

NEW ZEALAND CONCRETE SOCIETY
CONFERENCE

CONCRETE 2000

Better,
Faster,
Smarter

WAIRAKEI RESORT HOTEL, TAUPO
13 - 15 OCTOBER 2000

Technical Paper



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CEMENT & CONCRETE
ASSOCIATION



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NEW ZEALAND CONCRETE SOCIETY

CONCRETE '00
"BETTER, FASTER, SMARTER"

Technical Conference and AGM
Wairakei Resort Hotel, Taupo
13 – 15 October 2000

Conference Programme and Table of Contents

FRIDAY 13 OCTOBER 2000

12 noon	Registrations and Check In	
1.00pm	Welcome and Conference Opening - New Zealand Concrete Society	
1.10pm – 3.00pm	Session 1 – "Keynote Session – Breakthrough in Precast Seismic Structural Systems" Chairman – Alex Gray	
	<i>Preliminary Results and Conclusions From The PRESSS Five Storey Precast Concrete Test Building</i> Nigel Priestley, University of California, San Diego	1
	1. <i>A Presentation Of The PRESSS Technology Applied To A 39 Storey Building By Pankow Builders In California</i> Jason Ingham, University of Auckland	27
3.00pm – 3.30pm	Tea/Coffee	
3.30pm – 5.00pm	Session 2 – Commercial Properties Chairman – Paul Wymer	
	1. <i>Commercial Perspectives of Retail Developments in New Zealand</i> Martin Fahey, Mainzeal Construction	
	2. <i>Princes Wharf Development – Strengthening Of A Reinforced Concrete Wharf And Superstructure</i> Stuart George/David Turkington, Buller George Engineers Ltd	33
	3. <i>The Case For Concrete</i> Richard Henderson, Cement & Concrete Association of NZ	39
5.30pm	NZCS AGM	
6.30pm	President's Reception	
7.30pm	President's Dinner	

SATURDAY 14 OCTOBER 1999

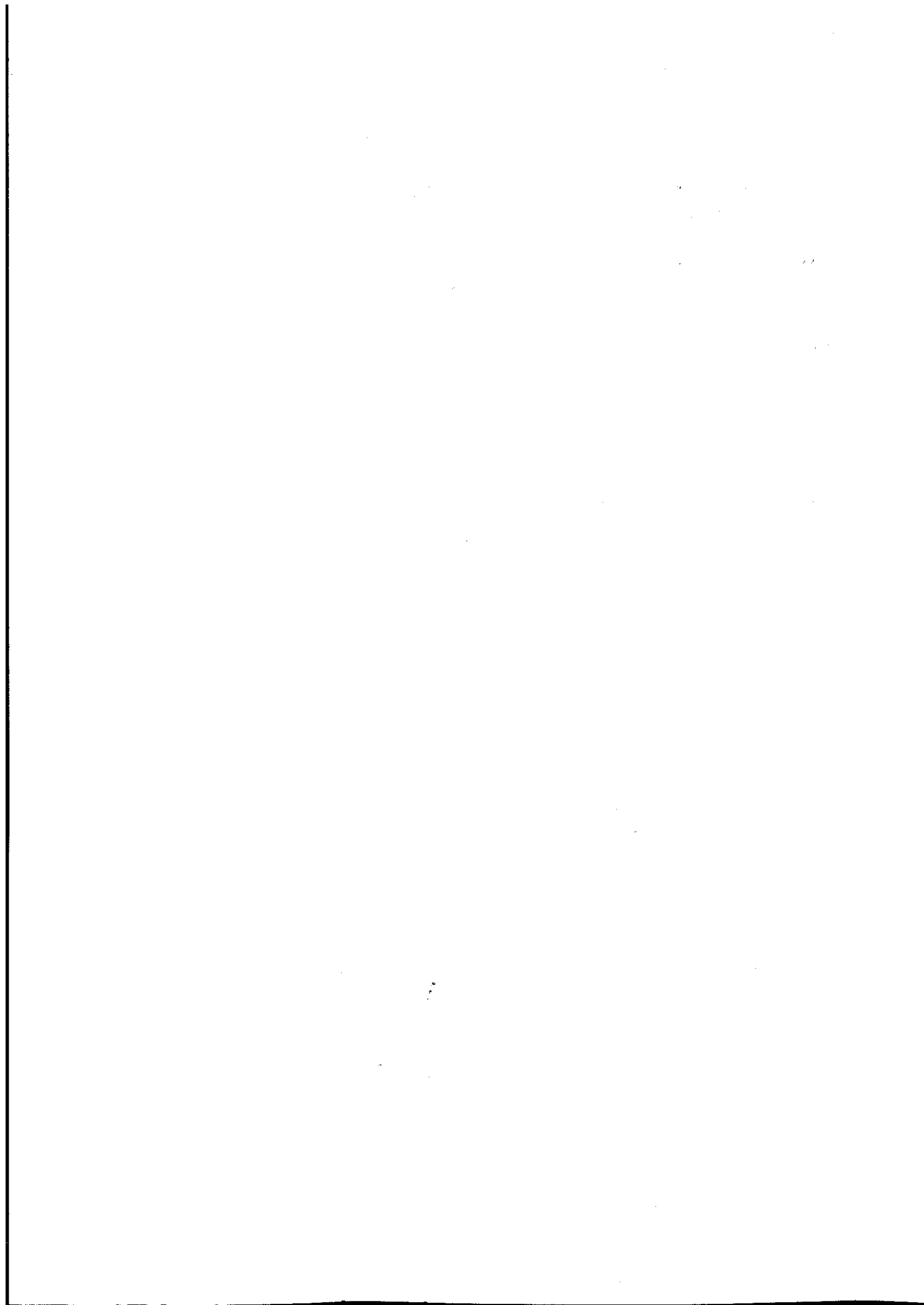
9.00am – 10.30am	Session 3 – Innovative Structural Research Chairman – Len McSaveney	
	1. <i>Damage Avoidance Seismic Design of Bridge Piers</i> John Mander, University of Canterbury	42
	2. <i>Recent Advances In The Use Of Prestressed Concrete Systems In Seismic Design</i> Jose Restrepo, University of Canterbury	50
	3. <i>Current Research On Post-Tensioned Concrete Masonry Walls</i> Peter Laursen, University of Auckland	56
10.30am – 11.00am	Tea/Coffee	

