AtkinsRéalis

Structure Options Report

Mayo County Council

March 2025

N58 STRADE RIVER BRIDGE REHABILITATION WORKS

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Comhairle Contae Mhaigh Eo
Mayo County Council

Notice

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Strade, Co. Mayo

Structure(s)

Name and nature of the Structure(s) Strade River Bridge

Single Span Underbridge carrying the N58 National Secondary Road over the Strade River

Structures Options Report

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1. Introduction

AtkinsRéalis were appointed by Mayo County Council for Eirspan Task Order 315 Mayo Bridge Assessments and Strengthening 2023, comprising the assessment and rehabilitation of 10no. bridges in County Mayo. MO-N58-001.00 Strade River Bridge is one of the 7no. structures which required an assessment to be undertaken to confirm the structure's load carrying capacity for HA, HB and SV loading.

The assessment of MO-N58-001.00 Strade River Bridge comprised the Stage 2 assessment of the 2no. span filler beam slab structure in accordance with TII Publications *AM-STR-06056 Stage 1 Structural Assessment of Road Structures* and *AM-STR-06057 Stage 2 Structural Assessment of Sub-Standard Road Structures.*

The Stage 2 Assessment report for the structure determined the structure has a reduced 7.5t load capacity due to bond failure between the concrete and steel beams with significant delamination and spalling visible to the deck slab soffit providing evidence of the issue. The deck slab was recommended to be either strengthened or replaced.

This Structure Options Report (SOR) outlines the proposed options for the strengthening/replacement of the structure, evaluating each option in accordance with TII Publication DN-STR-03001 and presents conclusions and recommendations.

2. Site and Location

MO-N58-001.00 Strade River Bridge carries the N58 National Secondary Road over the Strade River in Co. Mayo. The structure comprises a two span filler beam deck structure with the filler beam deck slab comprising railway girders encased in concrete and supported on mass concrete pier and abutments.

The structure has square spans of 3.44m and 3.42m and skew spans of 3.82m and 3.79m for the south and north spans respectively. The overall square length of the structure is 7.59m with a skew length of 8.6m. The structure has a skew of 26 degrees.

The overall kerb-to-kerb width on the bridge is 6.90m with the carriageway measuring 5.70m wide. Concrete verges are provided across the structure measuring 1.1m (east) and 1.7m (west) wide respectively with concrete parapets also provided measuring 900mm and 750mm high respectively. The overall width out-to-out on the structure is 10.3m square to the carriageway with a skewed width of 11.4m.

The ITM co-ordinates of the existing structure are:

Easting: 525753 Northing: 797497

The location of the existing structure is shown in Figure 2-1 overleaf.

