

INDEPENDENT STRUCTURAL INVESTIGATIONS REPORT

INVESTIGATIVE REPORT



17 APRIL 2025

PROJECT DETAILS

JOB DETAILS

JOB NUMBER	254019
JOB NAME	Petone Grandstand
ADDRESS	36 Udy Street - Petone Recreation Ground

CLIENT DETAILS

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SCOPE SUMMARY

Corrosion survey on the Grandstand Petone.
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REPORT DETAILS

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Job 254019



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1 PROJECT SCOPE

Concrete Structure Investigations Limited (CSI) were engaged by Sawrey Consulting Engineers Limited to undertake a comprehensive corrosion survey at the Petone Grandstand.

Our brief was supplied by Stephen of Sawrey Consulting Engineers Limited for cover mapping of steel, Half-Cell Potential investigations, Carbonation testing and intrusive investigations to conduct a comprehensive corrosion survey. The locations investigated were picked by CSI to suite the condition and the applied technique. The information/data taken on site has been analysed, peer-reviewed and provided in the below report.



2 METHODOLOGY

Half-Cell Potential testing was conducted to evaluate the probability of active corrosion occurring. The technique is neither suitable to provide a corrosion rate, nor to establish directly the actual state of corroded material. Refer to the section Limitations for more detailed information. Testing was carried out as per the ASTM C876 – 09.

Often it is possible to identify areas where corrosion is probable or active, and to establish a threshold through physical inspection. This threshold can be used as a baseline to map out areas of corrosion and to assume the condition of the bars. – This method cannot be applied at the Petone Grandstand for reasons described in the section Site Conditions and Implications.

Cover Mapping was used to estimate the concrete cover to the reinforcement. The alkaline PH properties of concrete provide a passive protection against corrosion. A minimum material thickness (cover) is required to achieving this.

A reduced cover protection due to carbonation (see below) cannot be picked up by cover mapping.

Carbonation Testing was carried out to understand whether carbonation reduced the effective concrete cover. Carbonation is the result of the dissolution of CO₂ in the concrete pore fluid as this reacts with calcium from calcium hydroxide and calcium silicate hydrate to form calcite (CaCO₃). The process penetrates the concrete at a rate proportional to the square root of time. An indicator solution is used estimating the depth of carbonation.

3 BUILDING LAYOUT



Figure 1: Building Layout - Grid Reference

4 SITE CONDITIONS AND IMPLICATIONS

During the investigations it became apparent that large parts of the building have been remediated to some extent. Initially it was thought that only some areas were repaired.

It was found that the walls on the outside have an added layer of cement (or concrete with small aggregate), see the photo below. The history of the remedial work is not known.

CSI assumes that widespread corrosion occurred on the reinforcement, and that low concrete cover was a contributor. Subsequently, the additional layer was applied to increase the cover depth to the steel. Sufficient cover can slow down or halt active corrosion. It is suspected that this approach has been partially successful, although the success was hampered by bad workmanship.

Because the state of the structure before the remedial work is unknown the Half-Cell results must be viewed with caution. During the investigation bars were exposed and found to have been severely corroded, although Half-Cell measurements returned higher (less negative) values. The values indicate that no active corrosion is occurring. It is likely that the reinforcement was corroded before the remedial layer was added, and that corrosion has been slowed down or halted. No threshold for Half-Cell Potential testing could be established to allow an estimate of the condition of the bars.

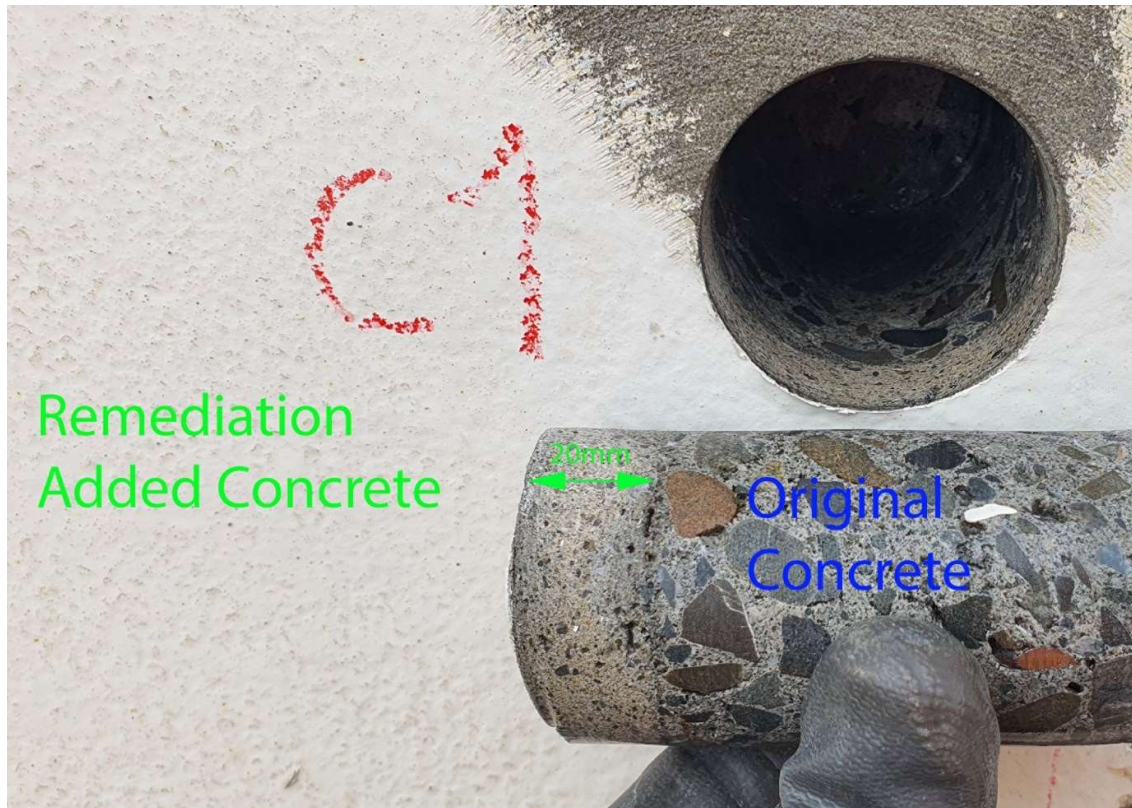


Figure 2: Wall - Added Layer



5 INTERPRETATION OF RESULTS

HALF-CELL POTENTIAL & COVER MAPPING

HALF-CELL POTENTIAL MAPPING

Due to the site conditions and the resulting implications results from the Numeric Magnitude Technique must be viewed with caution.

The table below shows the values for the Numeric Magnitude Technique. Maps have the colour allocations as depicted in the table.

Half – Cell potential (mv) relative to Cu-Cu sulphate Ref. electrode	Probability of Corrosion
Less Negative than – 200	90 % No Corrosion
Between – 200 to – 350	50 % (uncertain)
More Negative than 350	>90 % Possibility of Corrosion activity

COVER MAPPING

On the walls cover scanning was carried out to detect the vertical bars. Scans were taken with a spacing of 400mm. Data points should be joined in the vertical direction.

Whether the vertical or horizontal orientated bar is in front of the other was neglected, hence an additional tolerance of 9.5mm (one bar diameter) must be considered.

For beams and columns scans were taken to determine the cover thickness to the stirrups.

Cover maps show detections lower than 30mm in red, and from 30mm and greater in green.

Single low-cover data points do likely not relate to bars. In most cases these are assumed to be ties, although, some could be outliers of a different cause.

Ties, at low cover, can act like a “slow burning fuse” to initiate corrosion on reinforcing bars corrosion.

OVERLAY- HALF-CELL POTENTIAL & COVER MAPPING

Overlaying the two techniques allows to identify a possible correlation between low concrete cover and corrosion.

6 RESULTS

SOUTH WALL

HALF-CELL POTENTIAL & COVER MAPPING



Figure 3: South Wall - Half-Cell - Cover Map



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	South Wall Half-Cell Potential: • Blue shaded areas have a 50% probability of active corrosion Cover Map: • The reinforcing cover is $\geq 30\text{mm}$ • Most red data points are isolated detections, and likely relate to tie wires ○ Ties with insufficient cover can initiate corrosion ○ The corrosion from ties migrates deeper into the structure till it reaches the reinforcing, causing the bars to corrode		