11.00am – 12.30pm	Session 4 – Transport Infrastructure Chairman – Alex Gray	
	1. <i>Candy's Bend Road Widening, Arthurs Pass - Design Aspects</i> Melvyn Maylin, Opus International Consultants, Wellington	66
	<i>Candy's Bend To Starvation Point Project - Construction Aspects</i> Colin Chisholm, Fulton Hogan Civil, Christchurch	76
	2. <i>Axis Fergusson Terminal Expansion – Engineering Design</i> Murray Dennis, Ports of Auckland	80
	3. <i>Auckland Airport – Concrete Pavement Taxiway Extension Works 1999</i> Nick Miller, Fulton Hogan Civil, Auckland	89
12.30pm – 1.30pm	Lunch	
1.30pm	Range of Activities	
7.30pm	Dinner and Entertainment	

SUNDAY 15 OCTOBER 1999

9.00am – 10.30am	Session 5 – Concrete Briefs Chairman – Morten Gjerde	
	1. <i>Predicted Behaviour of Reinforced Concrete Columns</i> Chris Allington, University of Canterbury	100
	2. <i>The Durability Of Marine Concrete – How Well Have We Done, And How Can We Do Better</i> Sue Freitag/Sheldon Bruce, Central Laboratories, Opus International	108
	3. <i>The Strengthening of Two Churches, Using An Innovative Design Philosophy and the Helifix Strengthening System</i> Michael Newby, Michael Newby Associates/Chris Munn, GK Shaw Ltd	112
	4. <i>Specification of Concrete: The Role of NZS 3104/3109</i> Derek Chisholm, BRANZ	-
10.30am – 11.00am	Tea/Coffee	
11.00am – 12.50pm	Session 6 – Marine Durability Chairman – Andrew Dallas	
	1. <i>Marine Concrete Durability - Overview Of Options And Issues</i> Larry Gaerty, Concrete Consultancy	116
	2. <i>Expectations And Realities Of Concrete In Wellington Wharf Structures</i> Dick Carter, Project Engineer, Centreport Ltd	120
	3. <i>Seaview Wharf, Wellington: Rehabilitation By Cathodic Protection Utilising Computerised Remote Control Monitoring</i> Michael Lawson, Consultech	126
	4. <i>Durability Prediction For Coastal Reinforced Concrete Structures – Matching Reality And Theory</i> Derek Chisholm/Neil Lee, BRANZ	134
12.50pm – 1.00pm	Presentation of the Sandy Cormack Award NZCS	
1.00pm	Conference Closure	

Further copies of this volume, designated NZCS Technical Report (TR) 23
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Axis Fergusson Terminal Expansion

Engineering Design

Murray Dennis¹ and John Youdale²

A BRIEF HISTORY

Auckland has always been a port city and the port and the city have grown hand in hand throughout its history. In the early 1840s a sheltered anchorage was established at Auckland by the early settlers to New Zealand as the Waitemata Harbour was safe and highly suitable for trade.