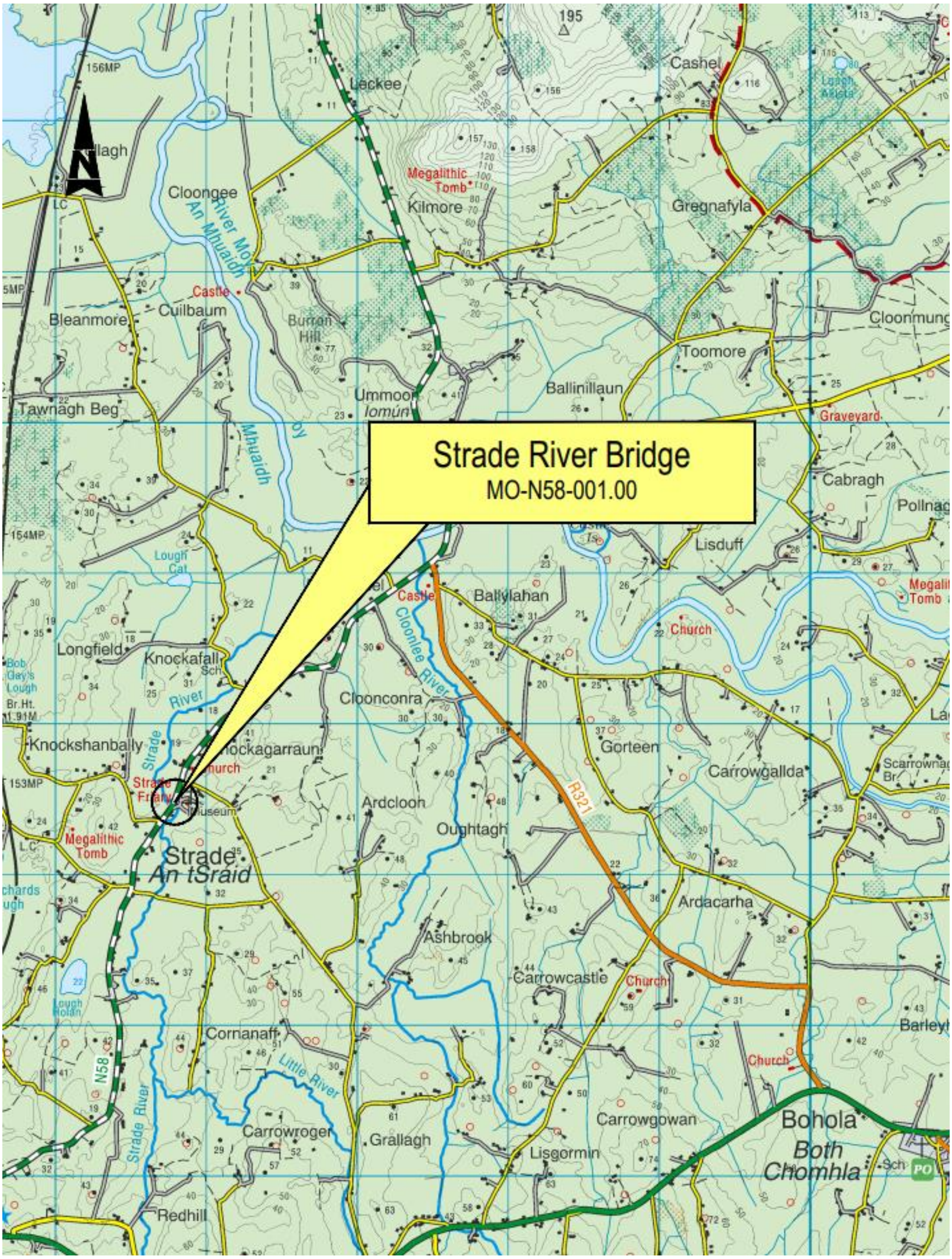


Figure 2-1 - Structure Location Map

The bridge is located in a rural location with farmland located northwest and southwest of the structure. The Michael Davitt Museum (NIAH 31307029) is located to the east of the structure with Strade Friary, the Catholic Church of Saint Peter and Saint Paul (RPS 0129; NIAH 31307027) and associated graveyards also located northeast of the structure. A public house and a residential premises is located southeast of the structure.

Two other protected structures are located in close proximity. Straide Bridge (RPS 0130; NIAH 31307030) is located 40m upstream of the existing bridge and was in use until bypassed as part of a road realignment in 1983 (ref. NIAH). The O'Donnell Mausoleum (RPS 0006, NIAH 31307028) is also located east of the structure.

The bridge location is also within the Zone of Notification for MA070-067001 (Religious House - Dominican Friars); MA070-067004 (Graveslab); MA070-067005 (Religious House - Franciscan Friars); MA070-067006 (Graveyard) and other associated monuments.

See Figures 2-2 to 2-5 for views of the existing structure.

Figure 2-2 – View of N58 carriageway looking south across the bridge

Figure 2-3 – View of N58 carriageway looking north across the bridge

Figure 2-4 – View of the west elevation

Figure 2-5 – View of the east elevation

3. Description of Structure and Options Considered

3.1 Project Need

The Stage 2 Assessment report for Strade River Bridge determined the structure has a reduced load capacity of 7.5t due to bond failure between the concrete and steel beams with significant cracking, delamination and spalling visible to the deck slab soffit providing evidence of the issue, see Figure 3-1 and 3-2 overleaf.

The structure therefore requires strengthening or replacement works to be undertaken to provide a structure with a full 40t load capacity. The respective merits of the strengthening or replacement options are discussed in Section 3.2 below.

Although Mayo County Council have advised of plans for a bypass in the area this scheme is in early stages of development with the preferred route located west of the structure, remote from the existing bridge location. As a result the required strengthening or replacement works are recommended to proceed as the structure is likely to remain in use into the future.

Figure 3-1 - South span with spalling and exposed filler beams evident

Figure 3-2 - North span with spalling, delamination and exposed filler beams evident

3.2 Replacement or Strengthening Considerations

Following the findings of the Stage 2 Assessment Report both strengthening and replacement options were considered with the merits of each option outlined below.

Strengthening

Strengthening options for the structure comprise either the overslabbing of the existing deck slab or the installation of new structural support beams below the deck directly supporting the existing deck slab.

The overslabbing option would result in a hidden critical element being created for the bridge with the deteriorating deck slab soffit remaining visible below the new overslab solution, which would give visual concerns on the overall safety of the bridge. This strengthening solution would also likely require amendments to the vertical alignment of the road due to the limited depth of fill (c.270mm) over the existing structure.