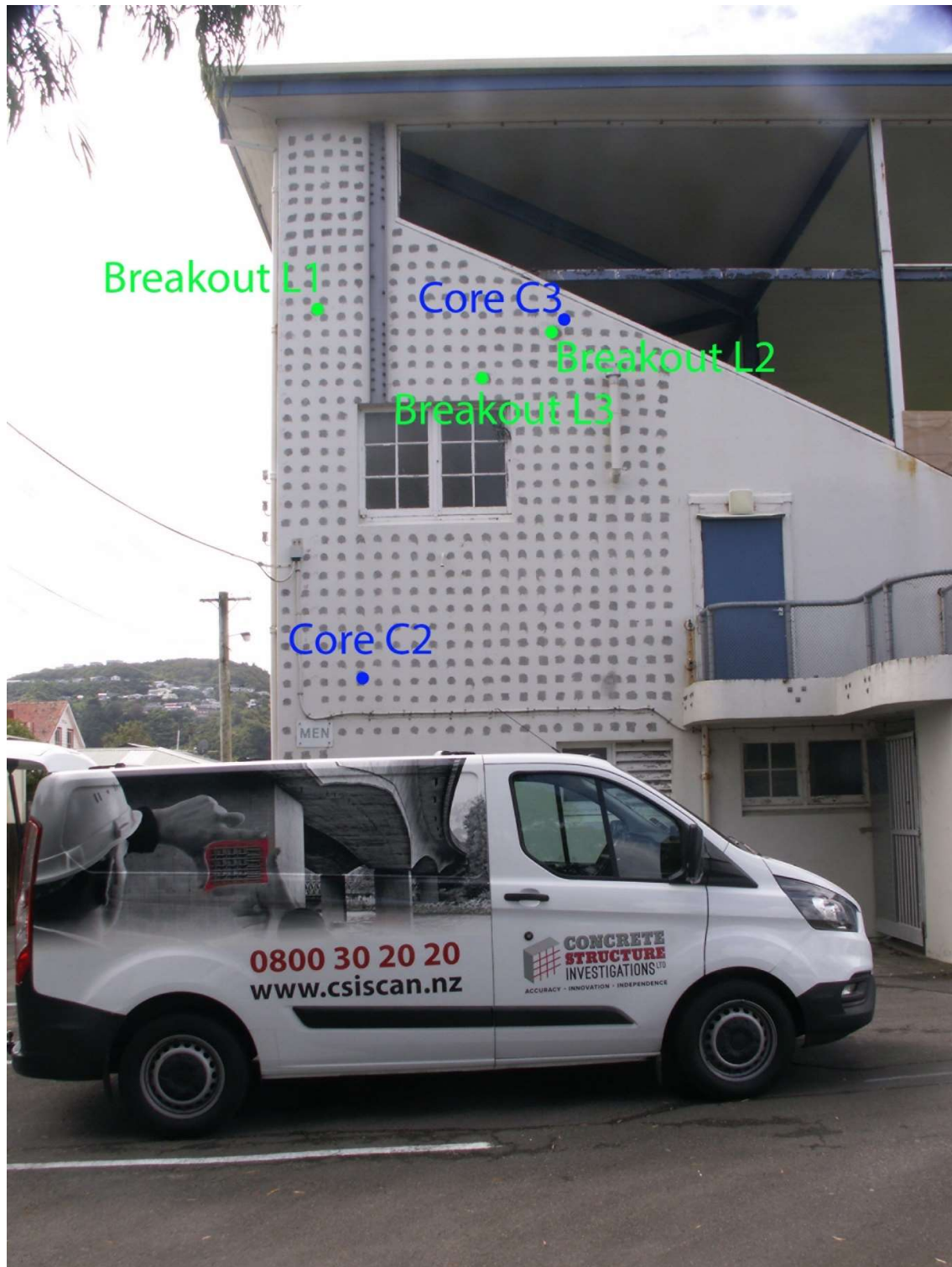


Figure 4: South Wall - Core and Breakout Locations



Figure 5: South Wall / South Face - Carbonation Testing



Figure 6: South Wall / North Face - Carbonation Testing

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	South Wall Carbonation: • South Face: ◦ Core C2: No carbonation is induced • North Face: ◦ Carbonation is apparent up to a depth of around 70mm ◦ The concrete does not provide any passive protection against corrosion Additional findings; • Shells are embedded in the concrete. It is possible that sand was sourced from estuaries containing potentially salts.		



Figure 7: South Wall / South Face - Breakout L1



Figure 8: South Wall / North Face - Breakout L2



Figure 9: South Wall / North Face - Breakout L2



Figure 10: South Wall / North Face - Breakout L2



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	South Wall Breakout: Breakout L1 – Column • Corrosion doesn't seem to be active • The main bar diameter is 32mm Breakout L2: • Active corrosion can be seen on the bars • Pitting is visible on the polished bars • The horizontal bar has a diameter of 9mm (the nominal diameter is assumed to be 9.5mm)		

HALF-CELL POTENTIAL & COVER MAPPING



Figure 11 North Wall - Half-Cell - Cover Map



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	North Wall Half-Cell Potential: • Blue shaded areas have a 50% probability of active corrosion Cover Map: • The reinforcing cover is $\geq 30\text{mm}$ • One area in the lower portion of the wall has cover values $< 30\text{mm}$ • Cover values $< 30\text{mm}$ (red) are observable for column reinforcing • Single red data points likely relate to ties wires ○ Ties with insufficient cover can initiate corrosion ○ The corrosion from ties migrates deeper into the structure till it reaches the reinforcing, causing the bars to corrode		



Figure 12: North Wall - Core and Breakout Locations

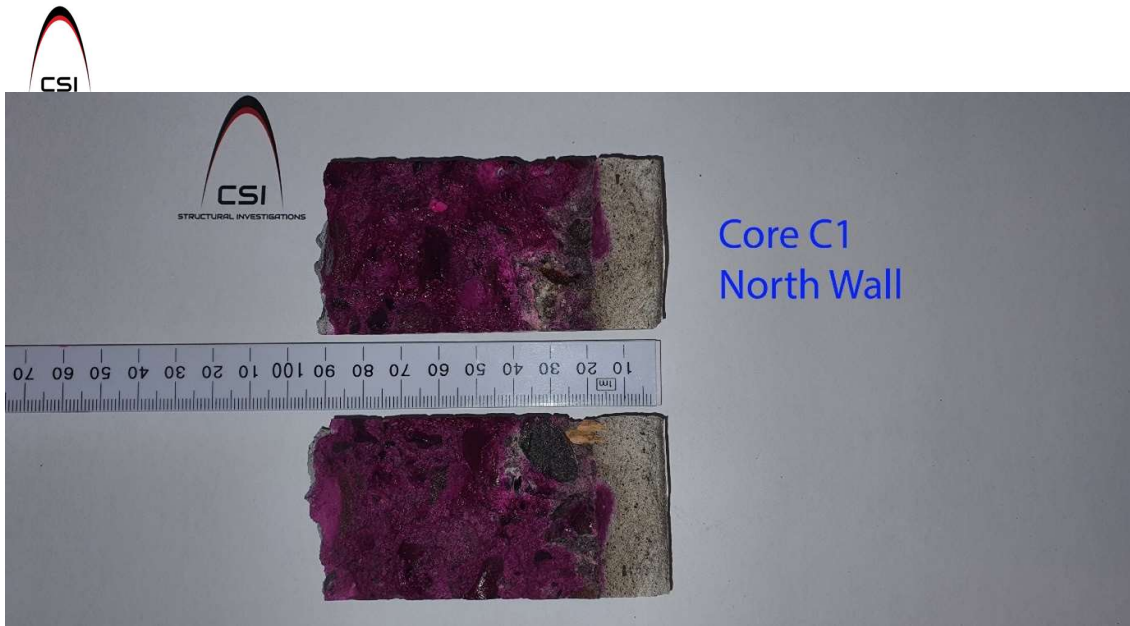


Figure 13: North Wall - Carbonation Testing

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	North Wall Carbonation: • North Face: ○ Carbonation is apparent throughout the added layer ○ The indicator suggests that the PH is lower for the first cm of the original concrete ○ Overall, carbonation to some level is apparent up to 30mm Additional findings: • Wood is embedded in the concrete		



Figure 14: North Wall - Breakout L1 & L2



Figure 15: North Wall - Breakout L3



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	North Wall Breakout L1 - The unpolished bar was measured to have a diameter of just below 10mm, the increased diameter is due to the volume expansion iron-oxide. Breakout L2 - Half-Cell testing indicates a 50% probability for active corrosion occurring - Some pitting is visible on the polished bars - The unpolished bars were measured to have a diameter of 10mm, the increased diameter is due to the volume expansion iron-oxide. Breakout L3 – Column - The main bar seems to have only a thin layer of corrosion - The diameter was measured to be 30mm (nominal diameter is 32mm)		



WEST WALL - GRID E-F

HALF-CELL POTENTIAL & COVER MAPPING

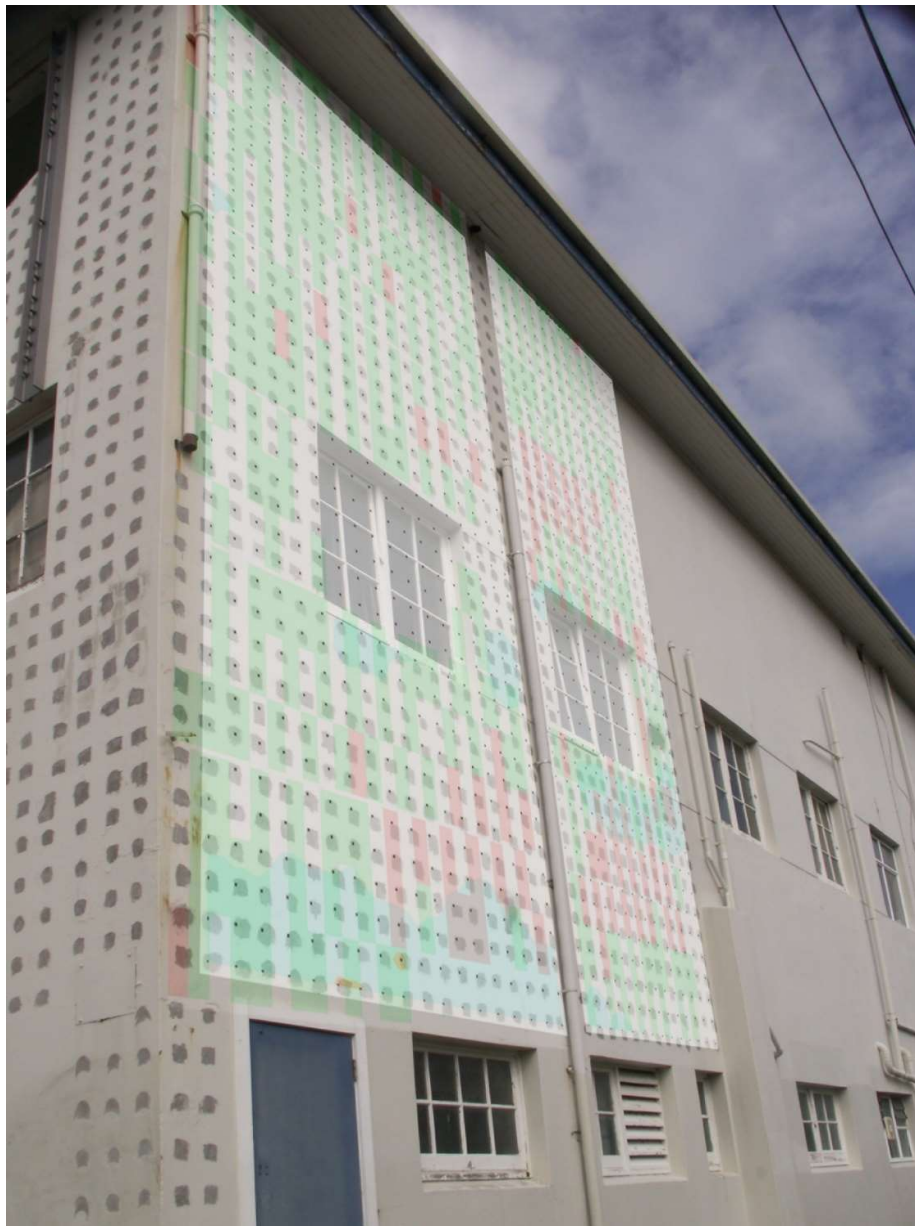


Figure 16: West Wall Grid E-F - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid E-F Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Large areas have reinforcing with covers < 30mm (red) - Some low cover reinforcing is within areas where Half-Cell testing has a 50% probability of active corrosion		



Figure 17: West Wall Grid E-F - Breakout Location



Figure 18: West Wall Grid E-F - Carbonation Testing

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid E-F Carbonation: - West Face: - Carbonation is apparent to a depth of 20-30mm Additional findings: - The added, remedial material is thinner than at other locations - Approx. thickness is 10mm		



Figure 19: West Wall – Grid E-F - Breakout L1

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid E-F Breakout L1 - The area was delaminated and some of the spalled material was removed - Half-Cell testing indicates a 50% probability for active corrosion occurring - The bar is severely corroded - A piece of timber is embedded in the concrete and in contact with the bar - Timber has a high absorption rate and may have contributed to draw and deliver moisture to the bar, which would have led to corrosion. - It must be assumed that the bar is in a similar condition as the exposed bar at the breakout L3 on the West Wall – Grid B-C		



