Northern Pathway Westhaven to Akoranga Bridge Component Design Summary

Prepared for Waka Kotahi NZ Transport Agency - Auckland

Prepared by Beca Limited

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Contents

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Executive Summary

As the Northern Pathway Westhaven to Akoranga (NPW2A) progresses to the next phase of delivery by the project Alliance it is vital to transfer knowledge of key constraints and residual risks to the proponents who will design and construct the facility. The section of the pathway crossing the Waitemata Harbour will be a transformational landmark for Auckland. This section includes some of the most challenging technical aspects of the NPW2A project. There are significant consenting issues to be addressed for the Auckland Harbour Bridge (AHB) component of the project requiring further consideration by Waka Kotahi with a range of stakeholders and partners.

Following approval of the Single Stage Business Case in December 2019 a Specimen Design was developed to assist the NPW2A Project Alliance to progress the Initial Target Cost (ITC) design during the interim Project Alliance Agreement phase.

During the specimen design development investigations were completed for the design of the bridge structure supported on the AHB including:

- Wind tunnel testing for design of the AHB-supported structure;
- Site specific seismic hazard assessment for the lifeline asset; and
- Site investigations of ground conditions adjacent to the AHB piers.

Outcomes of the investigations resulted in the design of complex strengthening measures at the connections of Northern Pathway Bridge to the AHB piers. Ground investigations also identified founding rock strength at some of the existing piers to be significantly lower than anticipated in the concept design. This necessitated additional measures to reduce demands on the concrete piers and foundations. Ground anchors tying some of the AHB piers to the seabed were incorporated into the Specimen Design.

This Design Summary report is intended to:

- Summarise the design constraints identified in the Specimen Design process;
- Describe the outcomes of critical investigations and design development;
- Compare the consenting issues of the AHB-supported design with issues associated with an option supported on independent foundations in the coastal marine area; and
- Highlight technical risks and issues to be addressed for both options in the next phase of the project.

The two alternatives included in the summary report have been reviewed for comparison purposes only and are not intended to be taken as the only options available for the Alliance to consider during the ITC design development. The Alliance will need to evaluate all options for the implications on cost, risk and programme.

The consenting issues for additional permanent structures in the seabed will need to be considered, and the Alliance will likely need to review alternative options including a bridge on independent foundations. Options requiring further stakeholder consultation and assessment of effects are expected to lead to a more complex and time consuming consenting process.

Ongoing consultation with mana whenua has identified that the impacts of the option for an independent structure on cultural values are anticipated to be very high, and governance-to-governance level discussions will likely be needed between Waka Kotahi and mana whenua.

1 Introduction

1.1 Purpose

This report is intended to provide a summary of the background information and the design basis to assist the Northern Pathway Westhaven to Akoranga (NPW2A) Alliance to carry out the Initial Target Cost (ITC) design for the Auckland Harbour Bridge (AHB) section.

A summary of the Single Stage Business Case (SSBC) and Specimen Design development is included, outlining key design constraints and criteria for assessment at each of these milestone delivery points.

A comparison is made between the specimen design solution (a structure supported by the AHB) and an alternative design of an independent pathway structure supported on new foundations in the Waitemata Harbour. This comparison is based on further investigations and assessment completed during the Specimen Design phase of the project and is intended to inform the Alliance of the potential risks associated with the two alternatives and issues to be resolved during the interim Project Alliance Agreement (iPAA) and Project Alliance (PA) phases of delivery. The two alternatives are intended to be used for comparison purposes only and are not intended to be taken as the only options available for the Alliance to consider during the ITC design development.

1.2 Background

A key objective of the Specimen Design was to develop a concept to support the Northern Pathway from the existing AHB without additional foundations on the seabed. There is a range of complexities associated with new structures in the coastal marine area particularly from a resource consent perspective. The AHB-supported bridge was the selected option from the multi-criteria analysis (MCA) carried out for the SSBC.

However, it was found from new geotechnical information obtained from recent site investigations that founding rock capacity is significantly lower than had been assumed at concept stage, and additional means of reducing demands on the foundations were required. These additional means are likely to include permanent structures in the seabed and several options have been considered to reduce demands on the foundations. The consenting issues for additional permanent structures on the seabed will need to be considered and the Alliance will likely need to review the findings of the MCA carried out for the SSBC and re-examine the preferred option

An alternative concept for independent piers was evaluated at an initial concept level for comparison purposes only. It was found that for the larger piers at Piers 1, 2, and 3 where load effects are greatest, significant foundation structures would be required. The Alliance should use the information included in this report and the additional design information referenced herein as an initial reference point for ITC design developmen T e Alliance may propose alternatives that comply with the project objectives and scope, as necessary.