The Auckland Harbour Board was established by an Act of Parliament in 1870. The Board was governed by an elected Board with three year

terms of office and administered by permanent staff. It remained in existence until the Port Companies Act. Auckland provided the commercial services and shipping centre that linked the timber miller, the farmer and the gum digger with international traders. By the 1860s the first harbour reclamation had been completed and Queen Street Wharf had become the port's main pier, a further series of reclamations through until the 1930s saw the development of the port as it is today. By the end of the 1860s overseas trade was

¹ Ports of Auckland Limited

² Beca Carter Hollings & Ferner Ltd

growing, mainly with England and Australia and a very active coastal shipping trade had been established. By 1920, Auckland was the busiest port in the country, more overseas and coastal vessels called at Auckland than at any other New Zealand port.

New Zealand has always been a trading nation - producing food and wool, which were exported to the other side of the world. In the 1860s with a tiny population New Zealand had 112 ports, 26 of them engaged in overseas trade. Over the next century, the expansion of road and rail services removed the need for many smaller ports. By the 1970s, there were 35 ports. New Zealand now has 14 ports owned by 13 port companies.

With continuing growth in Auckland's trade new wharves were built at the port. The major development between Princes Wharf and Kings Wharf (now incorporated into Bledisloe Wharf) was completed between 1904 and 1924. Bledisloe, Jellicoe and Freyberg Wharves were developed between 1940 and 1962 and Bledisloe was extended in the 1970s. Bledisloe now has two cranes on two berths.

The sea freight business began to change dramatically in the 1960s and 1970s with the advent of containerisation. Fergusson Container Terminal was built as a dedicated, specialist container operation in 1971. Today it handles over 300,000 containers each year, which is about 34% of New Zealand's total container trade.

Port Privatisation

Until the 1980s New Zealand ports were publicly-owned facilities managed by Harbour Boards. The members of these boards were elected in the three-yearly cycle of local government polls.

During the 1970s and 1980s there was increasing pressure from the business and exporting sectors to reform New Zealand's ports because of the costs they added to other sectors of the economy. In 1984 the Government began a major process of consultation on how to improve the efficiency of

the waterfront. It established the Ports Industry Review Committee to come up with recommendations. Out of this process the Government set three key objectives for change:

- The separation of the commercial functions of harbour boards from their non-trading roles;
- The freedom from legislative controls and the emphasis on commercial activities;
- The need for standards of accountability for performance similar to those which apply to businesses in the private sector.

Two pieces of legislation were implemented which facilitated change. These were:

- The Port Companies Act 1988
- The Waterfront Reform Act 1989

The Employment Contracts Act was also introduced in 1991. This brought about an ability to negotiate individual contracts and an end to demarcation.

Recent Growth

Ports of Auckland brought the land and assets of the company for about \$250 million and commenced business in October 1988.

In the past twelve years that the company has been in business it has:

- Tripled the volume of containers handled
- Reduced staff levels
- Decreased the average turnaround time for containers

Increases in ship calls and container volumes in the following decade were:

	1988	1998
Ship calls:	859	2,188
Containers	185,989	499,285

ENGINEERING DESIGN

The project timing and staging is still being developed to achieve the best financial and operational advantages for the Ports of Auckland. The detailed design was carried out by a team of engineers from Beca Carter Hollings & Ferner Ltd, Auckland.

The detailed design is now complete and the first significant site work commenced in September 2000.

These include:

- Reclamation area, approximately 9.42ha
- Container stacks and road layout
- New Wharf - approx. 1.0ha
- Existing wharf extension - approx. 1,100 m²
- New dolphins
- Services and substation relocation

Components of the Expansion

The major components of the expansion are shown in Figure 1.