The support beams option comprising the installation of structural beams below the existing deck slab would avoid hidden critical elements being created but would give the structure a temporary supports 'appearance' while also reducing the clearance below the structure. The reduction in clearance would cause additional hydraulic issues by decreasing the cross-sectional area of the existing river channel. The new beams would also require any loading to be transferred effectively through the existing deck slab which is currently in poor condition with extensive cracking, delamination and spalling evident.

These strengthening solutions are the most cost-effective to increase the structure capacity to 40t but would not provide a 120 year design life afforded by the replacement options due to the strengthened structure still comprising structural elements of the existing structure such as the abutments and pier supports.

In addition the hydraulic assessment for the existing structure found the existing soffit level (18.1mOD) is below the medium probability design flood level of 18.38mOD. A strengthening solution would not improve the conveyance through the structure, with the support beam solution decreasing the cross sectional area of the channel.

The strengthening option was therefore ruled out from further consideration.

Deck Replacement

The deck replacement options for the structure comprise the demolition of the existing deck slab and construction of a new bridge deck. The new deck would span behind the existing abutments to new support foundations rather than using the existing mass concrete supports of the existing structure. The existing pier support would be made redundant with the new deck slab acting as a single span structure.

The existing mass concrete abutments would remain in place to limit any potential impact to the watercourse but lowered to allow for inspection and maintenance access to the ends of the new replacement deck elements. The existing central pier and raised concrete apron would be demolished with a new reduced height concrete apron provided for the structure.

Durability testing undertaken to the structure as part of recent structural investigation works found the durability of the existing abutments to be good overall enabling their retention in any deck replacement solution. The mass concrete construction of the abutments would be a concern if directly supporting the new deck slab however with the overspanning solution outlined above instead preferred.

Structure Replacement

The structure replacement option for Strade River Bridge also comprises the demolition of the existing deck slab but includes the demolition of the existing abutments and pier also with a new reinforced concrete substructure constructed in its place. This option would allow an increase in the opening size of the existing channel by locating the new abutments further back than the existing arrangement. The hydraulic benefits of this increase in opening width was found to be negligible however due to the channel profiles upstream and downstream of the bridge, with only a small reduction in the design flood level achieved (18.24moD).

The full structure replacement and associated substructure works would also increase the potential environmental impact due to additional works being required adjacent to or over the watercourse with an increased cost also incurred for the full replacement of the existing substructure compared to the deck replacement option.

Conclusion

Due to the extensive defects to the soffit of the structure and the use of railway girders as primary structural members which have debonded from the concrete, the strengthening of the structure is not recommended. A deck replacement is recommended with the existing deck slab removed and a new deck installed across the structure, in a single span arrangement. This option would partially retain the existing abutments and has sustainability and environmental advantages over the full structure replacement option. The alteration of the existing abutments would remove the deck loading from the abutments with the existing abutments considered to have adequate capacity and durability to retain a reduced height of fill material.

3.3 Proposed Layout

The existing bridge superstructure is proposed to be demolished with a new replacement deck to align with the retained substructure. New independent foundation supports would be located behind the existing abutment walls with the proposed foundations comprising reinforced concrete bored cast in place piles and pilecaps. Ground Investigations are required to inform the ground conditions at the bridge location in order to confirm the piled foundation arrangement.

The existing carriageway cross section and horizontal alignment is to be retained across the new superstructure with the east raised verge width increased to achieve a minimum width of 1.5m. The vertical alignment of the existing road is required to be raised in order for the new bridge soffit to meet the design flood level.

New 1.25m high reinforced concrete masonry clad parapets would be constructed over the length of the structure with safety barriers installed on both verges on approach and crossing the bridge. The proposed masonry clad parapets are considered in keeping with the surroundings with a protected masonry arch bridge located upstream and visible from the bridge, with the masonry ruins of the abbey also located northeast of the existing bridge.

See the proposed layout shown in Figure 3-3 below.