2 Design Development Process

This summary report describes the design development to date and the investigations that have been completed during Specimen Design. Some of the critical technical design matters are outlined, and the residual risks and issues that need to be addressed are identified for further consideration in the next stages of the project.

In the Business Case stage several options for walking and cycling facilities across the Waitemata Harbour were compared. A summary of the findings of the multi-criteria analysis carried out at the early stage are described in this section. AHB-supported options and an independent structure option were included in that analysis.

Concept design of the preferred option from the Business Case identified some critical issues that required further investigation. Investigations of geotechnical ground conditions, seismic loading and wind tunnel testing were completed during the Specimen Design stage as summarised in Section 3. The outcomes of the recent investigations meant that detailed and complex assessments of the AHB structures were necessary to confirm the feasibility of the AHB-supported option. Ground conditions from site investigations were used in the foundation assessment that led to significant design changes. Several alternative design solutions considered for the bridge substructure are described in Section 4.

While an AHB-supported option was chosen at Specimen Design stage, due to the significant impact of the geotechnical findings the alternative independent structure has been briefly reviewed during design development.

An outline summary of issues that remain to be addressed for consenting of the Northern Pathway is provided in Section 5.

A high-level assessment of the outstanding technical issues to be investigated in comparing substructure options is provided in Section 6 for consideration by the Alliance.

2.1 Single Stage Business Case assessment of options

A multi-criteria analysis for a walking and cycling facility on the AHB was carried out in 2019 in close collaboration between designers, planners, Waka Kotahi and the business case team. The MCA process assessed several options for supporting the shared path on the AHB together with assessment of a completely independent structure. The assessment criteria were:

1. Alignment with project objectives;
2. Constructability – covering ease of construction, risks to road users and potential damage to existing infrastructure, potential unforeseen circumstances, design complexity and programme;
3. The potential requirement for additional AHB strengthening – superstructure and/or piers needing to be strengthened to carry the shared path;
4. Consentability – likelihood of achieving consents taking into consideration whether SkyPath consent could be used, and the possible significance of adverse effects;
5. Operational impacts – restrictions on the level of service of SH1; and
6. Impact on harbour use – restrictions on navigation under the bridge.

2.1.1 Shared path supported on AHB MCA summary

The AHB-supported option was assessed to have negative constructability impacts due to the design and construction complexity associated with the strengthening of the concrete piers and construction of the elevated superstructure from the harbour. It was also assessed that resource consent would be required, but that the existing SkyPath consents could likely be used or altered.

2.1.2 Independent structure on new foundations MCA summary

Amongst the options considered through the MCA process, an independent structure with additional piers in the harbour was assessed. A key negative impact assessed was that new piers in the Waitemata Harbour would require coastal resource consents which would likely be very hard to secure and would not be able to make use of the existing SkyPath consents. The programme risk associated with gaining new consents for work in the Coastal Marine Area (CMA) was deemed to be significant. This option was also assessed to have minor impacts on harbour use due to the piers adjacent to the navigation channel

Both options were assessed to be difficult to construct because of the major challenge with constructing the high-level superstructure close to the existing AHB from the harbour. The optioneering and MCA process was reported in the Single Stage Business Case report in November 2019.

The conclusion from the SSBC report stated "a new completely separate structure within the harbour was deemed to have a significant consenting risk when there is a feasible option (Option 10) which could achieve the same objectives with lesser impact" and the option was not preferred. The shared path supported on the AHB piers was taken forward for the business case which was approved by Waka Kotahi in December 2019.

2.2 Structures Option Report and Minimum Standards and Requirements

The development of the Specimen Design of the bridge component of the Northern Pathway following conclusion of the SSBC is reported in document G.1.1 Structures Options Report. The design basis is reported in G.1.2 Structures Design Standa ds. The Structures Options Report summarised key design considerations and assessment of options for superstructure and substructure of the AHB section of the project.

The preferred option taken forward from SSBC was the AHB-supported structure. An assessment of the existing piers was carried out to confirm feasibility. Although the feasibility study found that the proposed addition was technically feasible it may expose the existing bridge to the risk of damage by either construction activity or by the addition of significant new loads to the existing substructure while the bridge is open to traffic.

