Canterbury Bridge Group

Ferrymead Bridge

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Site Location
1864 Bridge
Bowenvale Bridge
1907 Bridge
Ferrymead Historic Park Tram Bridge
1967 Bridge Under Construction
1967 Ferrymead Bridge

- 57m long, 3 span continuous post tensioned concrete
- Severely damaged by the Feb 2011 EQ and subsequently demolished
Geological Section

Existing bridge elevation

CROSS SECTION GEOLOGICAL PLAN
(GOLDER ASSOCIATES PLAN - MAY 2003)
1:250 approx.
Widening and Strengthening GA’s
Feb 2011 EQ Damage

- Bridge elevation & temp cofferdams
- Rotated existing & new abutments*
- Displaced existing piers
- Displaced temp. staging foundations

* New abutment was yet to be restrained
Securing Works

Shear key restraint to new abutments

Re-built staging
Securing Works

- Tie backs to pier pile cap
- Tie back restraint at abutment
- Jacking props & shear keys
- Set up for pier jacking
Post Feb 2011 EQ Aerial
Presenter:

Michael Cowan

Principal Civil Structures Engineer

Opus International Consultants
Bridge & Site Features

• 30,000 vehicles per day
• Over-dimension route to Port of Lyttelton
• Numerous services – power, water, sewer & telecommunications
• Complex 5 leg intersection to the east
• 1967 bridge assessed to be vulnerable to earthquake and the effects of site liquefaction
• Suburbs to the east vulnerable to isolation with the alternative Bridle Pass Rd closed by slips and rock fall
Factors Influencing the Design

- Site geology – estuarine deposits of variable depth overlying basalt bedrock of variable quality
- Site seismicity – increased seismicity with ongoing seismic activity
- Combined seismic loading and soil lateral spread effects – The site is highly liquefiable
- Effects of ongoing seismic activity on construction
- Exposure to potential tsunami risk
- Maintenance of traffic flows
Seismicity

• NZTA Bridge Manual:
  – IL = 2, 1000 yr return period, Class C shallow soil site

• CCC desire for route security to eastern suburbs:
  – IL = 3, 2500 yr return period

• Z increased from 0.22 to 0.30 → PGA = 0.52g

• Probabilities of ≥M5.5 EQ
  – Within 1 month: 5%
  – Within 1 year: 44%
Geotechnical Conditions

• Approach fills: 2 – 3 m of dense gravel and loose sand

• Estuarine deposits: 7 – 21 m deep, liquefiable down to bedrock in EQs ≥ 150 year return period

• Bedrock: inter-bedded basalt and pyroclastic material of highly variable properties
  – Pyroclastics: 2 – 15 Mpa
  – Basalt: up to 120 MPa, but 25 – 75 MPa due to defects

• Groundwater levels in the approaches fluctuate with tide and river levels – RL 2.7 – 4.3 m
Site Overview and Traffic Provisions
Design Concept

• 2 span bridge → minimises out of balance lateral spread loading acting on the pier

• Superstructure: PSC super-T beams (based on cost, durability & maintenance considerations)

• Foundations: pier 4 ~2.4 m Ø cylinders, abutments 3 ~ 1.1 m Ø cylinders. Socketed into the bedrock
  – Abutment pile size & spacing to minimise lateral spread loading
  – Large pier piles to resist lateral spread and inertia loading
  – Permanent steel casing used to contribute strength
Design Concept

- Voids formed behind the abutments to isolate the bridge from larger lateral spread loads
- Superstructure tightly linked to abutments and pier, props lateral spread loads from one support to others.
- Abutment piles extended through cap to bear on beam diaphragms
- Ground improvement discounted due to:
  - The presence of numerous services (difficult/costly to protect)
  - Depth of liquefiable materials (> 20m at City abutment)
  - Uncertainty of performance (an adjacent block of flats on improved ground suffered severe damage)
  - Potential cost
Design Concept

Plan of Replacement Bridge
Design Concept
Design Concept
Pile Design

- Casing flexural strength utilised
- Casing thicknesses: pier 32 mm, abutments 20 mm
- Casing thickness constrained by minimum thickness required to avoid buckling + constrained by maximum thickness able to be roll
- Casing internal surface to be free of protrusions to facilitate installation. Designed as non-composite.
- Boreholes sunk at all pile locations to resolve founding levels and multiple analyses to optimise pile size and arrangement
Soil Lateral Spread Loading

- Estimated as 4.5 x passive pressure on the piles. Allows for:
  - 3-dimensional effects of the flow, and
  - post liquefaction soil strength assumed

