LIQUEFACTION MITIGATION FOR QUISIBIS RIVER BRIDGE, NEW BRUNSWICK

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Two new bridge structures were built in 1999, for a new section of highway in the northern part of New Brunswick. Each bridge consisted of three spans and an overall length of 154 m. The area is not prone to frequent large magnitude earthquakes, but is located within a zone that has been identified as a region of low seismic activity. The site is located in Acceleration Zone 3 (peak horizontal acceleration of 0.11 to 0.16 g) and Velocity Zone 2 (peak horizontal ground velocity of 0.08 to 0.11 m/sec) of the National Building Code of Canada (1995) that uses a 10% probability of exceedence in 50 years. During construction of the bridges, two earthquakes in eastern Canada occurred (magnitudes 4.7 and 5.2); both events were felt in the area.

An initial geotechnical investigation revealed a very loose silt deposit to a depth of approximately 15 m. The average void ratio, in-situ density, and moisture content for the silt deposit was determined to be 0.85, 1939 kg/m^3, and 30.9%, respectfully. Additional investigations consisting of static cone penetration testing and laboratory testing of undisturbed and reconstituted samples were undertaken to determine the liquefaction potential of the silt deposit. The analysis was carried out for a peak ground acceleration of 0.15 g and a magnitude 7.0 earthquake. Triaxial testing was used to determine the steady state line, and when the insitu stress state conditions were plotted most were above the line. Based on the results of this testing, coupled with the liquefaction potential analysis, it was determined that liquefaction mitigation measures were required at this site.

Considering the low probability of a major earthquake event, the ground improvements implemented consisted of installing vibro-replacement stone columns at the toe of each approach embankment and at each pier location. In addition, pre-fabricated vertical drains were installed under both embankments, extending back from the toe, nearly 50 m on each side of the river. As no clear guidelines or standards are available for low seismic activity areas, the mitigation system adopted was similar to the one typically implemented at existing bridge sites on Class B highways in high seismic risk areas, such as in the Province of British Columbia. Budgeting requirements dictated that all ground improvement measures be maintained within 10 to 15% of the total project costs. Therefore, it was decided to use vibro-replacement stone columns only in the critical foundation areas and use less expensive measures over the remaining areas of the site. Initially, stone columns were proposed below both approach embankments before being replaced with pre-fabricated vertical drains. The ground improvement measures used at this site were considered to be a balance between a cost effective design and an acceptable risk.

A total of 361 one-metre diameter vibro-replacement stone columns were installed at a spacing of 3 m centre to centre. At this spacing, densification of the silt was not anticipated but the primary objective was to provide drainage for dissipation of excess pore water pressures. It was estimated that the selected spacing would result in an excess pore water pressure ratio of 0.6. The gravel backfill gradation was selected to ensure that the coefficient of permeability of this material was at least 200 times greater than the silt. The pre-fabricated vertical drains were installed in an equilateral triangular configuration at 1.2 m spacing from the surface down to the more competent stratum underlying the loose silt deposit. Nearly 4600 pre-fabricated vertical drains were installed. The polypropylene drains specified were 100 mm in width, with a minimum discharge capacity of 140 x 10^{-6} m^3/sec at 10 kN/m^2.

A program of instrumentation and field testing was undertaken to evaluate the effectiveness of mitigation measures implemented at the site. As was expected, the results indicated that little densification of the loose silt deposit resulted due to installation of the stone columns using the vibro-replacement method. The main benefit of these stone columns was to reduce drainage paths and reinforce the silt deposit. The enhancement of drainage was confirmed by performing static cone penetration testing after the installation of the stone columns and comparing the data with the tests carried out initially. The initial testing required between 10 and 30 minutes to dissipate the excess pore water pressures and reach a fairly steady state condition, while the testing conducted with the stone columns in place required between 1 and 6 minutes. The monitoring of excess pore water pressures during driving of large diameter displacement piles for the bridge structure also indicated that the stone columns were effective in dissipating excess pore water pressures rapidly.

Instrumentation of the foundation soils is also being used to determine the effectiveness of the ground improvement measures at this site during an actual seismic event. Vibrating wire piezometers with an automated data logging system were installed to monitor pore water pressures during any future dynamic loading events.

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