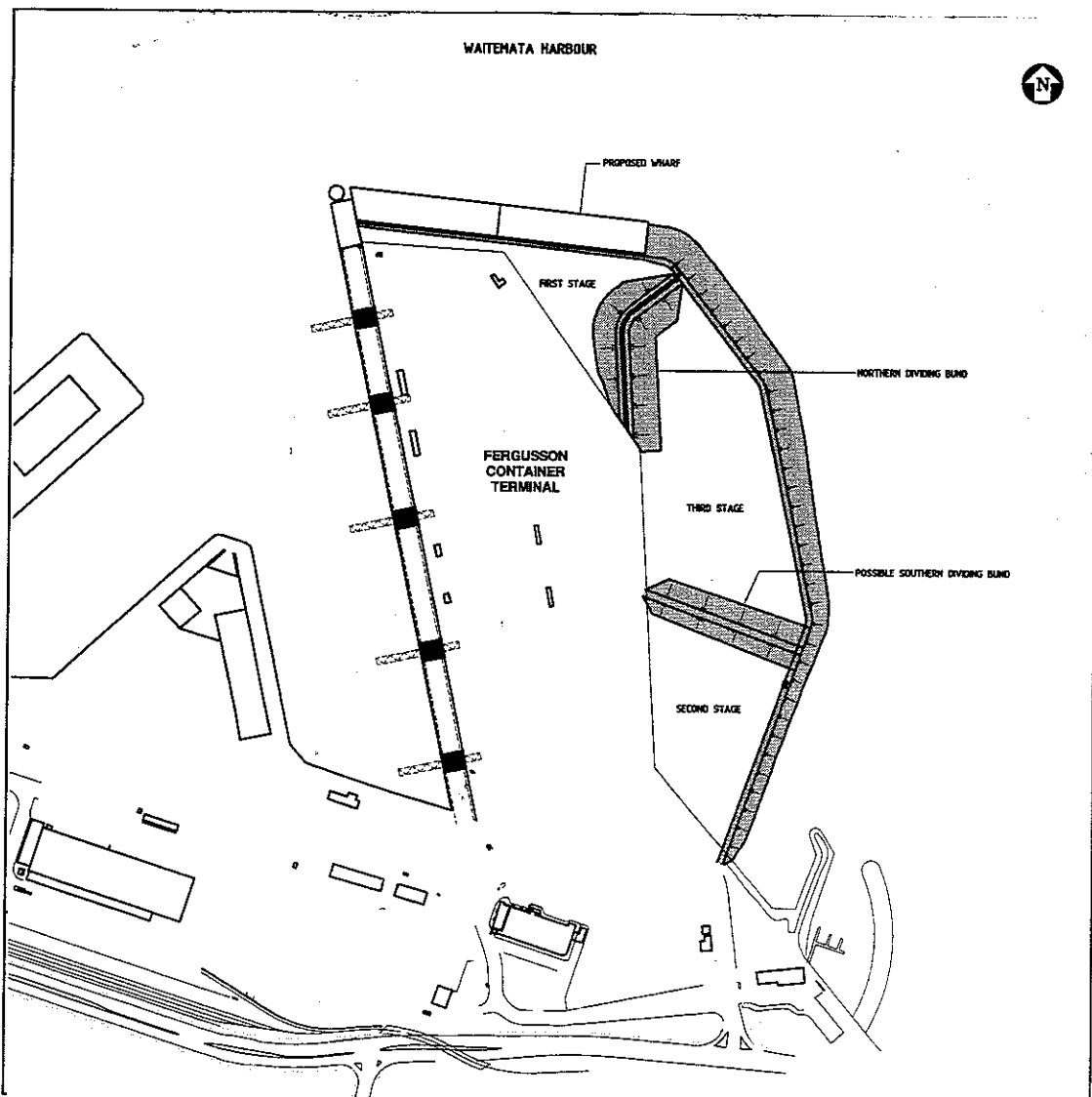


Figure 1 - Terminal Expansion Layout

THE NEW NORTH WHARF

Details of the new wharf are:

- 300m long (on back edge) by 33m wide
- Provision for three crane rails providing a 60 foot gauge and 30m gauge (60ft gauge crane rails installed now)
- 30m rail installed in future.
- Existing wharf FX/FY Extension, 47m long by 20m wide
- Turning Dolphin at NE corner
- Mooring Dolphin at east end

The wharf is to be sited east – west across the north end of the new reclamation

Design Loads

The wharf will have a uniform live load of 45kPa (equivalent to 3 high container stacking with 1.75m aisles and self weight of straddle carriers). Equipment loads are:

- Straddle carriers are 100t on 8 wheels (loaded).
- Container Crane loadings are 65t per wheel at 1.5m centres.
- Liebherr LMH 1300 harbour mobile crane (330t) on six axles with dual rubber tyred wheels.