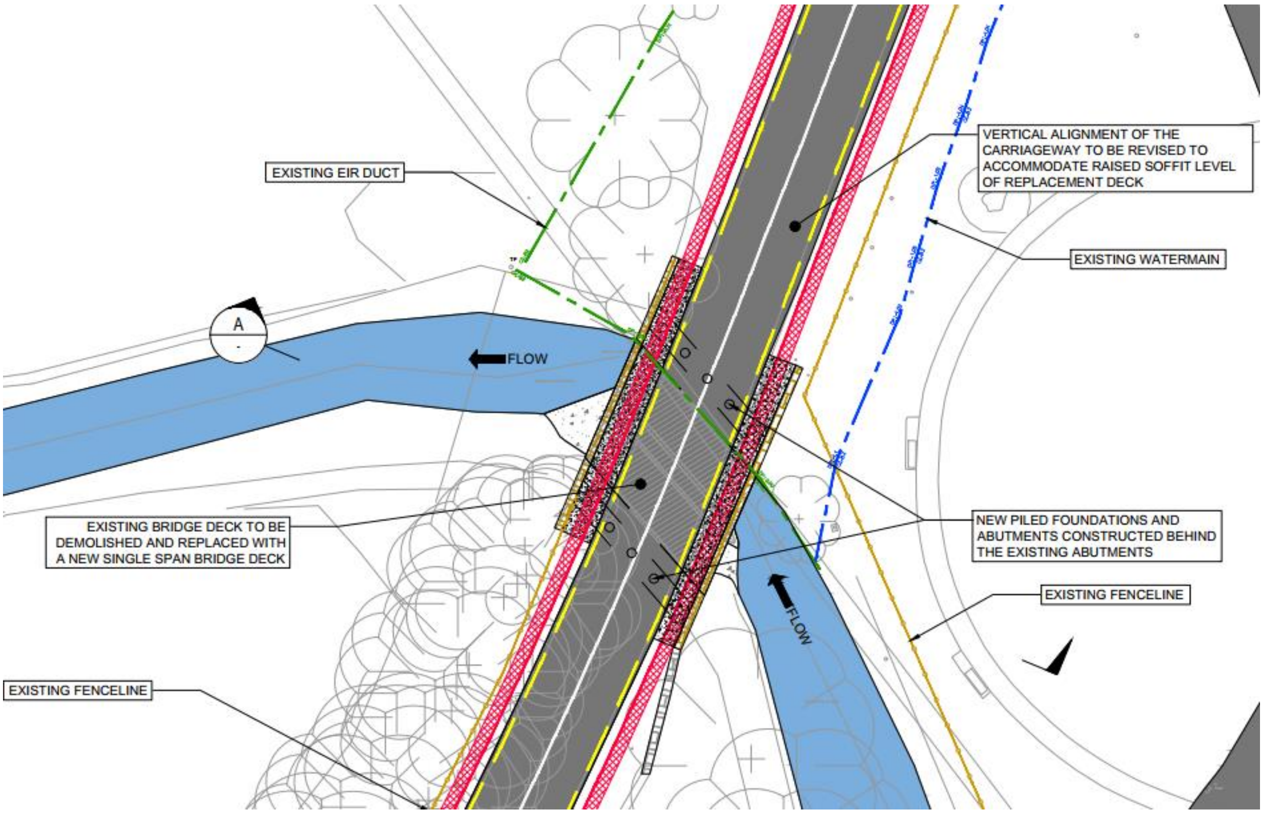


Figure 3-3 – View of the proposed layout for the structure

3.4 Design Constraints & Considerations

3.4.1 Design Constraints

The following design constraints for the new replacement deck were identified from both the project brief and the preliminary options review:

- Minimise working over water and potential ecology impacts to the watercourse
- Maintain existing carriageway cross section and alignment and meet requirements of TII DN-GEO-03036 and any other Mayo County Council requirements regarding future upgrades or improvements.
- Minimise environmental impact during construction with existing river walls and abutments to be retained with new foundation supports located behind.
- Adequate vehicle restraint system to be provided over the structure in accordance with DN-REQ-03034

3.4.2 Durability Considerations

The durability of the existing structure was considered through both a visual inspection of the existing structure as part of the inspection for assessment undertaken and also the durability testing undertaken to the existing structure as part of the structural investigations for the Stage 2 assessment. The purpose of the visual inspection and durability testing was to determine the suitability of the existing bridge elements to be reused in the rehabilitated structure. See Figure 3-4 for the defect plan to the existing deck and the test area locations.

The visual inspection of the structure found the deck to be in poor overall condition with extensive cracking, delamination and spalling evident. The abutments and piers were in good overall condition.

A summary of the durability test results are outlined below with the full testing report included in Appendix C of this report for reference.