Consequently, the option of an independent bridge supported on new piers in the harbour was also considered. However, this option would not be compliant with the existing resource consent and would require new resource consents for permanent structures in the CMA, which would delay the project and would likely have significant opposition. At that stage the cost of separate piers was estimated to be slightly higher and it was decided to proceed with the design of the AHB-supported option and to mitigate the risk of damage to the existing piers from new loads through a rigorous design and peer review processes.

Some of the constraints on the structural design included:

- The design must not add significant additional loads to the pier concrete in sections that directly support the extension bridge brackets;
- The bracket connection must introduce loads to piers in a way that avoids generating concentrated secondary effects;
- The design should only require modifications to the existing structure; and
- Stability and strength of the existing bridge was to be confirmed.

Investigations required to provide critical design information for the AHB-supported structure were carried out during the Specimen Design stage. These are summarised in Section 3.

The Structures Options Report and the Minimum Requirements that resulted from the design development process were reviewed and approved by subject matter experts (SME) from Waka Kotahi NZ Transport Agency. The SME's consulted include Barry Wright, National Structures Manager, Dante Legaspi, Principal Geotechnical Engineer, Simon Kennett, Senior Multi-modal Specialist, and Sam Bourne, Principal Advisor, Urban Design and Landscape. There are many constraints and design considerations that need to be addressed in other aspects of design including bridge architecture, urban design, design for walking and cycling, cultural values and affordability. However, this report is intended to summarise structural, geotechnical and consenting issues related to the AHB bridge component of the project only.

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3 Investigations and Outcomes

During development of the concept design of the AHB-supported structure some gaps were identified in design information needed to confirm the feasibility of the proposed option. Lateral load effects from wind and seismic loading were found to pose critical design challenges for the structure and its foundations.

Wind loading for the Northern Pathway structure is affected by the adjacent AHB bridges. Wind tunnel testing was carried out to provide data for design.

A Site-Specific Seismic Hazard Assessment (SSSHA) was completed to provide appropriate design loading spectra for the AHB in the Waitemata Harbour location.

The wind and seismic load effects were found to be critical for the existing bridge piers and foundations. Reliable geotechnical data was needed to assess the effects of design loading on the substrata. Geotechnical site investigations were completed to fill gaps in available information on ground conditions and rock strength beneath caisson foundations of the AHB. This required mobilisation of barge-mounted drilling rigs in the harbour to core samples of rock close to the base of the piers in early 2020.

For the AHB-supported structure, a key design constraint is the support of pedestrian loads in combination with existing bridge dead and live loads without overstressing the existing substructures. Dead and live loading on the AHB was derived from previous assessments completed by Beca.

The effects of pedestrian-induced vibrations on long spans were also assessed to address user comfort.

The main outcomes of these investigations and the implications for the Specimen Design of the structures are summarised below. A full description of the derivation of the loads used for the assessment is described in G.1.2 Structural Design Standards.

3.1 Wind tunnel testing

Wind engineering specialists, MEL consultants, carried out testing of scaled sectional models of the bridge decks in Spans 2 and 4 in a wind tunnel in Melbourne in early 2020. Data from the testing was used to derive the wind loading to be applied to the Northern Pathway bridge. Previous wind load assessments by Beca were used to derive the design wind loading applied to the AHB truss and extension bridge structures.

3.1.1 Wind vibrational response

During wind tunnel testing a vibrational response issue was identified for the Northern Pathway bridge which showed significant vertical excitation under a range of wind speeds. Testing showed large amplitude oscillations of the deck particularly in the longest span, Span 2, that was assessed to be unacceptable. Options for controlling vibrations aerodynamically were tested and it was concluded that additional damping was required.

An assessment of the feasibility of viscous dampers provided to limit excessive vibrations was carried out by Beca. This showed that viscous damping could be applied to effectively control the vibrational response of the Specimen Design. This study is described in document G.1.8 Preliminary Assessment of Viscous Dampers in Controlling Wind-induced Motion.

It is recommended by the wind engineering specialists that further wind tunnel testing of full aeroelastic models of the Northern Pathway and AHB bridges is carried out during design development to enable a refined assessment of the final design and the dampers required.