The wharf is not designed for reach stackers. For these units it is possible to load front axles to 100+tonnes, but they are not part of the normal operation within the Fergusson Terminal.

Earthquake design criteria have been established at two design levels:

- Ultimate (475yr RP): structure damage, expected to be repairable.

- Serviceability (one sixth of ultimate): minor cracking.

The design earthquake is based on a site specific hazard study which gives forces equal to two-thirds of the code values.

Wharf Structures

Wharf deck

- 575mm cast insitu flat slab with beams on crane rail lines
- sloped to collect surface runoff
- breast wall down-stands for each fender unit
- 3m retaining wall at reclamation

Piling Options

Several piling options have been developed to allow flexibility for tenderers. The options are:

- precast concrete in bored hole
- cast insitu steel cased bored piles
- driven precast concrete piles

Recent marine structures in Auckland have generally been insitu on precast concrete piles.

Piles for the outer grid lines are to be 760mm diameter. The inner most line of piles which provide the lateral support to the wharf will be 900mm diameter. All piles will be embedded in holes bored into the sandstone base, ranging in depths from 5.7 metres to 10.25 metres, dependent on the load requirements and depth to competent material.

The wharf cross-section is shown in Figure 2.

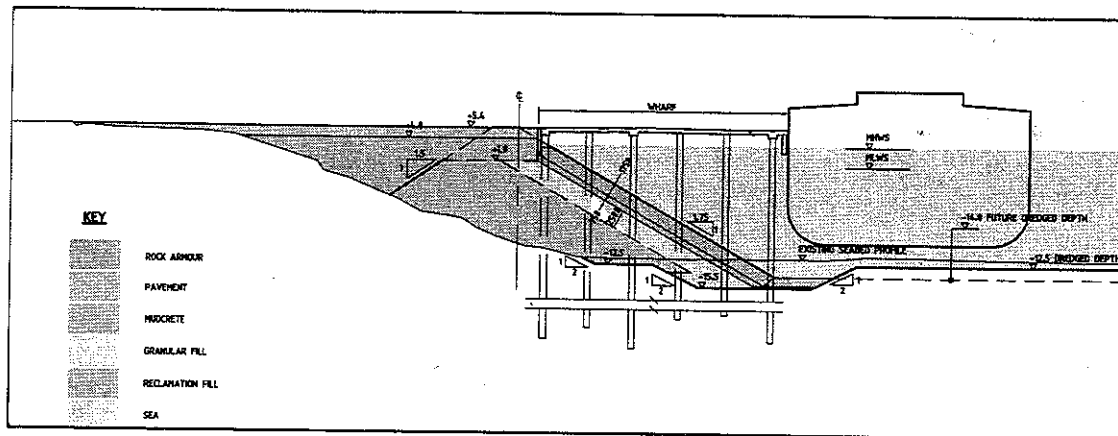


Figure 2 - Wharf Cross-section

Other structures

The two other marine structures are the dolphins located at either end of the wharf.

Turning Dolphin

- piled structure with concrete pile cap and fendering
- fitted with quick release mooring hooks for vessels at both FY and the new berth
- pedestrian bridge connects to main wharf
- 2.5m wide light vehicle bridge (steel) connects to the FX/FY extension

Mooring Dolphin

- piled structure with concrete pile cap
- fitted with quick release mooring hooks for vessels at the new berth
- two span concrete pedestrian access bridge from main wharf

Durability

Durability issues for the structures will be addressed as follows:

- high cement content concrete
- addition of silica fume to concrete
- low water cement ratio

- electrical connectivity of bottom reinforcement in deck to allow for future cathodic protection if required
- minimum 7 day curing of all concrete
- reinforcement detailing to prevent congestion and subsequent poor concrete compaction
- additional construction monitoring to ensure minimum cover as detailed is achieved

MOORING AND FENDERING

Because of strong tidal currents, a sophisticated fendering and mooring system will have to be used berth the ships and to hold them in position.