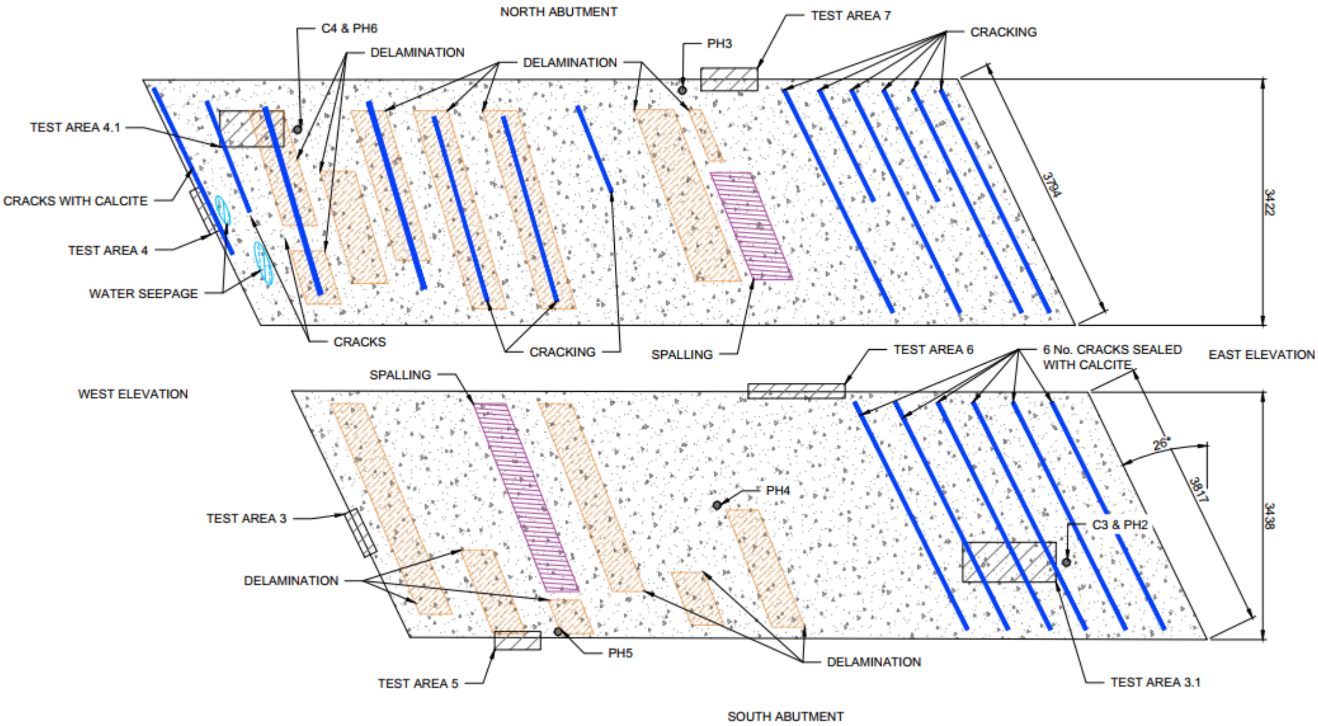


Figure 3-4 – Defect Plan & Test Area Locations

Carbonation Testing

Carbonation testing was carried out to the abutments, pier and deck slab to determine the depth of concrete affected due to a combined attack of atmospheric carbon dioxide and moisture causing a reduction in the level of alkalinity in concrete. Cement paste has a pH of approximately 13 which provides a protective layer (passive coating) to the steel reinforcement against corrosion. Loss of passivity in concrete occurs at about pH 9.

A 3% phenolphthalein indicator was used for the test. This was applied to freshly exposed concrete surfaces. Once the indicator is applied to the concrete surface, the change of colour of the concrete to pink indicates that the concrete is in good health/condition. Where no change in colour takes place, it is suggestive of carbonation-affected concrete.

The depth of carbonation provides a guide as to the risk of corrosion to any reinforcement in the test area. Concrete that is not carbonated (or has very low levels of carbonation) continues to protect the embedded steel reinforcement.

Table 3-1 - Carbonation Testing

Location	Depth of Carbonation(mm)
Area 1 - Top of Deck (northeast)	<1
Area 2 - Top of Deck (west above pier)	<1
Area 3 - Deck Edge Beam (southwest)	<1
Area 3.1 - Deck Soffit (southeast)	16
Area 4 - Deck Edge Beam (northwest)	<1
Area 4.1 - Deck Soffit (northwest)	<1
Area 5 – South Abutment Face	>20
Area 5 – South Abutment Face	<1
Area 6 – Pier Face (south)	<1
Area 6 – Pier Face (south)	<1
Area 7 – North Abutment Face	<1
Area 7 – North Abutment Face	<1

The two locations of high carbonation can be viewed as isolated instances of carbonation. All other results had negligible carbonation with the overall carbonation levels of the concrete therefore considered to be low.

Chloride Ion Testing

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination and spalling. Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions present in de-icing salts, seawater and other associated sources, into reinforced concrete can cause steel corrosion if oxygen and moisture are available to sustain the reaction. Chlorides dissolved in water can penetrate through sound concrete or reach the steel through cracks.

The risk of corrosion increases as the chloride content of concrete increases. For Strade River bridge the major concern is the extent of any existing chloride within the various concrete structural elements. While the levels recorded during the survey are likely to increase with time as the concrete is continually exposed to the natural environments and weathering.