WEST WALL - GRID B-C

HALF-CELL POTENTIAL & COVER MAPPING

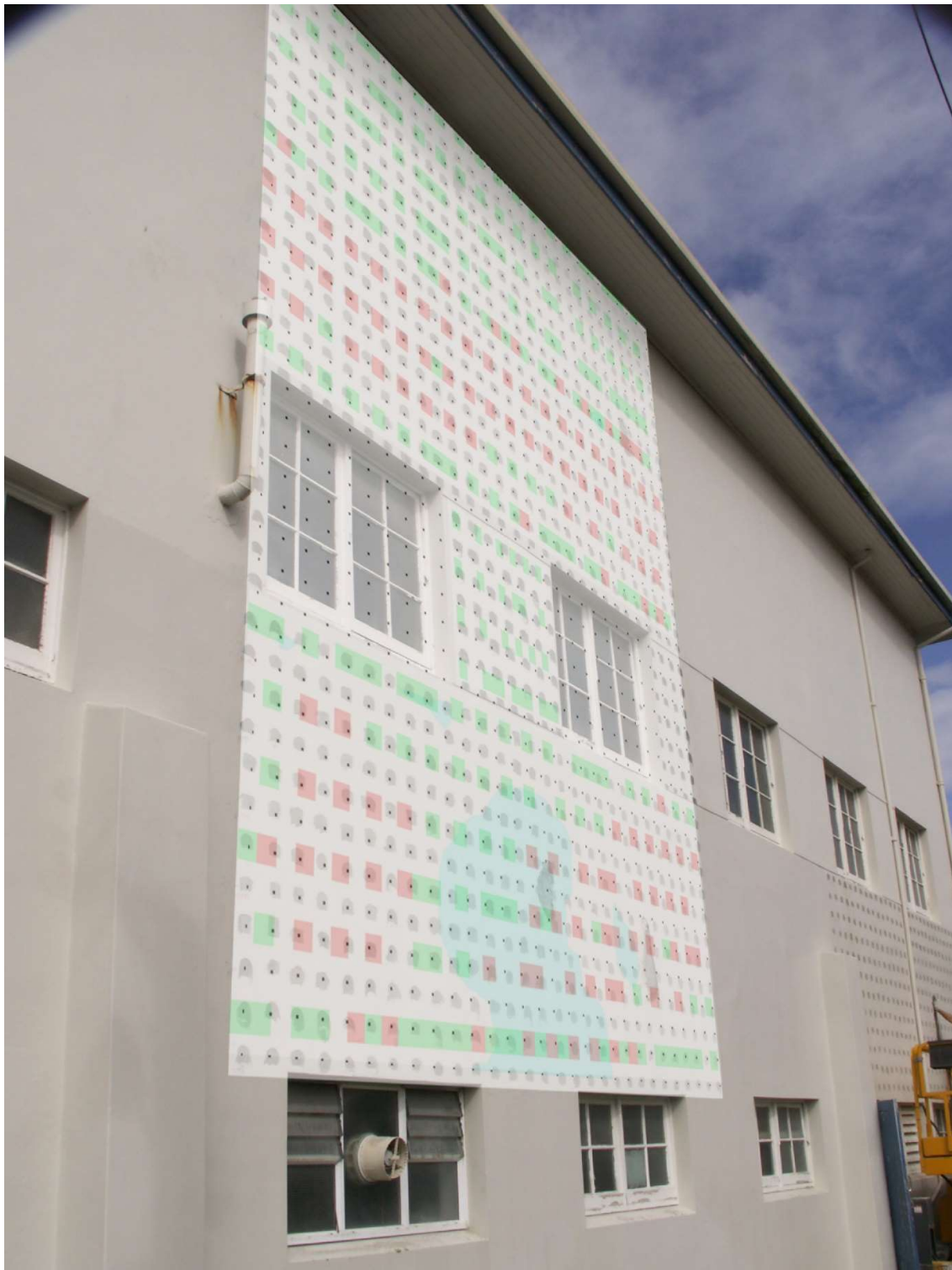


Figure 20: West Wall – Grid B-C - Half-Cell - Cover Map



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid B-C Half-Cell Potential: • Blue shaded areas have a 50% probability of active corrosion Cover Map: • Large areas have reinforcing with covers < 30mm (red) ○ Some low cover reinforcing is within areas where Half-Cell testing has a 50% probability of active corrosion		

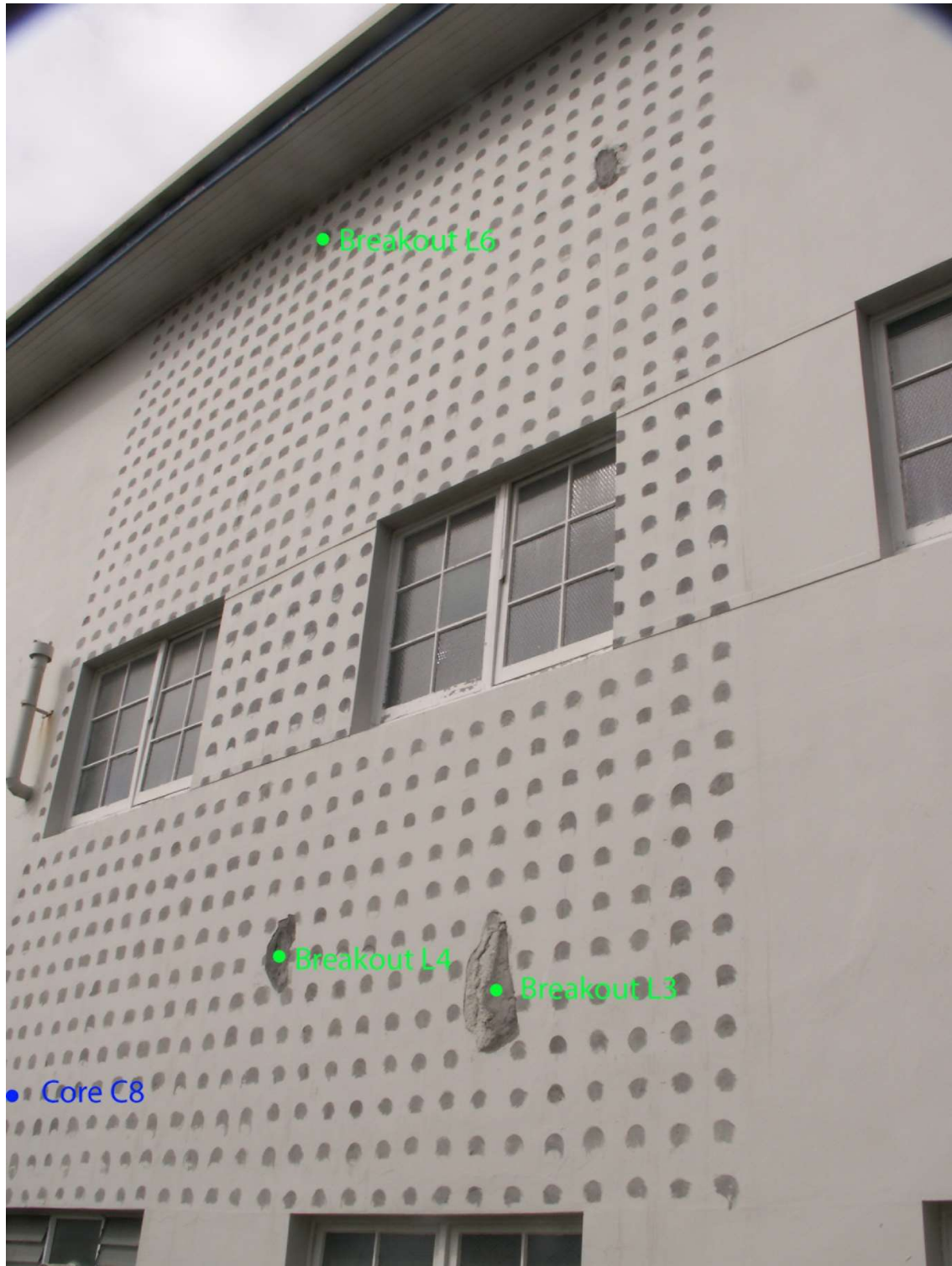


Figure 21: West Wall Grid B-C – Core and Breakout Locations

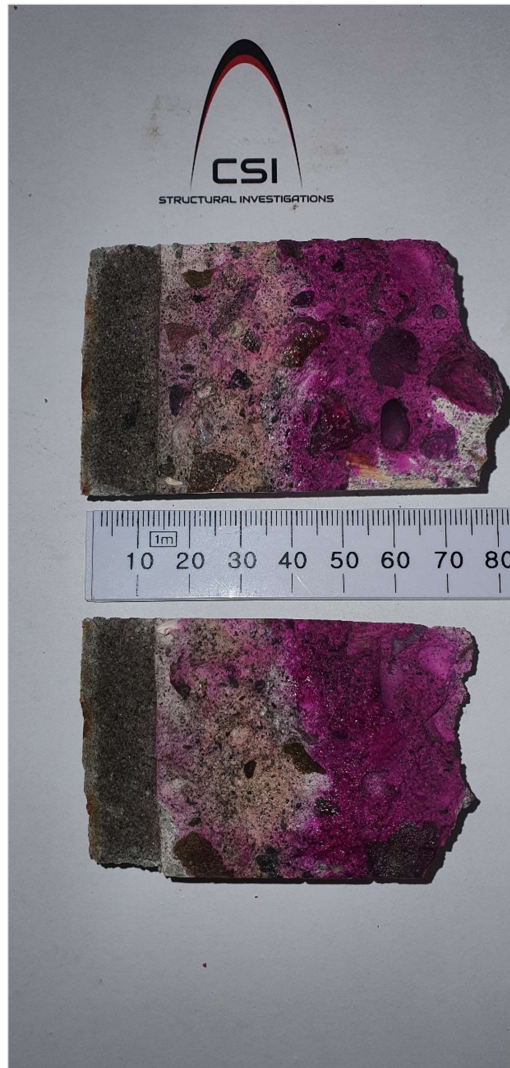


Figure 22: West Wall Grid B-C - Carbonation Testing

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid B-C Carbonation: - West Face: - Carbonation is apparent to a depth of 40-45mm Additional findings: - The added, remedial material is thinner than at other locations - Approx. thickness is 12mm		



Figure 23: West Wall – Grid B-C - Breakout L3



Figure 24: West Wall - Grid B-C - Breakout L3



Figure 25: West Wall - Grid B-C - Breakout L3

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid B-C Breakout L3 • The location had a spalled area, observed by CSI already two years ago • The reinforcing was exposed to the atmosphere and is severely corroded • The vertical bar has a remaining diameter of 3mm • The horizontal bar has a remaining diameter of 6mm • The concrete is porous, nested aggregates were found		