- Partial removal of the existing abutment to avoid them loading new abutment piles through soil arching
Grouting of Pile-Rock Interface

External grouting using tube-a-manchette method adopted
Seismic Risk During Construction

Risk mitigation measures adopted:

– Piles socketed into bedrock → base fixity

– Increased tolerances built into abutment and pier headstocks to tolerate small displacements of piles

– Gap excavated between abutment piles and embankment to minimise lateral spread loads on piles

– Abutment piles propped off more robust pier piles until they are propped by the superstructure

– Construct less vulnerable pier piles first, followed by the abutment piles
Temporary Propping System

Assessment Cases Considered to Evaluate Effectiveness of TSR System

<table>
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<th>D_b</th>
<th>D_c</th>
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<tr>
<td>5</td>
<td>All</td>
<td>10</td>
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</table>

Acceptable Limit [mm]: 150 100 150

FEM Model showing piles braced by TSR system
Temporary Propping System
Presenter:
Werner du Plessis
Construction Manager
HEB Construction
Temporary Structures

- Location of the bridge over existing estuary meant substantial temporary works was required during construction.
- Consisted of temporary bridges with piles to top of rock – between 15 – 25m long.
- Approx. 350m of 9m wide (3150m²) temporary bridge installed in approx. 5000m² estuary area.
Piling
Pier Casing and Installation

- 2.4 m dia x 25 m long casings weighing up to 50t each
- 180t Crawler crane used
- Pitching plate manufactured and placed at toe of pile to avoid pile punching through staging during pitching
- Drill rig with custom rock buckets to drill through hard volcanic rock
- Bottom 1m section of casing reinforced using Bizalloy

- Abutment Piles up to 30m long 1.1m dia casing
Pier Pile Reinforcing Cages

- 9 ton, 21 m long cages
- Special star shaped former rings to hold the shape of the cage during pitching and placement.

- Single crane lift using main and auxiliary lines with snatch blocks to pitch cage
Pier Pile Concrete Pour

- Highly sensitive marine environment
- Concrete pours of up to 90 m³ per pier pile
- Extensive collaboration with ECan on pouring methodology and high PH water treatment

- Large amount of silts generated during piling operation
- Silt trap used at night to assist with cleaning
Column Construction

- Pile column joint below water level requiring cofferdam setup
- Safety concerns due to previous experience with sheet pile cofferdams under original contract
- Cofferdam box clamped around pier piles to create dry conditions for column construction
Pier Cap Reinforcing

- Highly “congested” zones especially around each of the pier columns
- As a result - reinforcing clashes encountered required collaborative quick thinking from project team.

- Approx 80#, 18mm fillet welds on reinforcing and anchor plates locally to four columns
Pier Cap Pour

• Highly congested pier headstock reinforcing
• A special 50 MPa, fly ash self-compacting mix was developed
• Nominal aggregate size was reduced from 19 mm to 13 mm
• 720 mm nominal spread to ensure “flow-ability”

• 75 m³ continuous pour
• Pour depth 1.0 – 1.2 m and length 30m
Abutment Temporary Works

- Abutment cap weight approximately 220t so required large steel sections
- Tidal zone with high tide approx. 150mm below soffit RL
- Temporary works had to be retrievable
Abutment Construction

• Utilised existing temporary propping “forks” to suspend main members under the cap

• Propping “forks” suspended using ties connected to “Crucifix” arrangement at top of piles

• Main members spanning between “forks” consisted of 800UB’s
Super Tee Mould

- Mobile Super Tee Mould mobilised to the heritage park approx. 2km from site
- Complete with Hot water curing facility
- Match curing used to provide certainty around early strengths
- Beams de-stressed 16hrs after casting
Super Tee Production

- Produced 5 super tee beams every 2 weeks
- Beams cast in sequence working from centre beam outwards to mitigate effects of differential hogging

- Total production 10.5 week period to construct 26 beams to high standard
Transporting Beams to Site

- Beams transported to site during the day
- Short 5 min closures enabling the beam transport to enter site
400t Crawler Crane

- Rigged with 70m of boom, 200t counterweight and 200t superlift lift ballast
- Simplified the beam placement operation
- Positioned on 8# 25m long piles and purpose built staging bay at city abutment
- Placed 48t at 58m radius
- Max capacity 73t at 58m
Beam Placement
Deck and Footpath Construction

- Used trailered pump with 45m reach to place deck slab concrete from each abutment
- 2 x 180m³ concrete pours finished to dual graded deck levels
- Concrete placed during the early hours of the morning to avoid delays due to traffic
Time Lapse Video and Questions