Table 3-2 – Chloride Ion Testing

Location	Depth (mm)	Chloride content % mass of cement
	5-30	0.08

Location	Depth (mm)	Chloride content % mass of cement
Area 1 - Top of Deck (northeast)	30-55	0.08
	55-80	0.15
	80-105	0.08
Area 2 - Top of Deck (west above pier)	5-30	0.20
	30-55	0.15
	55-80	0.15
	80-105	0.05
Area 3 - Deck Edge Beam (southwest)	5-30	0.13
	30-55	0.13
	55-80	0.13
	80-105	0.13
Area 3.1 - Deck Soffit (southeast)	5-30	0.20
	30-55	0.13
	55-80	0.20
	80-105	0.20
Area 4 - Deck Edge Beam (northwest)	5-30	0.19
	30-55	0.10
	55-80	0.10
	80-105	0.10
Area 4.1 - Deck Soffit (northwest)	5-30	0.33
	30-55	0.25
	55-80	0.25
	80-105	0.33

Based on Irish concrete standard (EN 206) the chloride content as a percentage of cement should be below the maximum allowable limit of 0.4% for concrete mixes containing embedded steel. At all the test locations the values are below this limit and therefore the risk of corrosion is minimal. The maximum value found is limited to 0.33% at the area of spalling and delamination on the north span.

Cement Content

The cement content analysis for Strade River Bridge was undertaken on twelve samples. The samples were taken from the deck slab, abutments, and pier. The mean cement content results for the twelve samples is 14% with a range of 8% – 20%. A summary table of the results is shown below.

Table 3-3 - Cement Content

Location	Cement Content %
Area 1 - Top of Deck (northeast)	13
Area 2 - Top of Deck (west above pier)	20

Area 3 - Deck Edge Beam (southwest)	16
Area 3.1 - Deck Soffit (southeast)	15
Area 4 - Deck Edge Beam (northwest)	21
Area 4.1 - Deck Soffit (northwest)	12
Area 5 – South Abutment Face	10
Area 5 – South Abutment Face	8
Area 6 – Pier Face (south)	14
Area 6 – Pier Face (south)	14
Area 7 – North Abutment Face	12
Area 7 – North Abutment Face	18

A cement content of 16-17% would normally indicate an approximate in-situ compressive strength of 50N/mm^2. The values found here show that the expected cement content for the soffit is a little lower than expected. The difference in strength values between the top and bottom of the deck slab is considered attributable to the variation in density found in the cores from the respective locations. See Table 3-4 below for the compressive strength results.

Table 3-4 - Compressive Strength

Location	Compressive Strength (N/mm^2) from core test
Area 1 - Top of Deck (northeast)	18.9
Area 2 - Top of Deck (west above pier)	21.1
Area 3 - Deck Edge Beam (southwest)	-
Area 3.1 - Deck Soffit (southeast)	49.6
Area 4 - Deck Edge Beam (northwest)	-
Area 4.1 - Deck Soffit (northwest)	57.1
Area 5 – South Abutment Face	-
Area 5 – South Abutment Face	-
Area 6 – Pier Face (south)	-
Area 6 – Pier Face (south)	-
Area 7 – North Abutment Face	-
Area 7 – North Abutment Face	-

The concrete strengths found in the soffit of the deck slab were found to be significantly higher than the strengths found in the top of the slab which is most likely due to varying compaction during construction. The results of the concrete testing undertaken in the Stage 1 assessment found strengths ranging from 38.1N/mm^2 to 13.5 N/mm^2 in the soffit of the deck slab with a significant variation across the deck slab.

Half Cell Potential

Half-cell potential measurements are suitable mainly for reinforced concrete structures exposed to the atmosphere. The method can be applied regardless of the depth of the concrete cover and the rebar size. Half-cell potential measurements will indicate corroding rebars not only in the most external layers of reinforcement facing the reference electrode but also in greater depth. In the assessment of the half-cell results, ASTM C876 uses a numeric technique to assess the half-cell potential results which is given in the table below.

Measured Potential	Probability of steel corrosion activity
Greater than -200	Less than 10%
-200 to -350	Uncertain
Less than -350	More than 90%

The table above sets three phases of corrosion activity – Initial Phase, Transient Phase, and the Final Phase. For any half-cell potential results that are > -200 it is deemed to be in the initial phase where the probability of corrosion activity is less than 10%. Where the half-cell potential results are in the range of -200 to -350 (Transient Phase), the probability of corrosion activity is uncertain. Where the half-cell potential results are <-350 (Final Phase), the probability of corrosion activity is more than 90%.