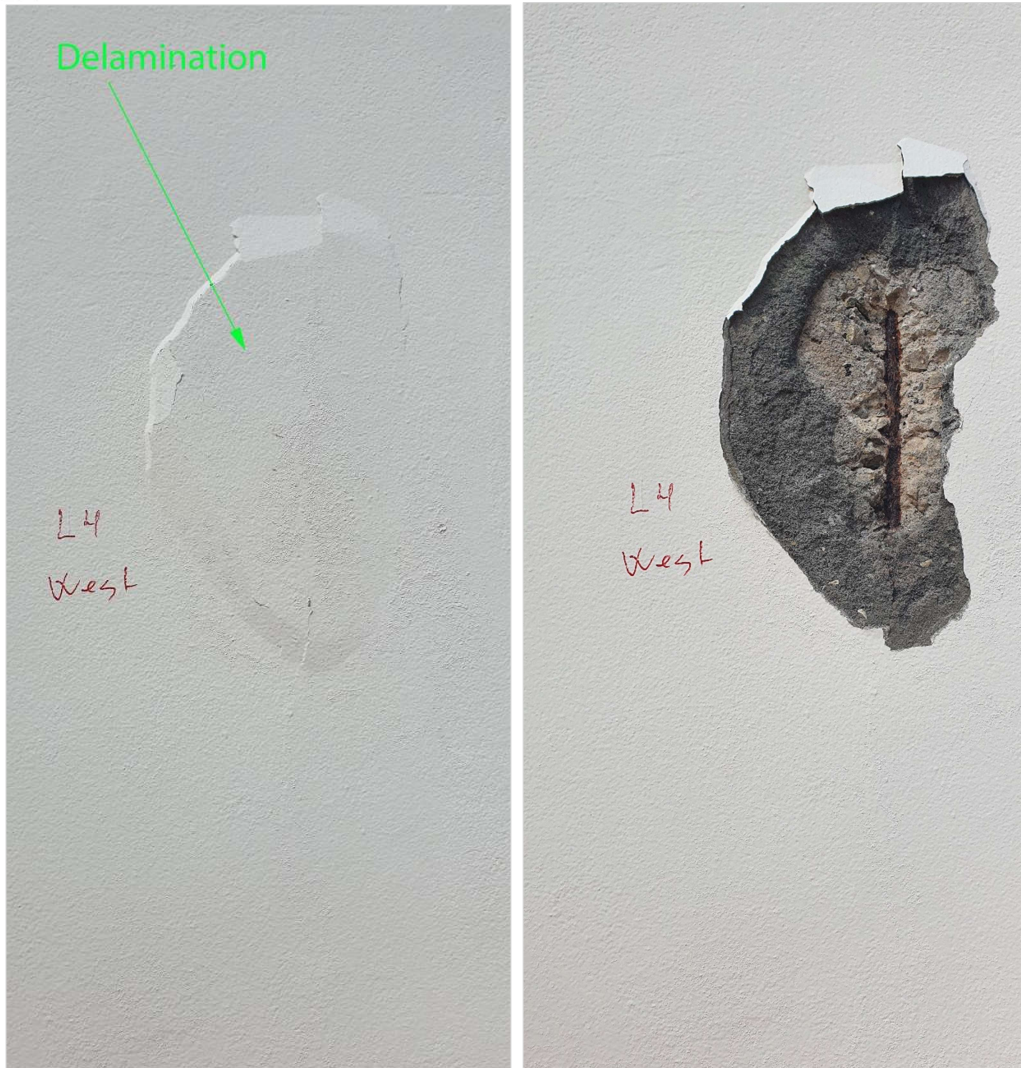


Figure 26: West Wall - Grid BC - Breakout L4



Figure 27: West Wall - Grid BC - Breakout L4

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid B-C Breakout L4 • The location was delaminated • Although the delaminated material hadn't spalled, atmosphere getting to the reinforcing would have accelerated the corrosion process • The vertical bar has a remaining diameter of less than 8mm		



Figure 28: West Wall - Grid BC - Breakout L6



Figure 29: West Wall - Grid BC - Breakout L6

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid B-C Breakout L6 • Only surface corrosion on reinforcing bars is present • The bar diameter is 9.5mm • The cover was measured to be 75mm		



WEST WALL - GRID A-B

HALF-CELL POTENTIAL & COVER MAPPING



Figure 30: West Wall Grid A-B - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid A-B Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Some reinforcing with cover values < 30mm (red) is apparent - Isolated detections likely relate to ties wires - Ties with insufficient cover can initiate corrosion - The corrosion from ties migrates deeper into the structure until it reaches the reinforcing, causing the bars to corrode		

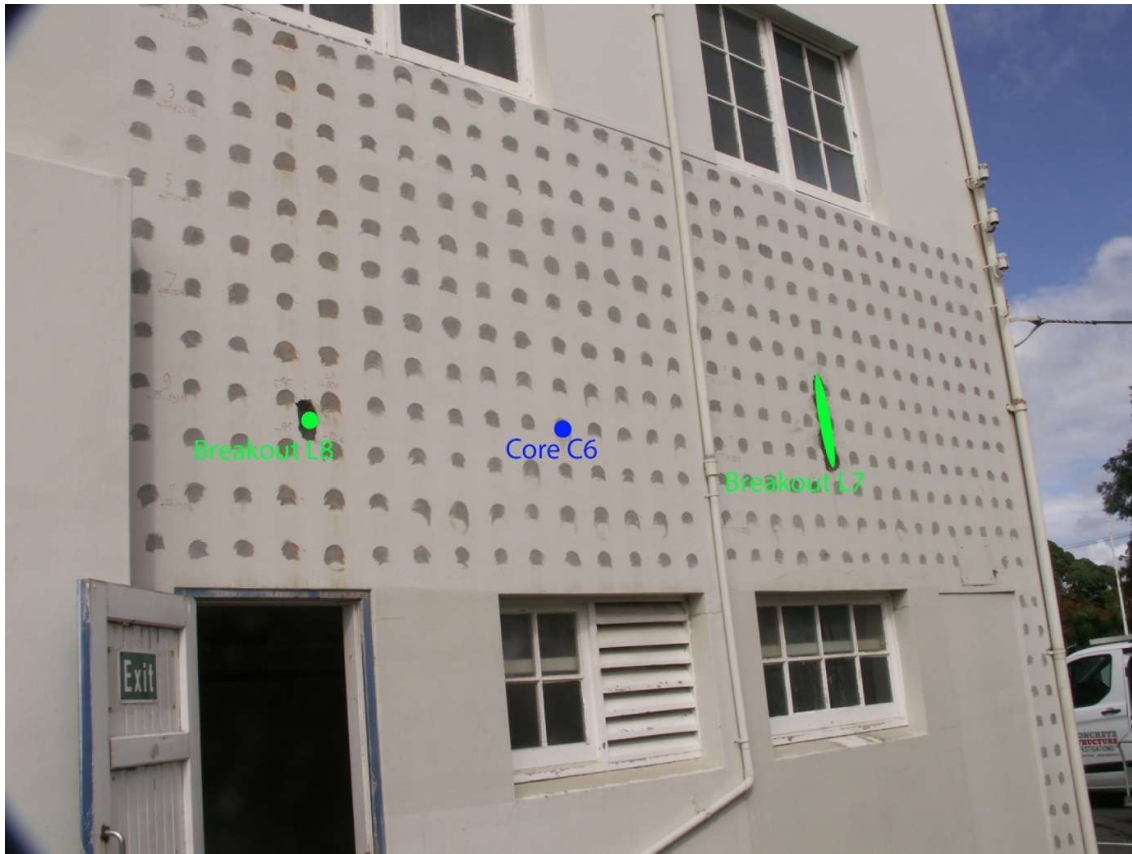


Figure 31: West Wall Grid A-B - Core and Breakout Locations

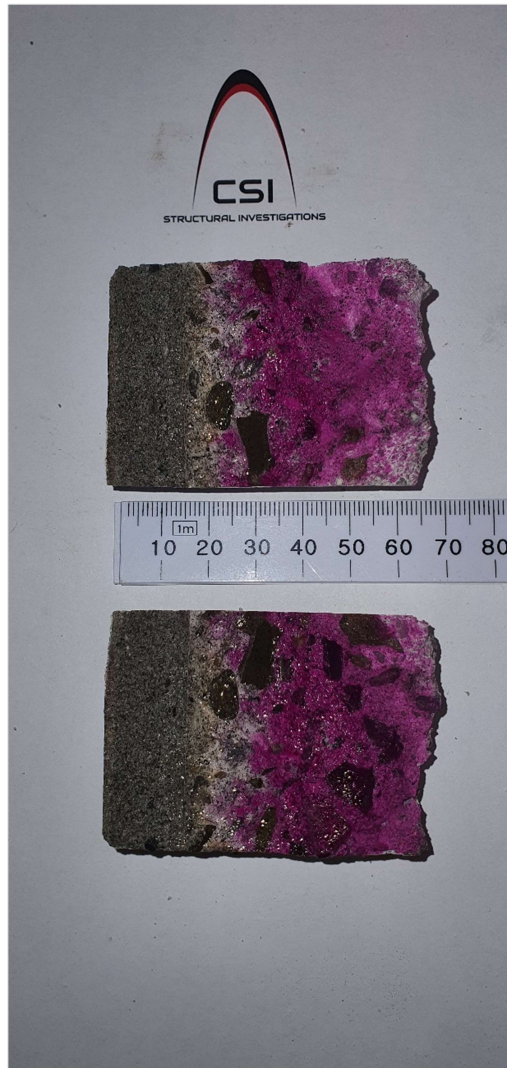


Figure 32: West Wall Grid A-B - Carbonation Testing

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid A-B Carbonation: - West Face: - Carbonation is apparent to a depth of 25-30mm Additional findings: - The added, remedial material is thinner than at other locations - Approx. thickness is 15mm		



Figure 33: West Wall – Grid A-B - Breakout L7



Figure 34: West Wall – Grid A-B - Breakout L7

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid A-B Breakout L7 • No spalling was visible in this area • The bar is severely corroded • The vertical bar has a remaining diameter of 7mm • Corrosion seems to be active • It is likely that the tie wire found at low cover has contributed to the corrosion in this area		



Figure 35: West Wall – Grid A-B - Breakout L8

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	West Wall Grid A-B Breakout L8 • No spalling was visible in this area • No corrosion was found at this location • The vertical bar diameter is 9.5mm		



Figure 36: Column Grid A-X - Half-Cell - Cover Map



Figure 37: Column Grid A-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid A-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Some stirrups with cover values < 30mm (red) is present on the inside		

