foundation system. Depending upon the type of crossing, irregular structural configurations such as outrigger piers or highly skewed abutments may have been employed. River crossings tend to have both deep foundations and a higher risk of liquefaction-induced lateral spreading, requiring the bridge to accommodate large movements at the abutments. In contrast, highway crossings with man-made embankments have significantly lower lateral spread potential and therefore smaller abutments can be used.

The bridge length and number of spans provides an indication of its overall dynamic behaviour. As length and number of spans increases, the bridge becomes more affected by higher modes and more vulnerable to differential displacement due to spatial variability in ground motion [3]. For short bridges with few spans, the dynamic behaviour is controlled by the first mode response of the structure and is more sensitive to the embankment-abutment interaction [4].

In addition to the length and number of spans, the structural response is controlled to a large degree by the bearing type used in the bridge. Bearings can range from fully integral monolithic concrete, to rocking and sliding steel, to elastomeric pads. Monolithic bearings provide continuity between spans, but induce large forces and moments in the superstructure and piers during seismic loading. Rubber or steel bearings reduce these forces by forming a pseudo-isolation plane between the piers and superstructure.

Superstructure construction gives an indication of relative weight of the superstructure to the substructure, which has implications on the overall inertial forces induced during shaking. The locations of ductility demands are also highly dependent upon both superstructure construction and pier and foundation type.

The final criterion, construction year, can be related to design code changes and gives an indication of the philosophy used to design the bridge. Before 1965, seismic loading was comprised of a uniformly distributed force equal to 10% of gravity, regardless of structural composition or proximity to faults [5].

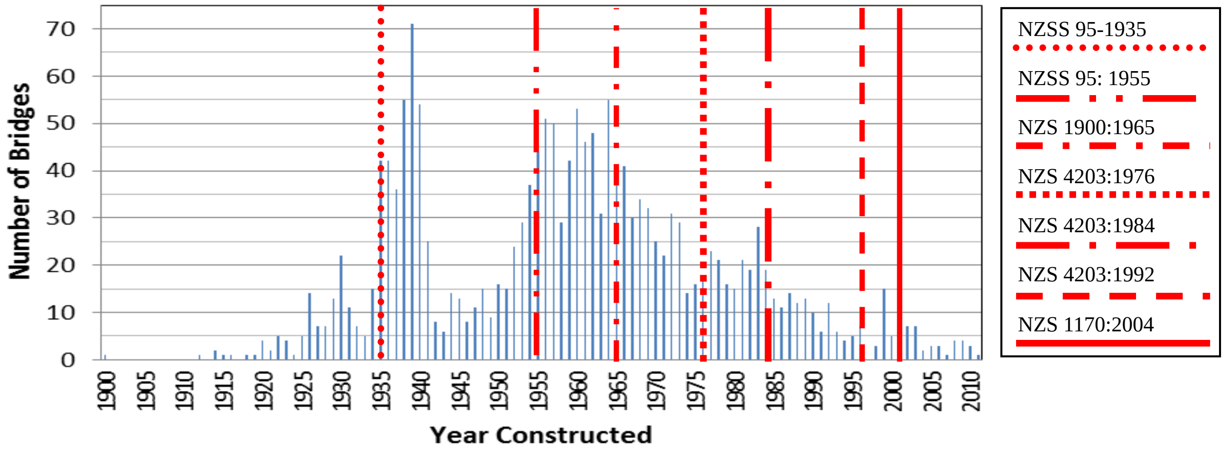

Fig. 1 Age Distribution of New Zealand State Highway Bridges. Dashed lines indicate inception of various earthquake loadings standards

Bridges built before 1976 lack consideration for capacity based design philosophy upon which current design practice is based [6]. Approximately 80% of bridges built in New Zealand were constructed before this standard was used (Fig. 1), and are therefore vulnerable to brittle failures during an earthquake. The basis of the current loading standards was introduced in 1992 [7]. Fig. 1 indicates that only 6% of the bridge stock was designed to this or the current 2004 standard.

In addition to the categorisation of bridge typologies, the proximity of bridge locations to sources of known seismic hazards was determined. New Zealand straddles the boundary between the Australian and Pacific plates, with subduction zones off the southwest coast of the South Island and northeast coast of the North Island. The Axial Tectonic Belt, an area of parallel oblique-slip and strike slip faults running through the top half of the South Island to the East Cape of the North Island, connects these subduction zones. Both the south-western subduction zone and the Axial Tectonic Belt contain faults capable of producing damaging earthquakes [8]. Bridge locations were compared to current seismic hazards in these areas [8] to determine the occurrence of seismically deficient bridges likely to experience strong shaking.

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