3.2 Seismic assessment

The AHB is a critical piece of Auckland's transport infrastructure and a detailed assessment of its resilience to earthquakes is necessary. The addition of the Northern Pathway to the structure led to a detailed analysis of the seismic performance of the bridge.

A new SSSHA was prepared in 2020 to generate the design loading spectra for assessment of the AHB piers. Complex analysis of the performance of the bridge under maximum considered earthquake loading was required to assess the effects of rocking foundations on the reinforced concrete pier and founding rock. Non-linear time history analysis was carried out together with a non-linear push-over analysis, using a finite element model of the pier. The effect of the founding rock deformation was modelled in the analysis using information obtained from the site investigation and geotechnical modelling carried out for this project.

The overall outcome of the seismic analysis was that the critical piers were found to comply with assessment standards, and it was concluded that ULS wind load effects were more onerous than the seismic case.

3.3 Geotechnical investigations

Original borehole data from the construction of the AHB in the 1950's did not provide sufficient information regarding rock strength at the piers for the detailed analysis of substructure foundations under wind and seismic loading. Therefore, site investigations were carried out in early 2020 to retrieve rock samples from boreholes adjacent to each pier for laboratory testing. The laboratory testing was completed in May after the nationwide COVID-19 Level 4 and3 lockdown periods. This provided the data necessary for a detailed computer analysis of the rock stresses when wind and earthquake loading are applied to the bridge.

The outcome of the geotechnical investigations was that rock strength was found to be lower than anticipated at the concept design stage, for some piers. Differing ground conditions were discovered across the critical foundation at Pier 2 and a potential fault was identified on the western side of the AHB.

A Plaxis 3D model used geotechnical data from recent and historical site investigations to develop a three-dimensional ground profile at Pier 2. The structural demands were applied to the Plaxis 3D model in an iterative process to obtain stress-strain conditions beneath the foundation. Further detail of the Plaxis analysis is discussed in G.1.6.1 Preliminary Geotechnical Assessment Report. The results of this complex soil/structure interaction assessment are summarised in Section 4.1 below.

3.4 Pedestrian and live load design

While wind and seismic loading are critical for the AHB substructures, the combination of dead and live loads was found to be critical for the Northern Pathway superstructure and the connection of the pier brackets to the AHB piers.

Live loads include traffic loading on the AHB and pedestrian loading on the Northern Pathway. Traffic loading was taken from previous assessments and design of strengthening for the AHB truss and box girder structures. This includes bridge-specific assessment live loads derived from data measured from vehicles crossing the bridge to represent AHB traffic lane loading. The load combinations for dead and live loads effectively applied the maximum possible traffic loading the AHB superstructures can carry.

Pedestrian loading is derived from design standards for the box girder structure. Standard pedestrian loading intensity depends on the length of the span being designed. The loading applied effectively represents a limit on the number of users of the bridge at any one time. From a safety perspective it was assessed at high level that the maximum user numbers calculated from design pedestrian loading could evacuate the bridge safely in an emergency. The number of users will need to be monitored during operation of the bridge.

For long-span structures like the Northern Pathway the effects of synchronous pedestrian-induced vibrations also need to be checked. An assessment of vertical and horizontal vibrations from groups of pedestrians walking in step showed that the Specimen Design complied with the appropriate standards.

4 Alternative Substructures Considered

4.1 AHB supported substructure

The new Northern Pathway Bridge is proposed to be attached to the existing AHB piers in a similar way to the extension bridge support brackets by adding a hollow steel bracket to the eastern edge, supporting a vertical column to carry the new steel superstructure. The new brackets are wider than the existing extension brackets enclosing them to minimise visual impact and reduce work below water level on the shorter piers. The existing extension brackets occupy the full width of the pier so new concrete panels are added to the north and south pier faces to attach the new brackets. These panels are prestressed to distribute forces across the full width of the piers and strengthen the existing walls to resist the local combined demands of the new and existing bridges.

The AHB-supported substructure is shown on Specimen Design drawings and the assessment of load effects on the AHB piers is described in detail in document G.1.4 Preliminary Structures Assessment Report.

A key objective of the Specimen Design was to develop a concept to support the Northern Pathway from the existing AHB without additional foundations on the seabed.

However, it was found from the recent geotechnical information obtained from the latest site investigations that founding rock capacity is significantly lower than had been assumed at concept stage, and additional means of reducing demands on the foundations were required.

