# Seascape Project - Review of Diaphragm Wall Defect Report

Prepared for Auckland Council
Prepared by Beca Limited

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# Contents

## Revision History

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| 1 | **Ronald King** | Issued for Auckland Council Use | 20/12/2019 |
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## Document Acceptance

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| Prepared by | **Ronald King** |  | 20/12/2019 |
| Reviewed by | **Rob Jury** | | |
| Approved by | **Vincent Lobendahn** |  | 20/12/19 |
| on behalf of | Beca Limited | | |

# Executive Summary

The report by the Developer on far face defects in the upper 5 to 6m of the Seascape Project diaphragm retaining wall appears to say that known defects on the far face of the wall were not repaired and that there is no need or intention to carry out a repair.

The basis for this position appears to rely on two key points. One is provided by Mott MacDonald that wall design was governed by waterproofing performance so that structural capacity is or would be adequate despite the existence of far face defects. The other is provided by SOL Expert who propose that reinforcing exposed to bentonite inclusions will not corrode.

It is our opinion that the evidence provided in support of CCNZL's arguments is not sufficient to remove reasonable doubt that the strength and durability of the basement walls may be lower than the design intended or may be below the minimum standard required by the NZ Building Code. We have therefore suggested additional information that could be obtained from the Developer's experts to clarify if Building Code requirements have or have not been achieved.

CCNZLs report does not establish how the wall in its current state will meet the minimum requirements of the Building Code or if this is now different from the explanation provided in the building consent submission. We believe that Auckland City Council would be entitled to ask for confirmation that the means of compliance is unchanged and the justification for this, or, if it has changed, that this be supported by a revised PS1 and PS2 from the designer and peer reviewer, together with the justification for that position. A revised PS3 should then be sought for the revised construction details including the remedial works.

Defects on the near face of the wall were repaired to the satisfaction of the Designer Mott MacDonald, but are not the subject of the CCNZL report and are therefore not covered by our review.

# 1 Background

This report has been prepared by Beca Limited ("**Beca**") solely for Auckland Council ("**AC**").

AC commissioned Beca to review a defect report presented by China Construction New Zealand Limited (CCNZL) relating to several concrete defects observed in the upper portion of the basement diaphragm walls constructed for the Seascape Project at 85 Customs St in Auckland. A copy of the CCNZL report titled, "Seascape Project – D-Wall Structure Far Face Verification, prepared by CCNZL, Auckland 31/03/2019", was provided to Beca by AC.

The scope of Beca's service is to review the CCNZL report and advise AC if the information provided can support CCNZL's position that the defects on the inaccessible retaining face of the wall are acceptable without repair ("**Scope**"). The purpose of Beca's report is to assist AC to determine whether additional evidence is required to ensure that the Building Code requirements have been met ("**Purpose**"). This report has been prepared and provided to the Client solely for the Purpose.

Beca's responsibility is limited to the Scope and Beca will have no responsibility to AC or anyone else for services outside the Scope.

This report is confidential and is prepared solely for AC. The contents of this report may not be used by AC for any purpose other than in accordance with the stated Scope, nor may this report be relied on by any other party.

Our comments are provided per section of the CCNZL report, as are suggestions on what additional information may be useful to AC to increase confidence that the Building Code requirements have been met. The recommended requests for additional information are highlighted in the text below.

# 2 General Discussion

The CCNZ report is divided into 16 sections which provide input from various parties to the project. The report has no apparent structure or a statement on how the sections support a central argument. There is also no clear description of the nature and extent of the defects, or a clear description of whether repairs to full depth defects went to the back of the far face. Importantly there is no coherent argument on why repair of far face defects would not be needed to meet Building Code requirements of strength and durability. We have therefore reviewed each section of the report at face value to build our own understanding of CCNZL's position and have commented based on that understanding.

We understand that some of the known defects were through the full thickness of the wall, but it is not clear if these were completely repaired or if some remain on the far face of the wall. It is possible that there are also unknown defects on the far face of the wall, and it appears that some of the evidence provided is aimed at demonstrating that the likelihood of this is low if there is no defect on the exposed face. Clarification of these points should be sought.

No mention has been made of flexural or shear demands in the temporary or permanent state at the position of the defects or on the potential consequences of reinforcing being unbonded or corroding in the long-term. Although Mott MacDonald states that "imperfections … are relatively small" it is difficult to come to this conclusion based on the observations made from the near face and the noted difficulty of observing the far face.