Ship sizes and impact velocities

The new wharf has been designed for 60,000 dwt ships. As the new wharf is exposed to the tides of the main channel of the harbour, it is anticipated that the berthing velocities of the ships will be higher than generally experienced in the existing, sheltered berths. An impact of velocity of 0.15 m/s and quarter point (i.e., at a point one quarter of the length of the ship from the centre) berthing impact has been assumed. The berthing energy calculations take into account the "added mass" of water that is moving with the ship as it impacts the wharf.

Fender system

To absorb the estimated total kinetic energy of approximately 100 tonne metres, a series of buckling column fenders will be installed along the face of the wharf. These fender units comprise

pairs of rubber elements supporting a steel face panel, which, in turn, is covered with a low friction, high density, polyethylene rubbing surface. As the ship's hull impacts the fender panel, the rubber elements deflect – first elastically and then by Euler buckling. In doing so, the kinetic energy is absorbed as the force translates through a significant distance (in this case about 900mm), however the reaction on the wharf is limited to the buckling load of the rubber fender units. Once the ship has been stopped, the fenders will push the ship off the berth as they recover. Several impacts of the ship may occur before it is finally stopped. During each impact of the ship with the wharf, it may generate the full reaction of the fender system at the point of impact.

Mooring System

To hold the 275m long ships in place, a mooring system has been developed to allow for the potential wind and current loads on the ships.

The mooring system involves a series of high capacity mooring bollards along the face and rear of the wharf and on the mooring and berthing dolphins. To assist in normal ship management and emergency situations, quick release mooring hooks have been provided on the dolphins. These units can operate through a wide angle and release the mooring line under full load.

GEOTECHNICAL CONSIDERATIONS

The existing seabed lies between 3m and 12m below Chart Datum, with the surface of the reclamation at around 5.4m above chart datum, resulting in fill depths of up to around 18m. The site is located in the Waitemata Harbour, which is a drowned river valley system and has significant depths of weak sediments. The existing terminal is constructed over the top of an old remnant ridge. The proposed reclamation is located to the east of the ridge over a valley with thick layers of weak sediments.

The main geotechnical issues associated with this development include stability (static and seismic)

of 18m high bunds and reclamation on weak sediments, settlement of the reclamation and bunds, assessment of suitability and method of filling of various reclamation fill materials to obtain a reclamation of relatively low compressibility, reuse of marine dredgings and piling options to support the wharf deck structure.

Soil Profile

Geotechnical investigations have been undertaken at various stages of the project to obtain information about the underlying soil conditions. The investigations comprised a series of machine boreholes and Geonor in-situ large vane testing undertaken from a barge in the harbour and laboratory testing.

In summary, the foundation conditions encountered during these investigations typically comprised weak marine sediments overlying residual soils of the Waitemata Group (i.e. sands, silts and clays) grading to inter-bedded layers of Waitemata Group sandstone and siltstone.

The results of these investigations indicated that Fergusson Wharf was built along the top of a ridge and that the sandstone/siltstone surface generally dipped gently northwards. A gully has been identified along the eastern side of the existing terminal.

The insitu large shear vane testing along the eastern bund indicated three distinct areas of a relatively consistent soil shear strength profile.

In summary:

- At the southern end moderately thick layer (3-5m) thick layer of soft sediments with shear strengths 2 to 10kPa overlying stiff sediments and Waitemata Group soils.
- In a central section very thick layers of soft to firm sediments overlying stiff Waitemata Group soils, and
- Towards the northern end are relatively thin layer of soft sediments (1-2m) overlying stiff sediments and Waitemata Group soils.

Three machine boreholes were also drilled through the reclamation along the existing eastern edge. Soils encountered in these boreholes typically comprised stiff clayey silt and medium dense sand. In-situ testing in the Pleistocene sediments below the old rock bund indicated Pilcon vane shear strengths of 80 to 120kPa and standard penetrometer tests recorded typically 11 to 50 blows per 300mm.

Geotechnical issues

The key geotechnical issues for this development include:

- Overall stability of the bunds and reclamation;
- Settlement of the bunds and reclamation;
- Assessment of suitability and method of filling of various reclamation fill materials;
- Piling to support the wharf structure;
- Seismicity.

Overall Stability of the Bunds and Reclamation Fill

The bunds will act as a containment structure to hold the reclamation fill. Two modes of failure have been considered in design of the bunds

- Shallow surface slumping of the bund materials, and
- Deep seated failure through the underlying soils.