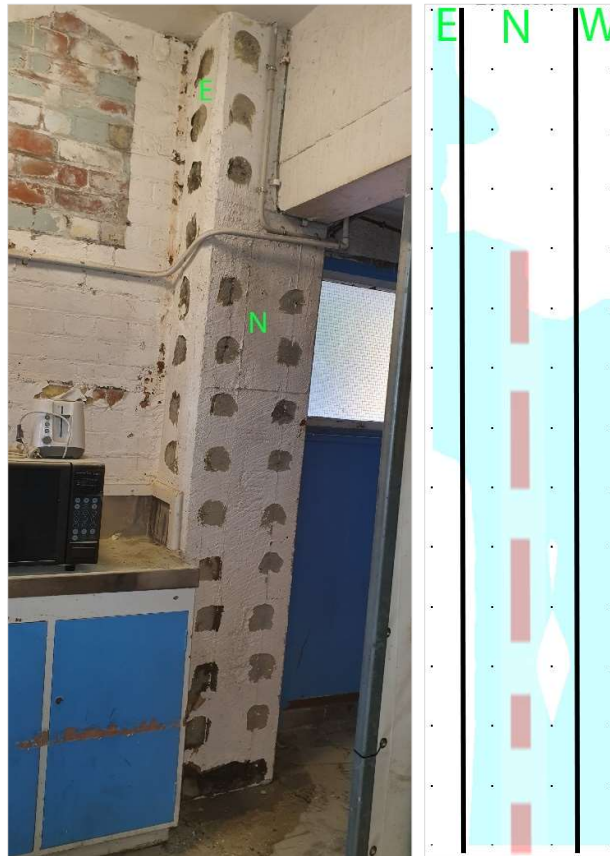


Figure 38: Column A-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid A-Y Data is displayed as flat projection - Black lines indicate the column corners - Green letters refer to orientation of the face Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - The stirrups have a cover < 30mm (red)		



Figure 39: Column A-Z - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid A-Z Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - The stirrups have cover values > 30mm (green) on the outside		



Figure 40: Column Grid A-Z - Breakout Location

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid A-Z (inside) Breakout • A large area was found to be spalled • The bars (main bar and stirrup) are severely corroded • The main bar has a remaining diameter of 31mm ◦ The back of the bar was not able to be polished ◦ The residual diameter must be assumed to be lower than the measured one • Corrosion is active		

GRID B-X



Figure 41: Column Grid B-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid B-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - An area at the bottom of the column towards the outside is within this range, though difficult to see on the graphic above - The area next to the beam, and upwards the raking column is within this range - Orange shaded areas have a 90% probability of active corrosion - An area at the top of the map has a high probability of active corrosion - It is likely that this progresses upwards the raking beam, although this cannot be confirmed without further investigations Cover Map: - Some stirrups with cover values < 30mm (red) are present on the inside and outside		

Half-Cell Potential & Cover Mapping

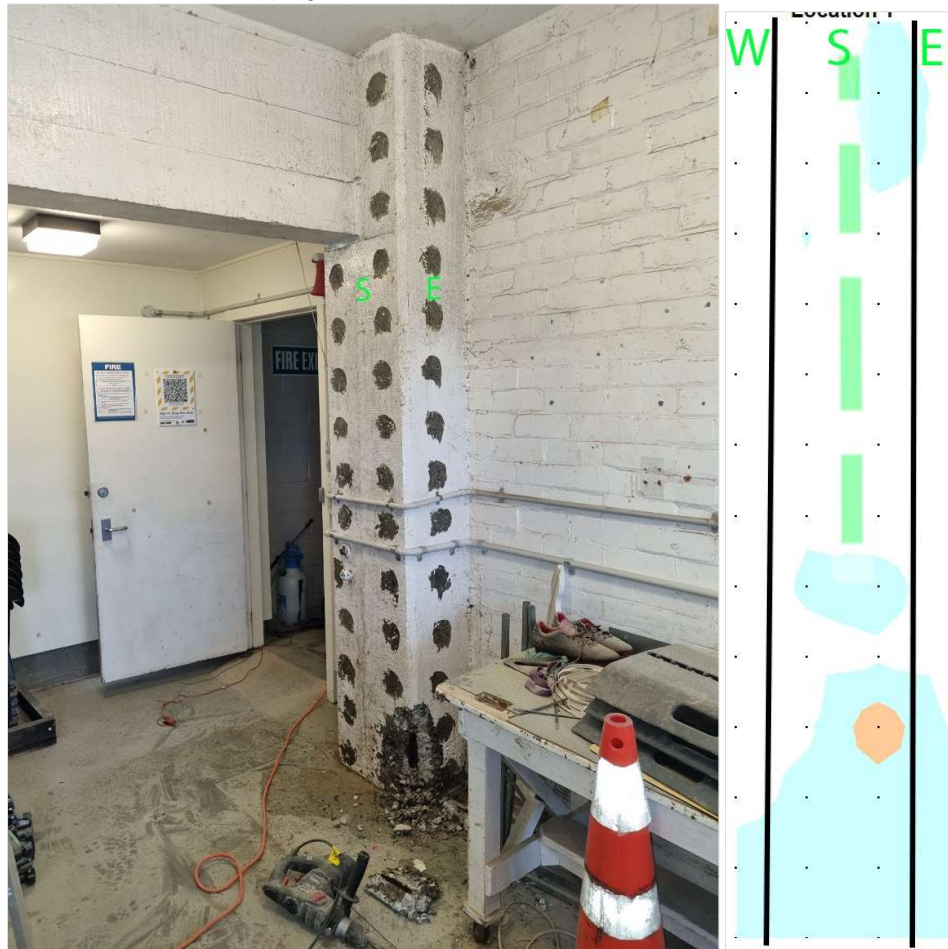


Figure 42: Column B-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid B-Y Data is displayed as flat projection - Black lines indicate the column corners - Green letters refer to orientation of the face Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded area has a 90% probability of active corrosion Cover Map: - The stirrups have a cover > 30mm (green)		



Figure 43: Column Grid B-Y - Breakout



Figure 44: Column Grid B-Y - Breakout



Figure 45: Column Grid B-Y - Breakout

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid B-Y Breakout Several factors have contributed to the deterioration of column B-Y • Nested aggregate was found in the bottom portion • A tie wire with virtually no cover, acting as a "slow burning fuse" was found • A piece of timber in contact with the bar was found approx. 80mm ◦ The timber was moist, indicating that it delivers consistently moisture to the bar • Active corrosion is apparent • The main bar has a residual diameter of below 29mm (the nominal diameter is 32mm)		

Half-Cell Potential & Cover Mapping

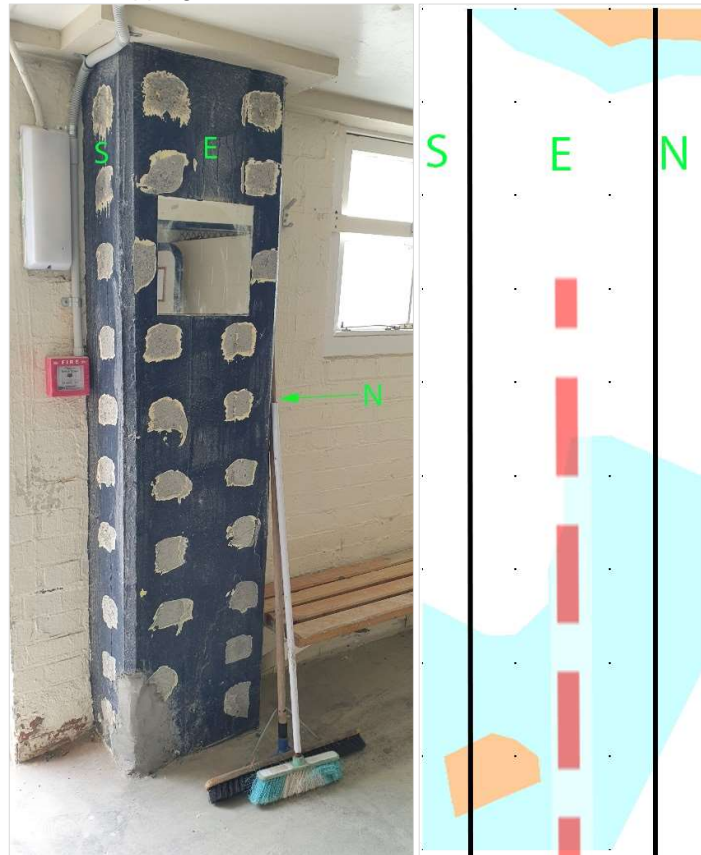


Figure 46: Column B-Z - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid B-Z Data is displayed as flat projection - Black lines indicate the column corners - Green letters refer to orientation of the face Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded area has a 90% probability of active corrosion Cover Map: - The stirrups have a cover < 30mm (red)		



Figure 47: Column Grid B-Z - Breakout Location



Figure 48: Column Grid B-Z - Breakout Location

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid B-Z Breakout • A large area was found to be spalled • The bars (main bar and stirrup) are severely corroded • The main bar has a remaining diameter of 30mm • The stirrup has a remaining diameter of 8.5mm • Corrosion is active		



Figure 49: Column Grid C-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid C-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		

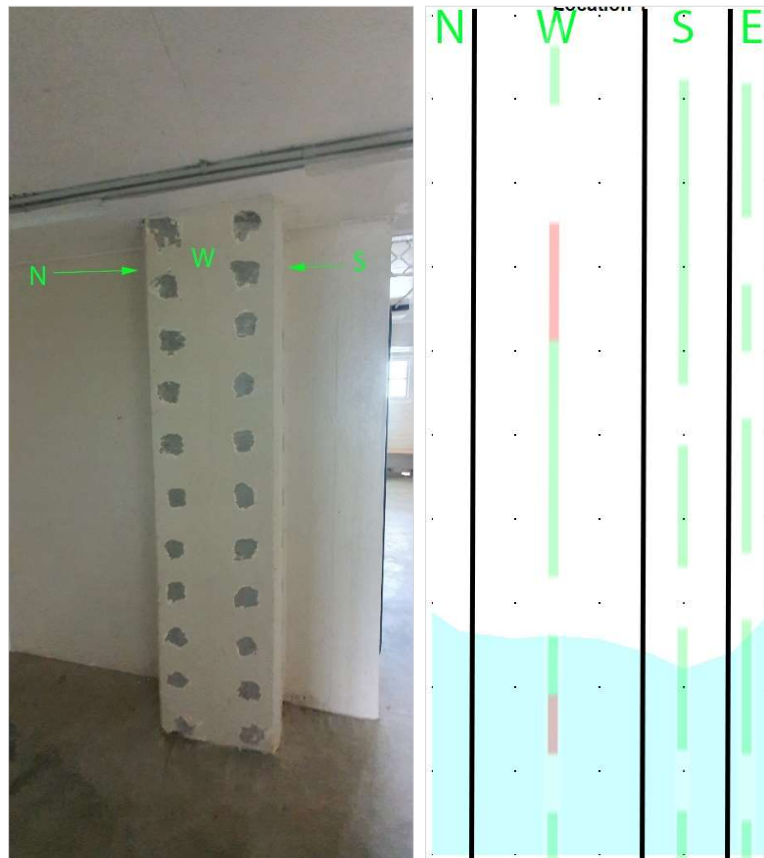


Figure 50: Column C-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid C-Y Data is displayed as flat projection - Black lines indicate the column corners - Green letters refer to orientation of the face Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) are present on the West face - Stirrups with cover > 30mm (green)		