Table 3-5 - Half Cell Potential Results

Location	Mean(mV)	Lowest(mV)	Highest(mV)
Area 1 - Top of Deck (northeast)	-239	-268	-207
Area 3 - Deck Edge Beam (southwest)	-54.9	-97	-27
Area 3.1 - Deck Soffit (southeast)	-333.5	-368	-320
Area 4 - Deck Edge Beam (northwest)	-237.7	-283	-198
Area 4.1 - Deck Soffit (northwest)	-165.8	-149	-129

Based on the results and visual examination of the bars on site when broken out, the likelihood of corrosion based on half-cell results is moving from the initial phase to the transient phase which indicates that corrosion is likely occurring or at least beginning to occur.

Electrical Resistivity

Resistivity measurements can be used to estimate the likelihood of corrosion in association with half-cell potential testing. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to the interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Table 3-6 - Resistivity Results

Location	Result 1	Result 2	Result 3	Result 4	Result 5

Area 1 - Top of Deck (northeast)	106	112	172	185	190
Area 3 - Deck Edge Beam (southwest)	69	55	72	-	-
Area 3.1 - Deck Soffit (southeast)	285	278	303	256	272
Area 4 - Deck Edge Beam (northwest)	186	156	194	-	-
Area 4.1 - Deck Soffit (northwest)	196	206	209	255	272

Based on the results above the likelihood of corrosion is determined to be negligible to low.

Summary

In summary the durability testing of the structure determined the durability of the structure to be in good overall condition based on the results gathered on site. The visual inspection of the structure identified significant defects throughout the deck slab however which were taken into consideration when progressing through the options stage for the project.

The existing substructure was found to have good overall durability with its mass concrete construction also reducing any risks from carbonation and chloride ingress. The existing substructure was therefore deemed suitable for retention in the proposed structure.

3.4.3 Primary Material

Various materials were considered for the new deck structure with concrete and steel the most suitable materials identified. The advantages and disadvantages of both materials are outlined below.

Concrete

Advantages

- **Cost:** Concrete is a low cost material although precast fabrication increases the overall cost.
- **Durability:** Concrete is a highly durable construction type which can last 120 years with nominal maintenance.
- **Constructability:** Precast concrete minimises working over water with the precast members manufactured off site and lifted into position.

Disadvantages

- **Constructability:** If individual beams are used then multiple lifts are needed with an insitu concrete deck infill then required to complete the deck construction. Beams spaced apart also require either temporary or permanent formwork for the insitu deck construction.
- **Weight**: The weight of the material is greater than other options, which increases support and craneage requirements.
- **Sustainability:** Concrete has a significant carbon footprint and is not considered as a sustainable material but low carbon concrete solutions are being developed to improve the sustainability of the material.

- **Aesthetics:** Concrete has an industrial appearance and is dependent on the quality of the finish at construction stage. Limited design variations are possible.

Steel

Advantages

- **Durability**: Steel is considered durable with the correct protective coating and has a 120 year design life.
- **Cost**: The high strength of steel means that less material is required to achieve the same load-bearing capacity as other materials, reducing material costs. The fabrication costs need to be considered however.
- **Constructability**: Steel beams are fabricated off-site and lifted into position, minimising construction time on-site and working over water. Steel is lighter than concrete, allowing an easier installation.
- **Aesthetics**: Steel can achieve slender depth ratios with extensive design variations feasible to improve aesthetics.

Disadvantages

- **Maintenance:** Steel requires a protective coating to prevent corrosion with maintenance required to the protective coating. Modern protective coatings require periodic maintenance after 20 years and replacement after 50 to 60 years. Access to the steelwork would be provided from the watercourse below with environmental protection required.
- **Sustainability:** Steel has a significant carbon footprint and is not considered a sustainable material but has advantages over concrete due to the reduction in quantity of material required.

3.4.4 Impact during Construction

The proposed deck replacement will require the closure of the N58 National Secondary Road for an estimated 6 months duration. A proposed traffic diversion has been identified as shown in Figure 3-5 below which diverts southbound traffic from the N58 north of Strade onto the R321 Regional Road before joining the N5 National Primary Road west of Bohola. N58 northbound traffic joining from the N5 will instead be diverted further east along the N5 onto the R321 Regional Road west of Bohola before joining the N58 carriageway north of Strade.

The proposed diversion route has a length of 11.1km with the current route along the N58 having a distance of 5.8km from the proposed diversion points, an addition of 5.3km to the travel distance.