More detailed assessment using data from wind tunnel testing was carried out applying ULS wind loading for a 1/2500-year Annual Probability of Exceedance (APE) event. This refined analysis showed the flexural capacity to be exceeded in some piers at ULS.

This led to the development of the concept of stressed tendons added to the western side of the pier to counter some of the eccentric dead load effects applied by the Northern Pathway Bridge and reduce demands on the substructure and foundations where required. A series of options for the counterbalance tendon concept was investigated including:

- Vertical tendons stressed between new pier brackets and single large tension piles at sea level (Option 1);
- Vertical tendons connected to smaller tension piles (Option 2);
- Inclined tendons connecting concrete strengthening panels to inclined ground anchors; and
- Inclined tendons stressed between pier brackets and inclined ground anchors (Option 3).

Concept sketches of the options assessed are shown in Figure 4.1 below.

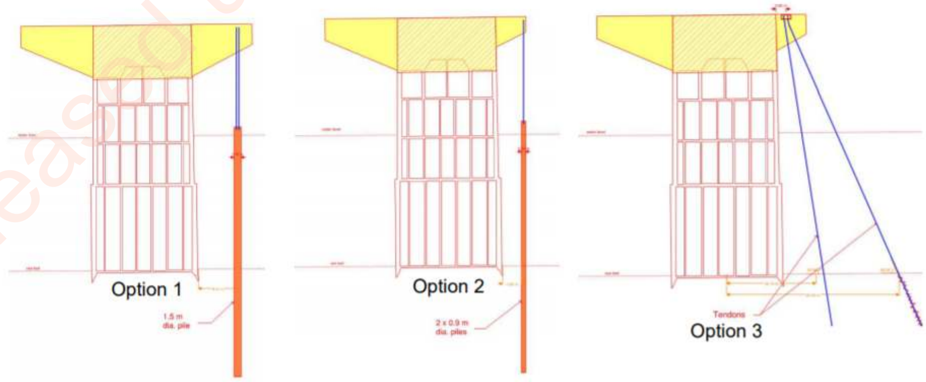

Figure 4.1: Concept sketches for Pier 2 counterbalance tendon options

The inclined ground anchors (Option 3) was taken forward to Specimen Design because these anchors were assessed to minimise impacts on the seabed compared to piled options. This concept is shown in outline in Figure 4.2 below. Note that marine navigation features and a protection structure against vessel impact will be required which may include fender piles at some piers.

The geotechnical issues that arose from recent site investigations, the assessment of foundations and options for tie-down elements are described in more detail in document G.1.6.1 Preliminary Geotechnical Assessment Report – AHB Existing Foundations.