Figure 51: Column D-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid D-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		



Figure 52: Column D-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid D-Y Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) are present on the West face - Stirrups with cover > 30mm (green)		



Figure 53: Column Grid E-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid E-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		



Figure 54: Column Grid E-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid E-Y Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		



Figure 55: Column Grid E-Z - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid E-Z Data is displayed as flat projection - Black lines indicate the column corners - Green letters refer to orientation of the face Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded areas have a 90% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red)		



Figure 56: Column Grid F-X - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid F-X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded areas have a 90% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		

Half-Cell Potential & Cover Mapping



Figure 57: Column Grid F-Y - Half-Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid F-Y Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		



Figure 58: Column Grid F-Y - Breakout Location



Figure 59: Column Grid F-Y - Breakout Location

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid F-Y (inside) Breakout • A large area was found to be spalled • The concrete consists of nested aggregate • The bars (main bar and stirrup) are severely corroded • The main bar has a remaining diameter of 29mm (the nominal diameter is 32mm) • The stirrup has a remaining diameter of 3mm (the nominal diameter is 9.5mm) • Corrosion is active		

Half-Cell Potential & Cover Mapping



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid F-Z Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded areas have a 90% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Single data points may relate to low cover tie wires - Ties with insufficient cover can initiate corrosion - The corrosion from ties migrates deeper into the structure till it reaches the reinforcing, causing the bars to corrode - Stirrups with cover > 30mm (green)		



Breakouts



Figure 60: Column Grid F-Z - Breakout Location



Figure 61: Column Grid F-Z - Breakout Location

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Column Grid F-Z (inside) Breakout • A large area was found to be spalled • The bars (main bar and stirrup) are severely corroded • The main bar has a remaining diameter of 27mm (the nominal diameter is 32mm) • The stirrup has a remaining diameter of 6mm (the nominal diameter is 9.5mm) • Corrosion is active		

BEAM - GRID X
INSIDE
Grid A-B



Figure 62: Beam Grid X/A-B

Figure 63: Raking Beam Grid A-B - Flat Projection - Half Cell

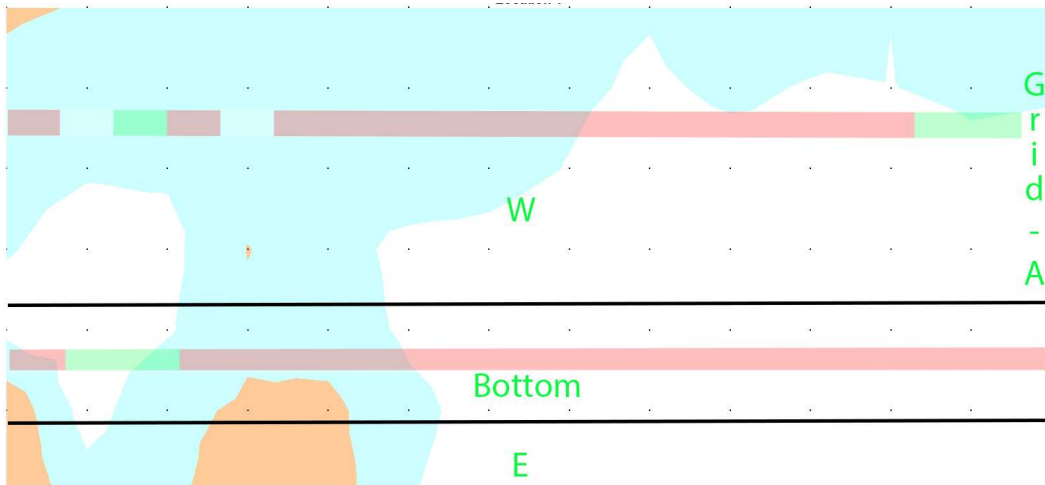


Figure 64: Beam Grid X/A-B - Flat Projection - Half Cell - Cover Map

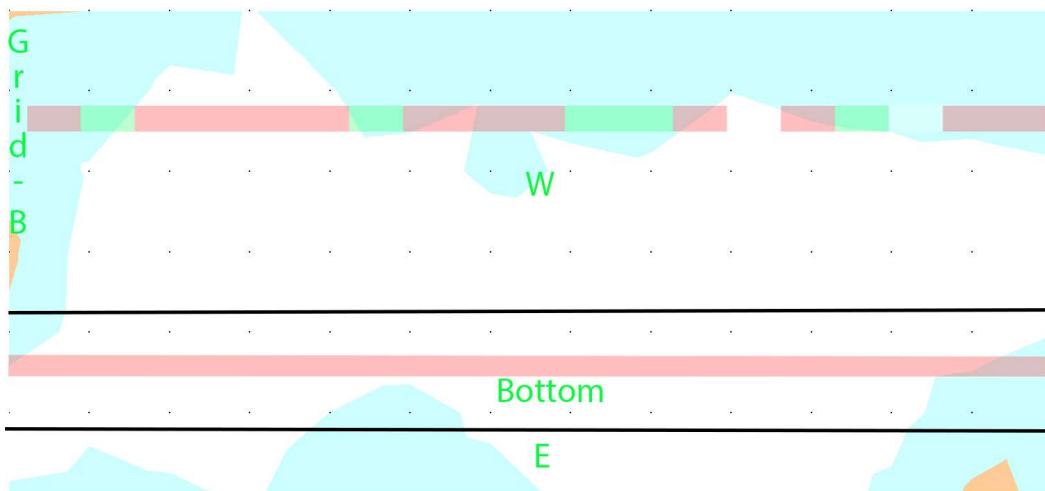


Figure 65: Beam Grid X/A-B - Flat Projection - Half Cell - Cover Map



Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Beam - Inside Grid X/A-B Data is displayed as flat projection • Black lines indicate the beam corners • Green letters refer to orientation of the face Graphics: • Top: Raking Beam – Grid A-B, at beam Grid X • Middle & Bottom: Beam Grid X Half-Cell Potential: • Blue shaded areas have a 50% probability of active corrosion • Orange shaded areas have a 90% probability of active corrosion Cover Map: • Stirrups with cover < 30mm (red) • Stirrups with cover > 30mm (green)		



Figure 66: Beam Grid X/E-D



Figure 67: Beam Grid X/D-C



Figure 68: Beam Grid X/D-C

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Beam - Inside Grid X/C-E No maps are displayed for the locations. Data indicate a 90% probability that no active corrosion is occurring. The reinforcing of the raking beam shown in photo Figure 67 is heavily corroded from the top (stands). Corrosion has not progressed further down.		



Figure 69: Beam Grid X/E-F

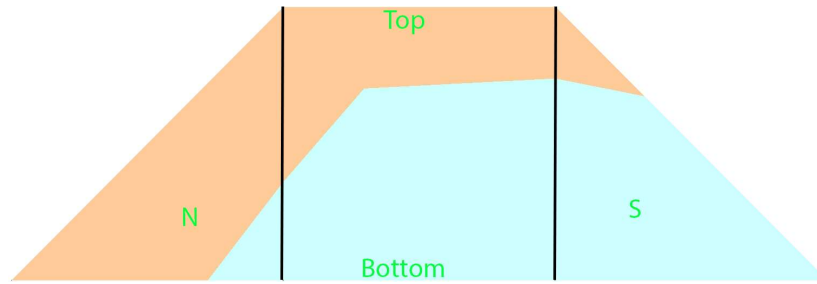


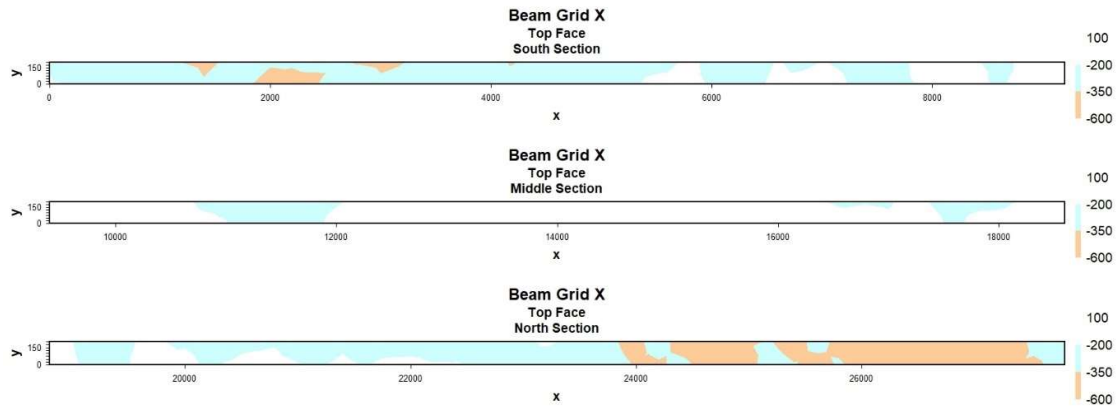
Figure 70: Raking Beam Grid E - Flat Projection - Half Cell



Figure 71: Beam Grid X/E-F - Flat Projection - Half Cell - Cover Map

Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Beam - Inside Grid X/E-F Data is displayed as flat projection - Black lines indicate the beam corners - Green letters refer to orientation of the face Graphics: - Top: Raking Beam – Grid E, at beam Grid X - Bottom: Beam Grid X Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded areas have a 90% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green)		