CCNZL's approach to closing the defect report appears to rely mainly on evidence provided by SOL Expert (SOL), that reinforcing surrounded by bentonite or a mixture of bentonite and concrete would be fully

protected from corrosion because of steel passivation in an alkaline environment, and Mott MacDonald's argument that waterproofing performance governed wall design.

# 3 Discussion of Sections contained in the CCNZ Report

## Section 1 – CCNZL Summary

A single page extracted from another 19-page report forms the opening chapter of this report and is assumed to convey CCNZLs position on the defects, particularly regarding far face defects that have not been repaired. This states that "(the) D wall met the structural capacity/integrity requirement", that "pH zone protects D wall reinforcement from corrosion" and that they are "confident that the D-wall structure has expected structural integrity".

It is understood from this that CCNZL has not and does not intend to repair defects on the retaining face of the wall.

**We will comment on the remaining sections of the report in a sequence that proceeds from background information to conclusions presented by CCNZLs experts, since we think this will provide a clearer understanding of the issues.**

## Section 5 – March Forensic Report

March provides a reasonably comprehensive description of the defects observed with possible explanations on how they occurred. Although March notes that some concrete was 5 and 6 hours old when placed they conclude that the concrete supply and bentonite quality were generally acceptable as no non-conformance reports were issued relating to concrete placement.

March states that the observed wall defects contain inclusions of bentonite, a mixture of bentonite and soil and a mixture of bentonite and concrete. These appear to be limited to the upper 5 to 6 metres of the wall and are confined to approximately 6 locations around the perimeter of the basement wall. Two types of defect are described:

- One type has bentonite and or soil contamination through the full thickness of the wall. March proposes that this may have been caused by large overbreak of the excavation allowing contaminated concrete to flow upwards outside the steel cage then being forced back inside the cage where the excavation narrows near the top of the wall.
- Another type of defect is described as "mattressing" which only occurs in the cover concrete and is believed to be caused by concrete of low workability being squeezed outwards through the cage, trapping bentonite in the process.

March describes the following defects which they describe as important:

- Panel E04 – full depth defect with concrete extending beyond the intended far face
- Panel N03 – full depth defect with concrete extending beyond the intended far face
- Panels S02 and S03 – "mattressing"
- Panels N07 – "unsound concrete"

All other defects are described as "localised" and "superficial" and no others are listed or described. However, in their report are photographs that appear to show significant defects in panel E03 and there is later reference to defects in panel W06.

The photographs in March's report appear to have been taken when the excavation depth was about 5m below the capping beam. A schematic representation of the defects, especially unrepaired defects, on an

elevation of the wall would have been useful to clarify the extent and significance of all significant defects and for record purposes.

It is recommended that AC request this information, also covering the remainder of the wall when excavation proceeds.

March's description of ground conditions is of interest when considering the potential existence of undetected defects and the risk of reduced durability and strength at sites where defects were not repaired. The following points were made by March:

- the upper soil strata at the site includes permeable soils consisting of reclaimed land fill, alluvium and marine soils,
- soil permeability was so high in places that pre-treatment using cement/bentonite slurry seal was needed to prevent bentonite loss,
- ground water at the site is tidal

These statements appear to indicate a reasonable risk that the soil and ground water may contain chlorides with a high replenishment rate, so that exposed steel may have a high risk of corrosion.

There is no information in any part of the CCNZL report on ground water/soil quality and chloride content,and evidence that the reinforcement is not always embedded in bentonite or concrete. It is recommended that AC request this information and that it be commented on by SOL Expert.

## Section 6 – Excavation below Ballantyne House Basement Slab on Grid Line 8

This presents photographs that appear to show reasonable concrete quality on the retaining face 1.5m below ground level, but no description of precise location or if there is a correlation with known defects on the opposite face. The photographs appear to have no relevance to the question of whether defects on the retaining face are acceptable.

## Section 7 – 3D Survey and Inclinometer Monitoring

This data does not appear to be relevant to the issue of whether defects on the retaining face of the upper portion of the D-wall are acceptable.

## Section 8 – Wall Inspection Over Next 3 Months

A single drawing is provided showing a plan view of the basement capping indicating the general location of cracks in the capping beam. The reason for including this is not stated and does not appear to be relevant to the issue of defects on the retaining face of the D-wall.

## Section 9 – Horizontal Cores at W06

This section covers a trial carried out to check if GPR or ultrasonic tests could detect the far face of the wall or defects in the wall, and cores taken horizontally from wall panel W06 through sound concrete and repaired area. There is no discussion of what was learned from these trials.