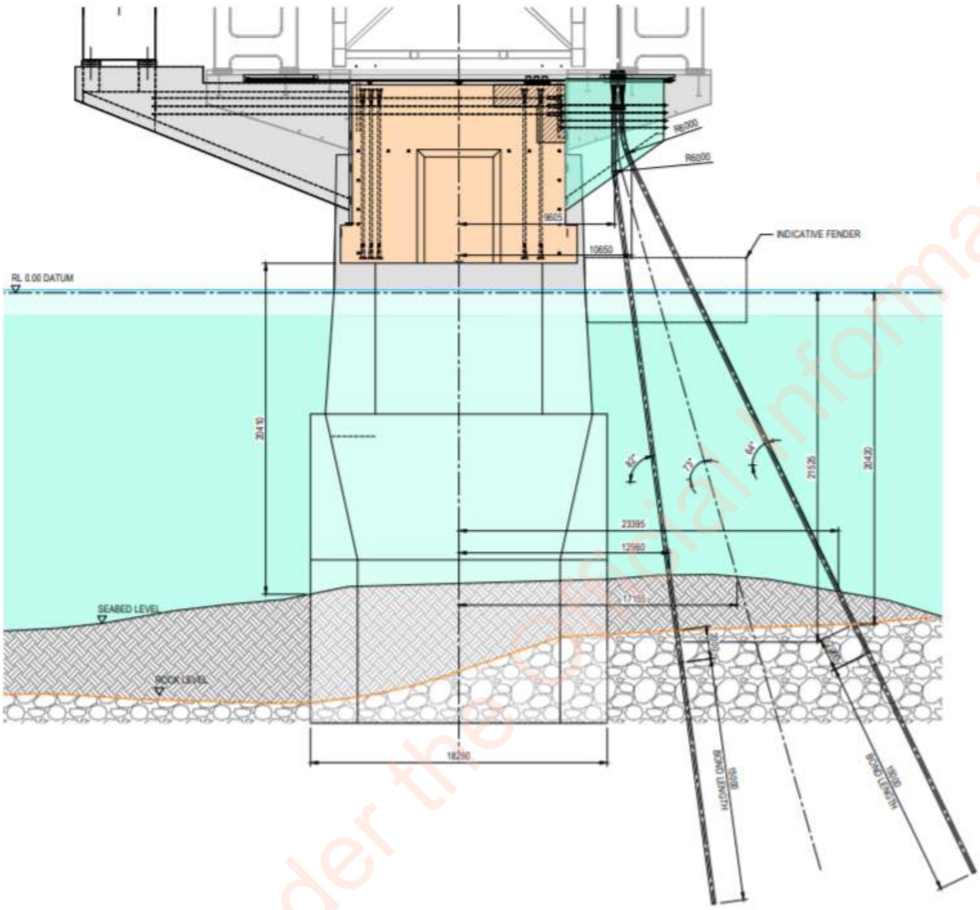

Figure 4.2: Specimen Design sketch showing inclined counterbalance tendon concept

The concept has been assessed for the two different types of AHB pier. It was found that Pier 2 is the worst case for the arger pier section, and Pier 4 is the worst case for the smaller pier section. Pier 2 was found to have added complexity in the geotechnical assessment due to the potential presence of a fault, inferred from bathymetry on the west side of the existing structure. This required ground anchors to be located to avoid the fault Further ground investigation is necessary to confirm the location and orientation of the fault plane and to provide information on ground conditions on the west side of all piers since only limited borehole data is currently available.

Design development of the concept is required to confirm the solution for all six piers once the site investigation data is available. Further geotechnical analysis will optimise the design and confirm the number of piers requiring counterbalance and the size and extent of counterbalance tendons required. A conservative approach was taken in the assessment for the inclined ground anchor concept indicated in the Specimen Design and further assessment and design is expected to result in a reduction in the number of tendons required and the use of vertical tendons or piles at many of the piers. This would likely mean any vessel impact protection could be supported directly off existing piers in many cases.

A further complexity associated with the AHB-supported structure at Piers 5 and 6, the lowest southern-most piers closest to Westhaven, is that the Northern Pathway pier connections need to be constructed below water level. Construction of the pier strengthening needs to be carried out in a dry zone within a temporary cofferdam or caisson. The new pier brackets are proposed to be fabricated using stainless steel to minimise ongoing maintenance liabilities for Waka Kotahi. An extract from the Specimen Design drawing for Pier 6 is shown in Figure 4.3 below with Mean High-Water Spring (MHWS) tide levels indicated by a blue dashed line in the elevation. For details refer to the Specimen Design drawing set.

