



Bored pile design, construction and base grouting on the Takitimu North Link Stage 1 project

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Abstract: : The Takitimu Flyover Bridge is a new structure along SH29 Takitimu Drive Toll Road (SH29) in Tauranga, New Zealand, delivered as part of the NZ Transport Agency Waka Kotahi (NZTA) Takitimu North Link Stage 1 project. The flyover will enable free flowing north-bound travel along SH29, over the new at-grade interchange between SH2 and SH29.

At the piers, the 11-span structure is supported on reinforced concrete bored piles in a monopile arrangement. The bored piles pass through alluvium, the sedimentary deposits and tephra/thin distal ignimbrites of the Matua Subgroup and found within the dense to very dense, non-welded Chimp Ignimbrite encountered at depths between 20m and 45m below ground level. The abutment piles also found into the Chimp Ignimbrite, but closed-end steel tube piles were applied at those locations.

For the Takitimu Flyover Bridge, being a continuous bridge structure, deriving bored pile capacity through shaft friction was the initial approach; but this approach required long and large diameter piles. To minimise bored pile size and lengths, the inclusion of the end bearing component of load resistance (from embedment into the Chimp Ignimbrite) was also considered in the design. For the ultimate end bearing capacities for bored piles in dense to very dense sands (these materials being a close approximation for the Chimp Ignimbrite), a value between 3 MPa and 5 MPa would typically be adopted and is supported by the interpretation of the full-scale pile load tests that were completed on the Mackays to Peka Peka project in Kapiti, New Zealand in 2014. However, to achieve the significant reduction in pile size and length that was desired by the project team, a marked improvement in the ultimate end bearing capacity of the pile foundations was required. This was achieved via the introduction of base grouting into the design and works specification; and was informed by the results of the Tauranga Harbour Link pile load test on a base grouted pile (reported in 2008), where up to 12 MPa ultimate end bearing capacity was interpreted in the ignimbrite founding stratum.

The pier design for the Takitimu Flyover Bridge adopted 1.5 m diameter piles, changing to 1.2 m diameter columns at ground level. The detailing for the bored piles considered how the 4 No. steel tubes for cross-hole integrity testing, 8 No. grout tubes (for 4 No. grout circuits) and 2 No. tubes for rod extensometers interfaced with the pile reinforcing steel and, at the head of the pile, the column reinforcing steel. Whilst the design sought to mitigate the impact of congestion at the pile head, modifications to detailing during construction were required to address the practicalities of tube and reinforcing steel arrangement. The notable changes were i) the removal of the 4 No. steel tubes for integrity testing and the use of the grout tubes instead for that purpose and ii) the inward shift of the grout circuits to make more space for the reinforcing steel. Whilst the latter change offered benefits for the base grouting,

the combination of these two changes meant a reduction in the cross sectional area of the pile that would be subject to integrity testing.

The construction of the bored piles was completed under the following general sequence: site establishment and temporary works, driving permanent steel casings (between 16.5 m and 31 m deep), pile drilling, installation of the reinforcement cage, pile concreting via tremie, base grouting and cross-hole integrity testing.

For the base grouting, the design expected the following general progression of works: hydraulic fracture of the manchettes and the concrete at the pile toe, first stage grouting and then second (and subsequent) stage grouting with increasing grout circuit pressures observed and finally the ability to hold 15 bar of residual pressure over a period of 2 minutes to show satisfactory grout injection. A maximum toe uplift of 2 mm was specified in the design. In practice, each pile presented a unique response to base grouting. The results of each stage of grouting required review and interpretation to determine the objectives of the next grouting stage and hence any adjustments to the circuit volume limits and grout mix to apply. Overall acceptance of base grouting completion at a given pile then required a holistic view of results from the various stages of grouting, to confirm a trend of consolidation at the pile toe. A consistent theme interpreted from the base grouting results was lateral grout flow from the manchettes to the sides of the pile (rather than downward) and then running up the pile shaft between concrete and soil. In many cases, adjustments to the grouting parameters were required to compensate for this such that reaction of the pile toe could be achieved.

For future projects considering implementing a base grouting scheme, four key suggestions are offered. First, for the monopile arrangement, having either the same diameter for the pile and column or, perhaps more desirable, a larger difference in diameter between the pile and column (e.g., 1.8m diameter pile for a 1.2 m diameter column) to address congestion issues at the pile head. Second, for the grout circuits, positioning these midway between the pile centre and extremity to improve the likelihood of / promote downward (rather than lateral) pile cracking and grout flow paths. Third, being prepared to respond to grouting conditions quickly (e.g., decisions on varying target volumes and grout mix) in a collaborative setting between key members of the design and construction team. Fourth, the value of previous experience with these works is key to success. For the Takitimu Flyover Bridge, the combination of the third and fourth suggestions offered above enabled a successful base grouting operation for every bored pile at the site. And indeed, these suggestions extend to the wider piling operation, which for this structure, was completed efficiently and produced foundations that met all quality requirements..