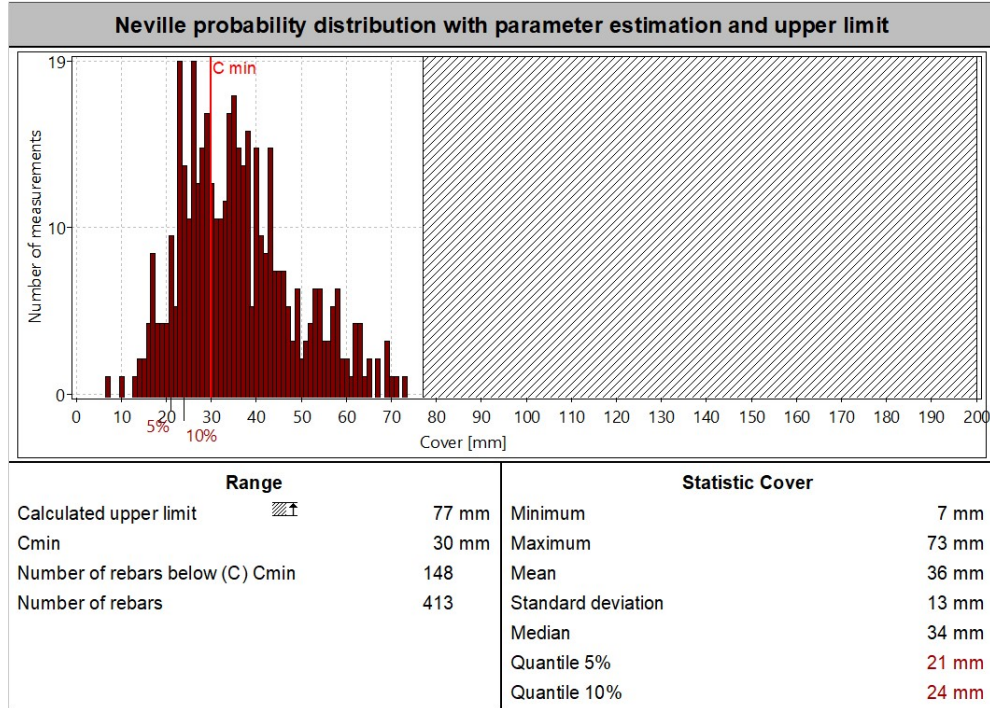
Half-Cell Potential Mapping



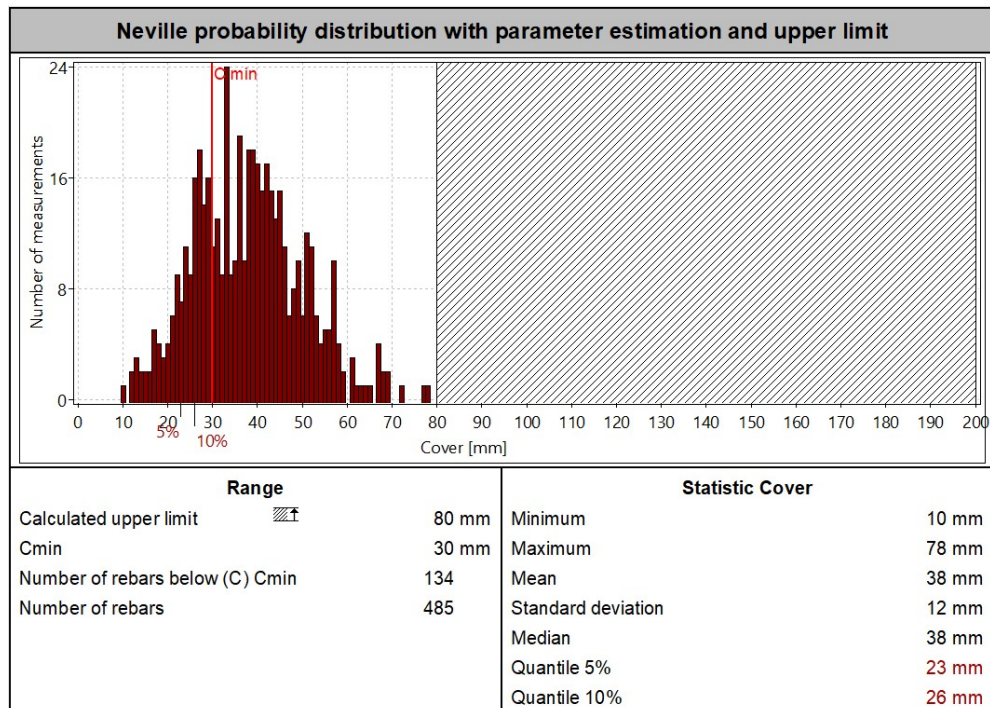
Project name:	254019	Customer:	-
Location:	Grandstand Petone	Object:	-
Comment:	Beam - Outside Grid X Half-Cell Potential testing was carried out on the top face of the beam on grid X. The data is displayed in three tiers. The top tier starts on the South side, and the bottom tier finishes at the North side. Half-Cell Potential: - Blue shaded areas have a 50% probability of active corrosion - Orange shaded areas have a 90% probability of active corrosion Cover Map: - Stirrups with cover < 30mm (red) - Stirrups with cover > 30mm (green) Note: Half-Cell Potential testing was not carried out on the vertical face (facing Eastward) due to the bad condition of the beam. No statement for this part of the beam can be made.		

Cover scanning was carried out on the top of beams X & Y. It is not possible to distinguish the mesh from the stirrups, hence the cover values are provided as statistic. In areas where mesh is present, low cover values will relate to the mesh.

Beam – Grid X



Beam – Grid Y



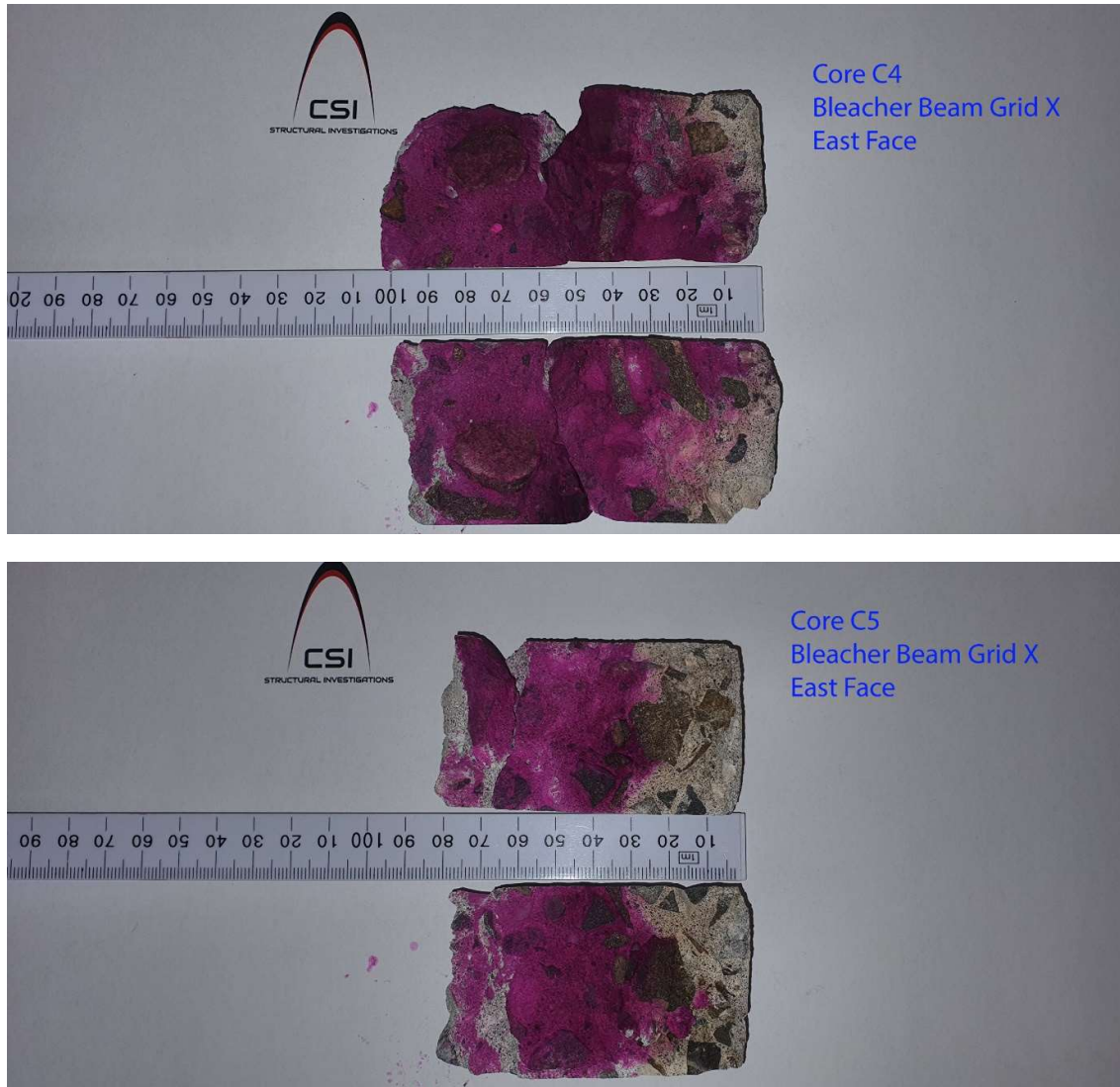


Figure 72: Beam Grid X - Carbonation Testing

Core C4 top and C5 bottom

Remedial work was carried out at some stage in the stands. Large areas on the beam on Grid X have been patched. A lot of the raking beams, if not all have been also remediated. No information about this work is known, however, this was likely done due to corrosion of bars and spalling of concrete. A lot of the remediated areas show severe signs of deterioration, such as delamination, spalling, and corrosion. Some of the cover concrete on raking beams could be lifted in one piece.

Some locations and their conditions are displayed in the section below.

The raking beam locations are labelled as follows:

The first letter refers to the Grids A, B, etc. Locations that are located between main gridlines contain a number in their label, with 1 being the first location northward from the adjacent main gridline. The second letter refers to the bleacher rows, written on the steps leading to the top.

E.g. Location C2B refers to the second raking beam northward from Grid C, and the location is in line with the seating row B.

A few examples of the conditions are provided below.

Raking Beam AC:



Figure 73: Raking Beam AC - Condition



Figure 74: Raking Beam AC - Condition



Figure 75: Raking Beam C2B - Condition



Figure 76: Raking Beam C2B - Condition



After the initial findings of deteriorated raking beams, locations in seemingly good condition were investigated. The locations were chosen by visual inspection and sounding. An additional focus at these locations was to confirm the condition of the mesh of the bleachers. Five locations were broken out and inspected. None was found to have noticeable problems with corrosion.

One example is displayed below.

Raking Beam D2E:



Figure 77: Raking Beam D2E - Condition



Figure 78: Raking Beam D2E - Condition



BAR DIAMETER

Note: Provided diameters are millimetres.