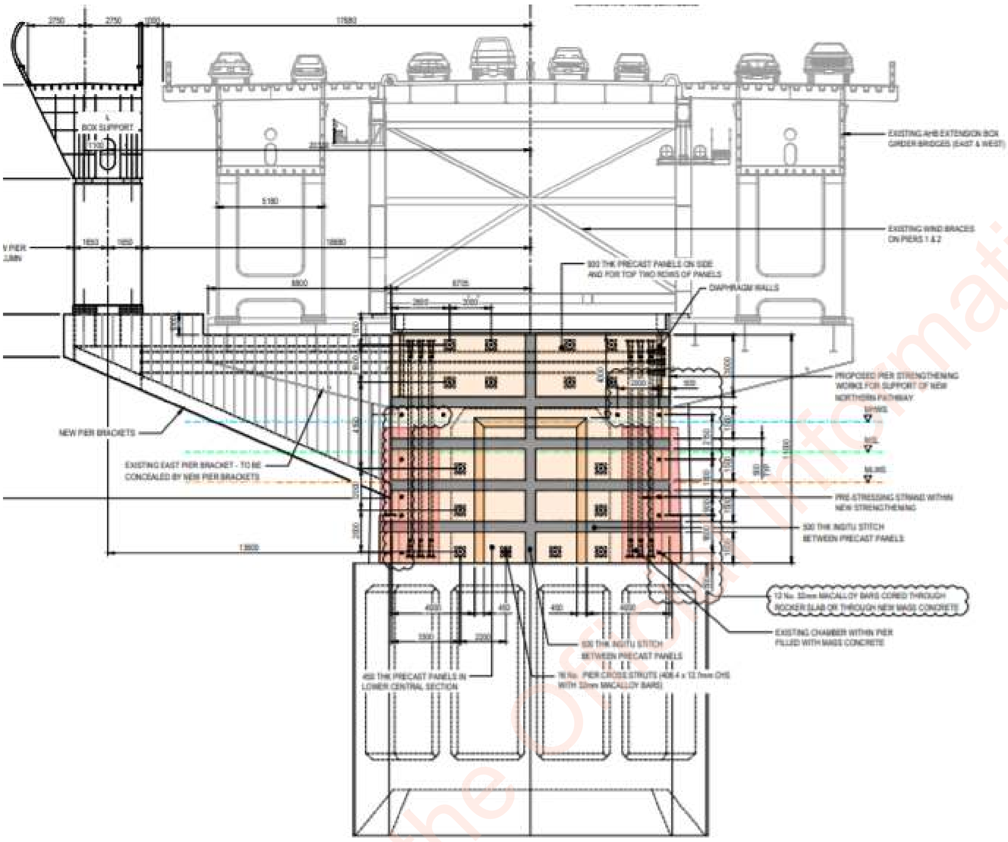

Figure 4.3: Elevation of Pier 6 showing pier bracket connection below water level

4.2 Independent substructure

An alternative concept for independent piers was evaluated at an initial concept level for comparison purposes only. It was found that for the larger piers at Piers 1, 2 and 3 where load effects are greatest, significant foundation structures would be required. Foundations are assessed to comprise groups of four large diameter bored piles socketed into the substrata beneath the seabed on the eastern side of the AHB piers. Piles would be connected by a concrete pile cap (approximately 14m x 10m x 3m deep) constructed below wa er and exposed above high tide level, supporting columns up to 35m in height. The smaller Pier 4 may be supported by 2 large bored piles on a smaller pile cap. For Piers 5 and 6, closest to Westhaven, where the piers are shorter and the harbour shallower, individual large diameter bored piles up to 3m in diameter are assessed to be required for the new foundations. The sketch below shows a cross-section of an initial concept for an independent structure at Pier 2.

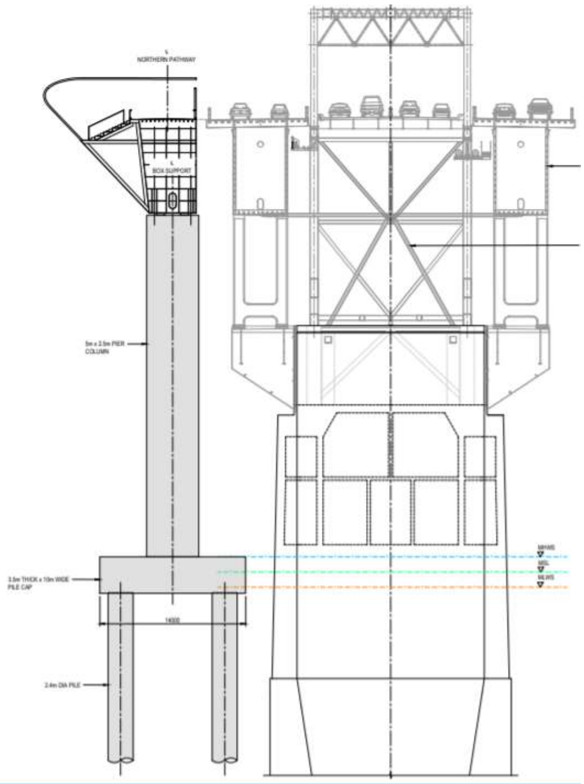

Figure 4.4: Cross-section sketch of Pier 2 showing the concept for an independent substructure option

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6 Technical Issues to be Resolved in iPAA stage

A review of risks for the project was carried out following with Waka Kotahi NZ Transport Agency standards during development of the Specimen Design. Project risk and safety-in-design documents have been provided to the Alliance. At a higher level, a review of residual risks and issues associated with the substructure was carried out to compare the AHB-supported proposal with an independent substructure after completion of the Specimen Design. The superstructure for the two options is similar and the risk profile for design and construction of the steel box girder deck is unchanged from that already identified in the risk register.

A summary of key technical risks and issues to be addressed for the two substructure options is shown in Table 6.1 below.