The shallow failures are mainly a function of the bund material while the deep seated failures are mainly a function of the strength of the underlying soils. The short term (i.e. during and immediately following construction) stability of the bund is likely to be critical and can be managed by staged construction, limiting surface loadings and sizing of the toe key or improvement of the underlying soils.

Settlement of the Bunds and Reclamation

The Holocene and Pleistocene sediments will consolidate and contribute to settlement of the

reclamation, bunds and structures founded above these materials. Settlement of the reclamation and bund will occur due to consolidation of the underlying soils and of the reclamation fill under the weight of the fill and applied (container stacking) loads. Design of the surface gradings, pavements, drainage and other structures will need to take into account predicted settlements.

Assessment of Suitability and Method of Filling of Various Reclamation Fill Materials

The majority of the reclamation and bund fill will be placed below water, and therefore will not be compacted. The selected fill materials must however be of low compressibility so as not to add to the large settlements due to consolidation of underlying soils and must not be susceptible to liquefaction during earthquake shaking. Selected suitable fill types are likely to be either granular in nature or stabilised.

Dredging of marine soils will be required during construction to remove unsuitable soils and obtain the required berth depth. Material will also be made available for maintenance dredgings around the port. These materials have been found to form a high strength fill of low compressibility when mixed with cement. Cement stabilised marine dredgings, namely "mudcrete" has been used successfully as a high strength structural fill material. The cement has also been used to "lock up" contaminants within the marine dredgings.

Piling to Support the Wharf Structure

The Waitemata Group rock is at between -22CD and -29mCD (i.e. some 27 to 34m below the top of the wharf). Piles will need to support the quay structure, container cranes containers and vehicles. Piling options including both driven and bored piles have been evaluated to obtain economic solutions.

Seismicity

Seismic hazard is an important aspect of the design of structures in New Zealand which lies on tectonic plate boundaries. For this project seismic effects must be considered in the design of the wharf structure, bunds and reclamation. A site specific seismic hazard assessment has been undertaken to determine the seismic design parameters for this site. Geotechnical investigations were considered necessary to determine the type and strength of the soils to allow an assessment of the performance of these soils under seismic loads and their susceptibility to liquefaction.

The details of the bund design are shown in Figure 3.

Construction Procedures

Porewater pressure

During construction of the bund, excess porewater pressures are likely to be generated within the underlying silt and clay materials due to the loading induced by the bund. The total stress analyses indicate that the bund complete with reclamation comprising granular fill has a factor of safety against failure greater than 1.3 immediately after construction (i.e., assuming the soil has not consolidated and that there is no improvement in its shear strength). This indicates that the bund may be constructed in one lift. However, construction of the bund by endtipping off the end of a causeway is not considered practical as this is