The photographs show large defects with exposed near face reinforcing in a panel labelled W06, directly below the capping beam. It is not clear from the photographs if these defects were full thickness or "mattressing" type. Other photographs show the same area after repair and the cores taken from the repaired area. We note that the cores do not appear to be long enough to provide information on the condition at the far face of the wall.

It is noted that March's report (Section 5) does not mention defects in panel W06, so it is recommended that AC request information on these defects, including if the defect was through the full thickness and was

repaired full thickness. If these were mattressing type, request advice from March on the likelihood of similar defects existing on the far face.

## Section 10 – Horizontal Cores on E04, E05 and E06

This section provides test data from concrete cores extracted from panels E04 to E06 together with an excerpt from the March report that shows that concrete strengths were reasonable. However, this appears to have little relevance to the question of whether unrepaired defects are acceptable on the far face.

## Section 11 – Vertical Core through Wall Panel W02

Photographs are provided that show vertical coring and endoscope images, apparently from panel W02. W02 is not reported to have defects of the type in question, so the relevance of this to the issue of whether unrepaired defects are acceptable on the far face of the wall is unclear.

## Section 12 – Sheet Piling and King Post as Far Face Formwork

This section is not relevant to the issue of whether defects are acceptable on the far face of the wall.

## Section 13 – Vertical Core Drill at N07

This section contains photographs and site records for a vertical concrete core taken from panel N07, apparently close to the far face of the wall. It is noted that N07 is one of the panels with known defects described in the March report as "some unsound concrete in a localized area". The cover sheet for this section states that the core went to 4.2m depth but the site records and core photographs show that it went to 12.7m with no obvious defects indicated on the photographs.

## Section 14 – Additional Wall Liner on Grid lines 1 and A

This section provides a plan view drawing of the basement showing the location of a 600mm thick concrete liner constructed in front of the D-wall. It is noted that this liner only coincides with reported defects in panels N07 and W06 (refer earlier comments on Section 9).

The cover sheet to this section states that the liner can compensate for minor defects on the far face of the D-wall but with no explanation on how it could accomplish that, i.e. does the liner make the D-wall fully or partially redundant for strength and durability or would it only reduce the risk of leakage. There is also an excerpt of a Substructure Design Report which explains that the purpose of the liner is to transfer vertical reactions from the superstructure across vertical joints in the D-wall, but this does not discuss the permanent function of the D-wall and how the liner could mitigate the consequence of a defect on the far face.

It is recommended that AC request that Mott MacDonald comment on this.

## Section 15 – NDT Scans of Grid Lines A and H

This section contains a report on Impact Imaging investigations of panels N02, W06 and S03. It is noted that all three of these have known defects (subject to confirmation of points raised on Section 9 covering W06). This investigation covered small portions of wall 1.25m long. The report provides heat maps showing impact response magnification on a scale of 0.2 to 2.0 and states that any contours higher than 0.8 may indicate "inhomogeneous material composition". The heat maps have a horizontal scale of 1.25m and a vertical scale of 0.45m, which on the map itself is described as "width" and in the text as "distance in the vertical direction", so it is not clear whether the map is describing material composition across the thickness of the wall or to a depth of 0.45m. It is noted that two of the maps (Figures 4.2 and 4.3) are identical, so one must be wrong.

The images and associated text indicate that all three portions of wall contain significant zones of "inhomogeneous material", which would appear to allow interpretation as having reasonable potential for

defect. Despite this, and without explanation, the report concludes that the concrete in all three test portions is "good concrete". It is noted that Mott MacDonald comment in their letter that the NDT was "somewhat inconclusive".

An explanation of the conclusion of good concrete should be requested.

However, whether the vertical axis of the map is horizontal or vertical, the test volume is probably too small to be of much relevance to the issue, even if they do indicate good concrete.

## Section 16 – Reference Projects

This section provides images of similar defects on other projects, which is of no apparent value because context is not provided covering the functional requirements of the wall, exposure condition, concrete material, nature of the defect, wall capacity vs demand and how the defects were treated.

## Section 3 – SOL Expert Letter on Reinforcing Corrosion Risk

This section contains a letter from Sol Expert International (SEI) that discusses the risk of corrosion of reinforcing in bentonite inclusions. It makes a point that other diaphragm walls that lacked cover (the causes and extent of defects are not specified nor are similarities with the subject wall and defects) have previously been found to have surprisingly little corrosion on far face reinforcing after 40 years of exposure. While this may be interesting it is of little practical use in resolving the question of defects at 85 Customs St because of the many factors that could differently influence potential for corrosion at different sites.