Table 6.1: Summary comparison of technical risks and issues for AHB-supported and independent substructure options

AHB-SUPPORTED OPTION		**INDEPENDENT PIER OPTION**	
Risk	Issues to be addressed	Risk	Issues to be addressed
Design			
The solution proves to be unworkable due to the complexity of design	Only piers 2 & 4 have been investigated to specimen design level others to be completed. All piers are different.	Transverse flexibility renders solution impractical due to requirement for significantly larger substructure.	Transverse stiffness of substructure – effect on superstructure
Design omission/error leads to potential poor future performance or damage due to unforeseen issues			Large piles adjacent to existing piers
Geotech proves worse than currently assumed after further site investigation	Geotech condition around Pier 2 fault zone plus other piers on west side require further investigation		Geotech information not specific for this option requires further investigation
Dynamic behaviour	Vibration of tendons in air and water	User comfort/vibration effects unacceptable	Transverse dynamic behaviour of slender piers
Construction			
Pier 5&6 connection below water safety risk	Cost allowance for added complexity	Construction of large diameter bored piles in deep water	
Condition of piers differs from design assumptions or as-built configuration differs			
Construction risk of damage to piers in-service from complex pier strengthening works		Damage to piers in-service during construction	The proximity of new and existing structures (1m gap)

AHB-SUPPORTED OPTION		INDEPENDENT PIER OPTION	
Risk	Issues to be addressed	Risk	Issues to be addressed
Inclined anchor construction	Construction methodology to be finalised		
Operation and Maintenance			
Durability of tendons	Inspection/repair/replacement of tendons		
Durability of the overall solution in the marine environment	Possible requirement for cathodic protection		
Damage to tendons from vessel strike or vandalism	Fender system concept	Damage to exposed pile cap in the navigation channel	Vessel impact protection

This comparison does not include an assessment of the risks and issues to be addressed with the superstructure or other sections of the project north and south of the AHB. These are very significant, but common to both options.

6.1 AHB-supported option: discussion of technical issues

6.1.1 Design issues

As outlined above there is significant complexity in the design of the pier connections of the AHB-supported substructure with a risk of damage to the existing piers in-service. Pier assessment and Specimen Design of strengthening has been carried out for critical AHB piers only at this stage. The combination of load effects on the concrete substructure from existing AHB bridges plus the Northern Pathway bridge has been assessed to exceed capacity in some locations and strengthening is required, including infilling some chambers of the reinforced concrete structures and stiffening existing pier walls. While the assessment to date has identified solutions to avoid exceeding assessment standards, further investigation and analysis are required for all piers. There is a residual risk that on completion of the detailed design and final assessment, the piers may not have adequate capacity as currently envisaged and design changes, departures from standards or additional stre gthening may be necessary.

6.1.2 Construction issues

The current condition of the concrete structures is assumed to be as shown on as-built drawings. Inspection, testing and investigation of pier condition is currently underway. There is a residual risk that the reinforced concrete structures are in worse condition than anticipated or that unexpected defects are found in the construction phase of the project which require additional works.

The risk of damaging the AHB structures during construction will need to be managed by the Alliance. While critical construction risks have been assessed to have a low likelihood of occurrence, the consequences could be extreme. It will be necessary for the Alliance to implement construction management procedures to mitigate the risk of a serious incident damaging the AHB.

Pier prestressing and counterbalance tendon solutions have ongoing maintenance requirements that will need to be addressed in detailed design.

6.2 Independent structure option: discussion of technical issues

The design of an independent foundation adjacent to the AHB piers has yet to be assessed in any detail. However, it is considered likely that tall slender piers on foundations in deep water will have design challenges regarding flexibility. Assessment of lateral load effects on the tall piers (e.g. from wind and seismic loading) could lead to changes being required to the concept of the superstructure.

Construction of foundations in the harbour adjacent to the AHB is also complex but with a potentially lower risk of damaging the AHB. Vessel impact protection for the piled structures in the harbour may also be complex, but there are fewer durability risks and maintenance liabilities without tie-down tendons and prestressing.

The issues around consenting, stakeholder and partner liaison, visual and environmental impact assessment have not been addressed for the independent structure option. These consenting issues related to the addition of tie-down tendons to the Specimen Design also need to be addressed as summarised in Section 5.

The Alliance will need to evaluate all options for the implications on cost, risk and programme.

The two alternatives have been reviewed in this document for comparison purposes only and are not intended to be taken as the only options available for the Alliance to consider during the ITC design development.