Location	Label	Bar type	Bar diameter moninal	Bar diameter measured	Cross sectional loss
South Wall	L1	Main bar	32	32	0
	L2	Horizontal bar	9.5	9	0.5
	L3	Vertical bar	9.5	9.5	0
North Wall	L1	Vertical bar	9.5	9	0.5
	L2	Vertical bar	9.5	9	0.5
		Horizontal bar	9.5	9	0.5
West Wall	L3	Vertical bar	9.5	3	6.5
		Horizontal bar	9.5	6	3.5
	L4	Vertical bar	9.5	8	1.5
	L6	Vertical bar	9.5	9.5	0
	L7	Vertical bar	9.5	7	2.5
	L8	Vertical bar	9.5	9.5	0
Column A-Z		Main bar	32	31	1
Column B-Z		Main bar	32	30	2
		Stirrup	9.5	8.5	1
Column B-Y		Main bar	32	29	3
Column F-Y		Main bar	32	29	3
		Stirrup	9.5	3	6.5
Column F-Z		Main bar - bottom	32	27	5
		Main bar - top	32	29.5	2.5
		Stirrup	9.5	6	3.5
Bleacher					
Column A-Y	AF	Main bar	19 or 22mm	16	3 or 6mm
		Stirrup	9.5	5.5	4



Location	Label	Bar type	Bar diameter moninal	Bar diameter measured	Cross sectional loss
Raking Beam Locations in Bad Condition					
Raking Beam	AC	Main bar	19	12.5	6.5
		Stirrup	9.5	0	9.5
Raking Beam	AM	Main bar	19	17	2
		Stirrup	9.5	7.5	2
Raking Beam	B2K	Main bar	19	18.5	0.5
		Stirrup	9.5	9	0.5
Raking Beam	C1F	Main bar	19	19	0
Raking Beam	C2B	Main bar	19	12	7
		Stirrup	9.5	9	0.5
		Stirrup	9.5	0	9.5
Raking Beam	C2F	Main bar	19	18	1
Raking Beam	C2K	Main bar	19	18.5	0.5
Raking Beam	D1B	Main bar	19	9	10
Raking Beam	D2C	Main bar	19	19	0
		Mesh	4	2	2
Raking Beam	EN	Main bar	19	18	1
		Vertical bar	19	18.5	0.5
Raking Beam	FH	Main bar	19	19	0
		Stirrup	9.5	7	2.5
Raking Beam Locations in Good Condition					
Raking Beam	BK	Main bar	19	19	0
		Mesh	4	4	0
Raking Beam	C1I	Main bar	19	19	0
		Mesh	4	4	0
Raking Beam	D1K	Main bar	19	19	0
		Mesh	4	4	0
Raking Beam	D2E	Main bar	19	19	0
		Mesh	4	4	0
Raking Beam	E1L	Main bar	19	19	0
		Stirrup	9.5	9.5	0
		Mesh	4	4	0
Portal Frame Support					
Portal Frame Support C-Y	CF	Bolt	22	19	3

7 CONSULTATION OF RESULT

WALLS

It is suspected that the walls have been remediated at some time in the past. A 10-20mm thick layer of grout or concrete was added to the original concrete and a thick coating of paint was applied. No historic information about the remedial work was provided to CSI.

Factoring in all observations from site and the type of remedial work it is likely that the remedial work was commissioned due to the occurrence of corrosion. Because the condition of the reinforcing bars varies greatly, results from the Half-Cell Potential technique cannot be concluded as per the ASTM C876 – 09 recommendations.

As per the ASTM C876 – 09, hardly any data points indicate an active corrosion process. Presumably, the remediation has slowed or halted corrosion in large parts.

Despite Half-Cell results indicating a low probability of active corrosion, physical inspections have shown that some areas, however, seem have active corrosion. Bars in these areas were found to have a significant loss in cross section. Where active corrosion was found it typically correlated with one or multiple findings as listed below.

- Timber embedded in concrete.
 - Timber has a high absorption rate for liquids, and when close enough to the surface timber can act as a wick. It can transport moisture deeper into the structure, and in some cases as discovered at the West Wall (Grid E-F - Breakout L1) right up to the reinforcing.
- Tie wires at low cover.
 - Ties, when close enough to the surface can act like a slow burning fuse for corrosion. This was observed as some locations.
- Nested aggregate / bony concrete.
 - Nested aggregate affects the compressive strength of concrete but also reduces the effective cover to the steel. The atmosphere can travel easier through areas of nested aggregates. This can accelerate the progression of carbonation and draw moisture into the structure through the capillaries.
- Low cover over reinforcement.
 - Low concrete cover reduces the passive protection of the steel against atmosphere. Despite the added layer of concrete areas with low cover were identified, mostly on the West wall.
- Delaminated or spalled concrete, reducing the effective concrete cover.
 - Any damage on the concrete surface reduces the cover and hence reduces the passive protection.
 - One cause of delamination is corroded steel. When steel oxidises, it increases in volume. The expanded material applies compressive forces to the embedding concrete. The forces can build up to a level where concrete cracks, delaminates and eventually spalls.
 - A lot of delamination was observed on the walls. It is probable that the corroded bars were covered up during the historic remediation and that corrosion continued, causing cracking and delamination. Most of these areas correspond to low concrete cover.
- Carbonation, reducing the effective concrete cover.
 - Carbonation migrates from the surface inwards, reducing the concrete cover leading to the same effects as described above.
 - Four areas with carbonation and subsequent corroded steel were found. One area was on the outside of the North wall, another area was the North face on the South wall in the stands. The third area was the bleacher beam on Grid X. The fourth area is the West wall. Although, based on 7 samples only it seems likely that carbonation occurs on the parts of the building that are exposed to the weather conditions from the North.

Embedded shells have been found in all crushed concrete cores. The sand for the concrete was possibly sourced from an estuary and could contain salts. Chloride testing conducted by CSI in earlier investigations did not find elevated salt levels. However, only a small number of samples were extracted and tested. Chloride testing on a wider scale is recommended.



COLUMNS

The columns have a wide range of conditions. Indications for active corrosion by a probability of 50% (as per Numeric Magnitude Technique from the ASTM C876 – 09) were found on all tested columns. A probability of 90% active corrosion was found on some columns.

Stirrups with low cover (less than 30mm) were found at some column.

The low cover areas don't seem to correlate with the corrosion maps. This could be because low cover is not the main contributor for corrosion. However, this cannot be concluded in this case as low cover reinforcing may have been a major contributor for corrosion before the remedial layer was added.

Some columns have volumes of nested aggregates (bonie concrete). Concrete in these areas will have a reduced compressive strength, noting that no tests were conducted to establish actual strength.

Bonie concrete reduces the effective cover and hence the passive protection to the steel as the atmosphere can penetrate easily and deep into the material.

At one column (column B-Y) bonie concrete was present below the slab level, and additionally timber was found to be embedded. The timber was moist, attributing to drawing moisture from the surrounding. The moisture also gets drawn through the capillaries of the nested aggregate. Both would have contributed greatly to the corrosion of the reinforcement. A main bar at this location had a residual diameter of 29mm (nominal diameter is 32mm), and a stirrup had a diameter of 3mm (nominal diameter is 9.5mm).

For specific details on the columns, refer to the individual locations.

CARBONATION

A total of 8 cores were extracted for carbonation testing. Carbonation is found in structural elements that are exposed to weather systems from the North (NW – NE). Weather systems from the North travel large distances over land carrying CO₂ with them.

No carbonation was found on the South face of to the South. Weather systems from the South do not travel over land, but the sea where low levels of CO₂ are in the atmosphere.

Two cores were taken on the South wall, one on the North face and one on the South Face. The core from the North face has a carbonation depth of 70mm. The core on the South Face has no carbonation at all, neither within the added remedial layer, nor within the original concrete.

A correlation between carbonation and the weather systems from the North is highly probable.

BEAM – GRID X

INSIDE

The beam on Grid X was assessed on the North and the South sides of the building. The investigated beam sections as well as the raking beam joints have areas with a probability of active corrosion of 50% and 90%, respectively.

In addition, a portion of the beam in the middle of the building was investigated. This section was chosen as the top of the beam above (in the stands) is heavily affected by corrosion. Data indicate that no active corrosion is occurring with a probability of 90% on the inside of this section.

OUTSIDE

Large parts of the top East facing corner has spalled, and the beam reinforcing shows severe signs of corrosion where it is exposed. Investigations on the vertical face were not feasible due to the condition of the beam.

Half-Cell Potential testing was conducted on the top face of the beam. The established values indicate areas with a high probability of active corrosion. The corrosion seems to be most active on the right portion of the beam.



BLEACHER

The investigations on the bleacher focused initially on locations with obvious deterioration. At some of these locations it was possible to lift the entire concrete block as these were delaminated or spalled. At most of these locations a cross-sectional loss of reinforcing was confirmed. Some stirrups were entirely corroded and split, and some main bars have lost up to 10mm. – Refer Bar Diameter for results.

The second part of the investigation for the bleacher raking beams concentrated on locations that appeared to be in a better condition. These locations were chosen by the criteria of visual and sounding inspection. At these locations the mesh of the bleachers was also exposed, so their condition could be assessed. Five locations were picked and inspected; all reinforcing was confirmed to be in good condition.

The fixings for the portal frames holding up the roof are corroded and have caused concrete to spall. One fixing has lost 3mm of its cross-section.



8 LIMITATIONS

PS 200 LIMITATIONS

	Reliable Measurements
Base Material	- Reinforced concrete. - Reinforced CMU. (Brick)
Detected Objects	- Rebars which comply with one of the following standards: - DIN 488 - ASTM A615/A 615/M-01b - CAN/CSA-G30. 18-M92 - JIS G 3112 - GB 50012-2002 (China) - Metal conduit if sufficient spacing from rebars.
Environment / Working conditions	Smooth and flat surfaces.
Rebar layout Direction	- Rebars lying orthogonal or within $\pm 5^\circ$ of a right angle to the scanning direction. - Reinforcement running parallel to the surface.
Rebar layout Diameter	- Neighbouring bars with a similar diameter. - Standard diameters from 6-36mm, up to a depth of 60mm, if s:c $\geq$ 2:1. - Calibrated bar sizes: {6,8,10,12,14,16,20,25,28,30,36}mm - Device is calibrated to be accurate to within ± 1 of the above intervals; however, this is strongly affected by environmental conditions.
Rebar layout Spacing	- Minimum bar spacing either 36mm (1.4 in) OR The minimum ratio of spacing to coverage (s:c), whichever value is greater. - Minimum ratio of spacing to coverage - Depth calculation / bar diameter estimation s:c = min 2:1 - Bar location s:c = min 1.5:1
Rebar layout Depth calculation	- Neighbouring bars at similar depth/size. - For accurate depths readings minimum depth of 20mm (0.8 in). For readings at all min. 10mm. - Maximum depth determination differs with rebar diameter. - Typically, if diameter is known (DIN) Image Scan / Block Scan: $\leq 10\text{mm}$: up to 100mm $\leq 14\text{mm}$: up to 120mm $\leq 30\text{mm}$: up to 140mm 36mm: up to 160mm - Linear scan: up to 100mm - Accuracy for unknown bar diameter: $\pm 10\%$ for depths greater than 20mm.



HALF-CELL POTENTIAL TEST

- This test method only indicates the probability of corrosion present at the time of testing, and does not indicate the extent (condition of reinforcing) or rate of corrosion.
- The test does not measure the actual corrosion rate or whether corrosion activity has already started, but it indicates the probability of the corrosion activity depending upon the actual surrounding conditions.
- Potential mapping does not give information regarding corrosion rate.
- The test is difficult to perform when contaminants present on or in concrete. It also cannot be used with most overlays or coatings.
- The results obtained using this test method shall not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.
- The potential measurements should be interpreted by engineers or technical specialists experienced in the fields of concrete materials and corrosion testing.
- Half-cell potential technique using the existing standards may lead to mistakes in cases where the concrete is water saturated, carbonated and exposed to the very low temperature.
- Additional information gathered by e.g. breakouts, concrete cover, etc. must be considered when formulating a conclusion.
- Dense cover concrete and higher cover depth will shift the half-cell readings towards more negative
- Carbonation of concrete will shift the half-cell readings towards more negative
- Higher temperature will shift the half-cell readings towards more negative
- Increase in chloride ion concentration will shift the half-cell readings towards more negative
- Use of Anodic Corrosion Inhibitors will shift the half-cell readings towards more positive