SEI also provides a more scientific basis for considering corrosion potential on the far face of the wall, that being the Pourbaix correlation between pH and corrosion risk. A Pourbaix chart is presented that indicates that steel will be immune to corrosion or at least passivated against corrosion if the pH of the solution in which it is suspended is higher than about 9. They postulate that if the pH of Bentonite is 8.5 to 9 and is contaminated by concrete with a pH > 11, the pH of the mixture will always be higher than the passivation limit for steel. SEI concludes that the reinforcing will not corrode because of passivation and therefore no (remedial) action is required on the far face defects.

However, there are a few questions that should be answered before it could be accepted that reinforcing corrosion risk is low over the structures design life.

- March's forensic report states that the inclusions contained bentonite or bentonite and soil or concrete. SEI also mentions that the defects may contain soil. Depending on the pH of the soil and the proportion trapped in the defect it is possible that the pH in the vicinity of the reinforcing is lower than 9.

  Therefore, what is the pH of the ground water? Was the pH of the inclusions containing bentonite and soil/concrete mix measured? Would SEI's conclusion change if the defects are filled with soil or a bentonite-soil mixture or are unfilled (as can be seen in some photos and therefore completely exposed to ground water?

- It is understood that in the Pourbaix diagram the position of the passivation line varies depending on the chemical composition and molar concentration of the solution. In particular the presence of chlorides may allow pitting corrosion to occur even where high pH would normally indicate passivity.

  Has SEI considered the water quality data for this site and how the presence of chloride in the soil would alter the passivation limit on the Pourbaix diagram?

It is also noted that SEI has only commented on the issue of potential corrosion and they have not commented on potential strength loss from reinforcing not being fully bonded to sound concrete. This is discussed further under Section 2 for Mott MacDonald.

### Section 4 – Diaphragm Wall and Capping Beam Producer Statement PS3

Separate construction producer statements are provided by March Construction Ltd for the Diaphragm Wall and Capping Beam using the AC standard form. These cover NZBC clauses B1 and B2 for building work at Lot 1 DP 51212 with site address 71-77 Customs Street. 85 Customs Street is not mentioned.

It is noted that there is no PS4 from Mott MacDonald for these elements, but a letter from MM was provided to CCNZL commenting on the defects.

We query the validity of the current PS3 as the defects in the wall repaired or unrepaired are not in accordance with the construction documentation.

### Section 2 – Letter from Mott MacDonald on Remedial Measures and Substructure Sequencing

This letter was provided by MM to CCNZ to summarize agreements on remedial measures and consequence on the sequence of basement works. The cover sheet states that the walls were designed for waterproofing performance and that localized defects on the near and far faces of the wall have "very limited influence on structural capacity in the temporary case".

The letter states that the wall was designed to achieve Grade 1 waterproofing performance and goes on to say that because of the serviceability design requirements they are satisfied that the structural capacity of the wall would be adequate to allow propping to proceed with defects on the far face like those on the near face.

The letter also states that MM have reviewed and accepted the contractors repair strategy and that they have no objection to works continuing after completion of the agreed remedial works.

The letter does not specifically mention structural demands or capacity in the permanent case or comment on the risk or effect of potential long-term corrosion. Also, there is no comment on the loss of strength from unbonded reinforcing caused by bentonite inclusions in the cover zone. It is recommended that AC request that MM address these issues.

## 4 Review Conclusions

The type, size and incidence of defects observed on the front face of the wall indicate that there is a reasonably high probability that significant defects still exist on the far face of the wall. The defect report appears to conclude that there is no need to detect and repair far face defects.

The basis for the Developer's position appears to rely on two key points. One is made by Mott MacDonald that wall design was governed by waterproofing performance so that structural capacity would be adequate despite the existence of far face defects. The other is provided by SOL Expert who proposes that reinforcing exposed to bentonite inclusions will not corrode.

It is our opinion that the evidence provided in support of CCNZL's position is not sufficient to remove reasonable doubt that strength and durability of the basement walls may be lower than the design intended and may be below the minimum standard required by the NZ Building Code.

The highlighted portions of text in our review report provide suggestions of what additional information AC could request from the Developer to support the Developer's case.

This report should be read in full, having regard to all stated assumptions, limitations and disclaimers. No part of this report shall be taken out of context and, to the maximum extent permitted by law, no responsibility

is accepted by Beca for the use of any part of this report in any context, or for any purpose, other than that stated herein.