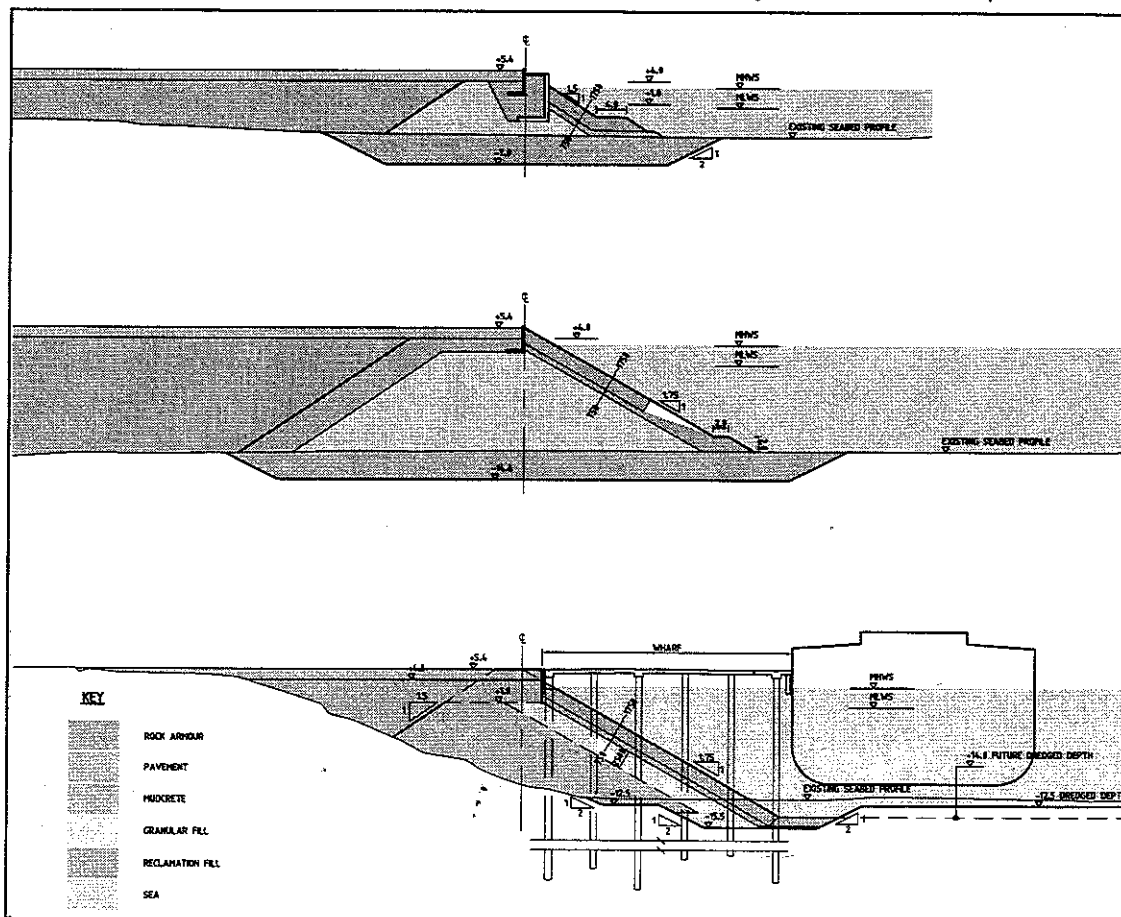


Figure 3 - Typical Bund Cross-sections

likely to cause shear failures of the weaker in-situ soils along the length of the bund and would result in foundation soils with only residual shear strength. This in turn would significantly reduce the overall stability of the bund. Consequently, it is recommended that an initial height of bund (e.g., 3 to 5m) be placed on an approved foundation level

to form a base cover before commencing construction of the remainder of the rock bund.

Monitoring

Monitoring of the degree of consolidation and strength in the underlying soils during and following construction is essential to the integrity of the perimeter bunds. A programme of pore water pressure, shear strength and settlement monitoring at key locations around the perimeter bund must be developed and implemented. The speed of progress must be controlled as the results of this monitoring indicate to maintain overall stability. Pore water pressure levels should be monitored during construction and compared to factors of safety obtained for stability of the bund for effective stress soil parameters.

Testing and sampling

Testing and sampling methods suited to the very weak Holocene and Pleistocene sediments (eg Geonor vane testing) will be undertaken during construction to confirm bund founding levels and the extent of undercut or stabilisation work. Weak soils found beneath the specified bund undercut will need to be either further undercut or strengthened insitu.

Settlements

Post construction settlements in addition to those detailed above will occur due to surface loadings such as container stacking. Additional settlements of the order of 50 to 100mm towards the northern end of the reclamation and 100 to 200mm in the central and southern area of the reclamation could be expected due to such loading. These settlements would occur over a long period of time and depend on the weight and duration of the surface load on any particular area, ie actual usage of the reclamation.

Effects of Settlement

Differential settlements will also occur between the piled quay structure and any adjacent reclamation. Such differential settlements could be of the order 0.1 to 0.3m as the piled quay will not settle. Therefore maintenance of the pavement on the reclamation e.g. overlays with asphaltic concrete will be required in particular for the area adjacent to the wharf structure.

ENVIRONMENTAL CONSIDERATIONS

Tidal currents

The terminal layout, in particular the new wharf alignment, was subject of considerable discussion during the resource consent process and was adjusted to reduce the effect on tidal currents in the harbour, at the cost of some operational efficiency.

Construction monitoring

Construction operations are being monitored in accordance with Management Plans approved by ARC. This includes regular monitoring of water quality and tidal currents.

Stormwater

Built into the wharf, as well as the new reclamation, will be storm water collection units where the water will be filtered before it enters the harbour. These involved a two-stage system, with filter bags within catchpits and sand filters adjacent to outfalls.

As part of the stormwater system design, an assessment of the risk was done for different areas of the terminal, and the degree of treatment adjusted accordingly.

The design also includes an allowance for local flooding of terminal roadways during an extreme storm event to provide retention and limit discharge rates and pipe sizes.