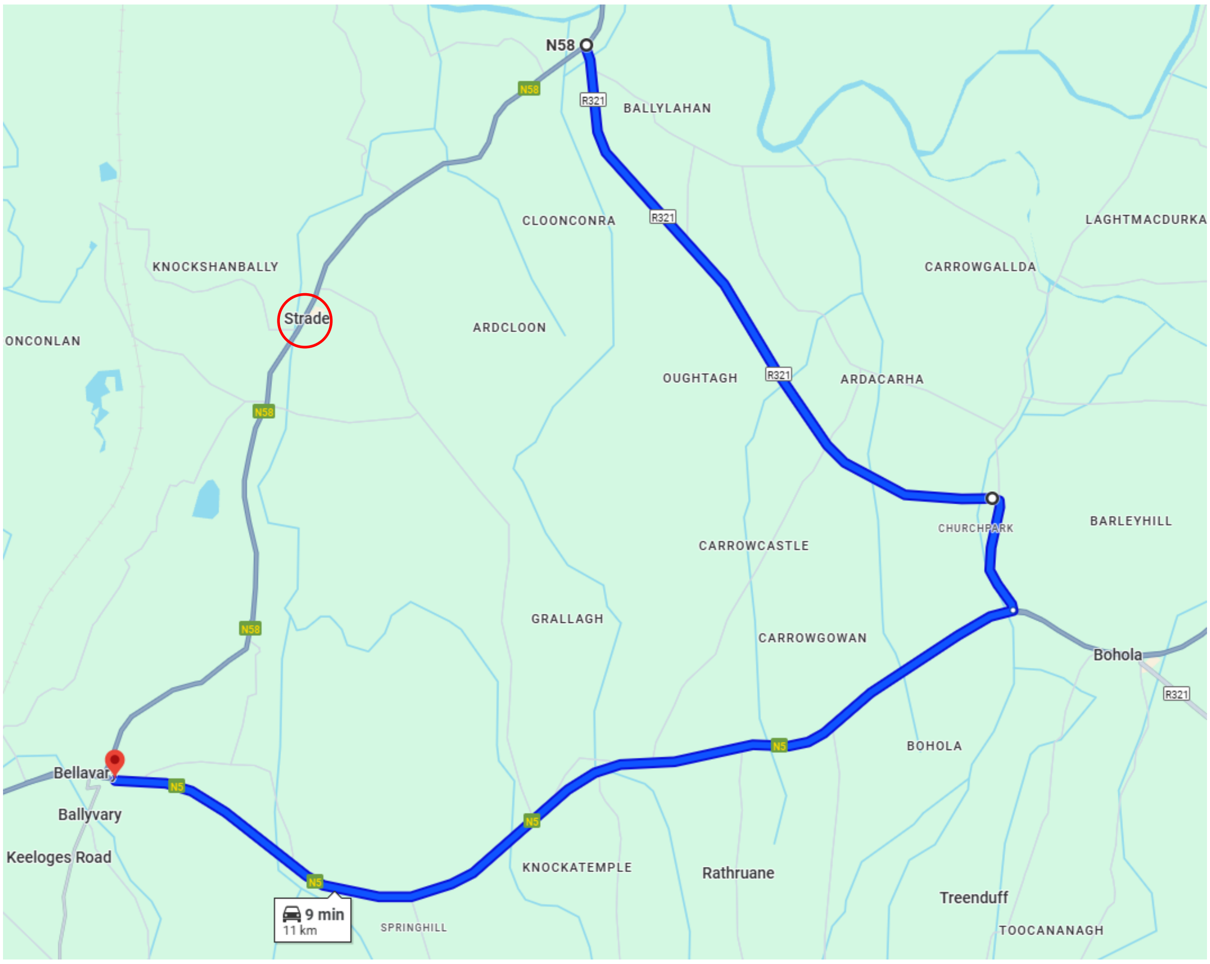


Figure 3-5 – Proposed Traffic Diversion Route (structure location circled)

3.5 Structure Options

Following a review of the design constraints and considerations in the sections above the following options are considered for the new bridge structure:

- Option 1 - Prestressed Concrete Beam & Slab
- Option 2 - Insitu Concrete Slab
- Option 3 - Composite Beams and Slab

All the structure options follow the proposed general arrangement layout plan shown in Drg. No. 0088572-ATK-02-XX-DR-CE-900203 in Appendix B. All options have a span length of 12.5m and an overall width of 10.9m.

3.5.1 Option 1 - Prestressed Concrete Beam & Slab

Option 1 comprises precast prestressed concrete beams with an in-situ concrete deck infill above the beams. The precast beam arrangement includes ‘TY’ beams with 2no. ‘TYE’ edge beams either side. The beams require a 150mm deck infill on top to bring the overall structural depth to 550mm. The structure will be of integral construction with the substructure comprising reinforced concrete piled foundations located behind the existing abutment walls. The piles would require partial isolation to accommodate thermal movement of the new superstructure.

The existing abutment walls would be reduced in height to allow for the inspection and maintenance access to the full extent of the deck.

See Figures 3-6 below for the general arrangement of the option. See drawing no. 0088572-ATK-02-XX-DR-CE-900204 in Appendix B of this report.

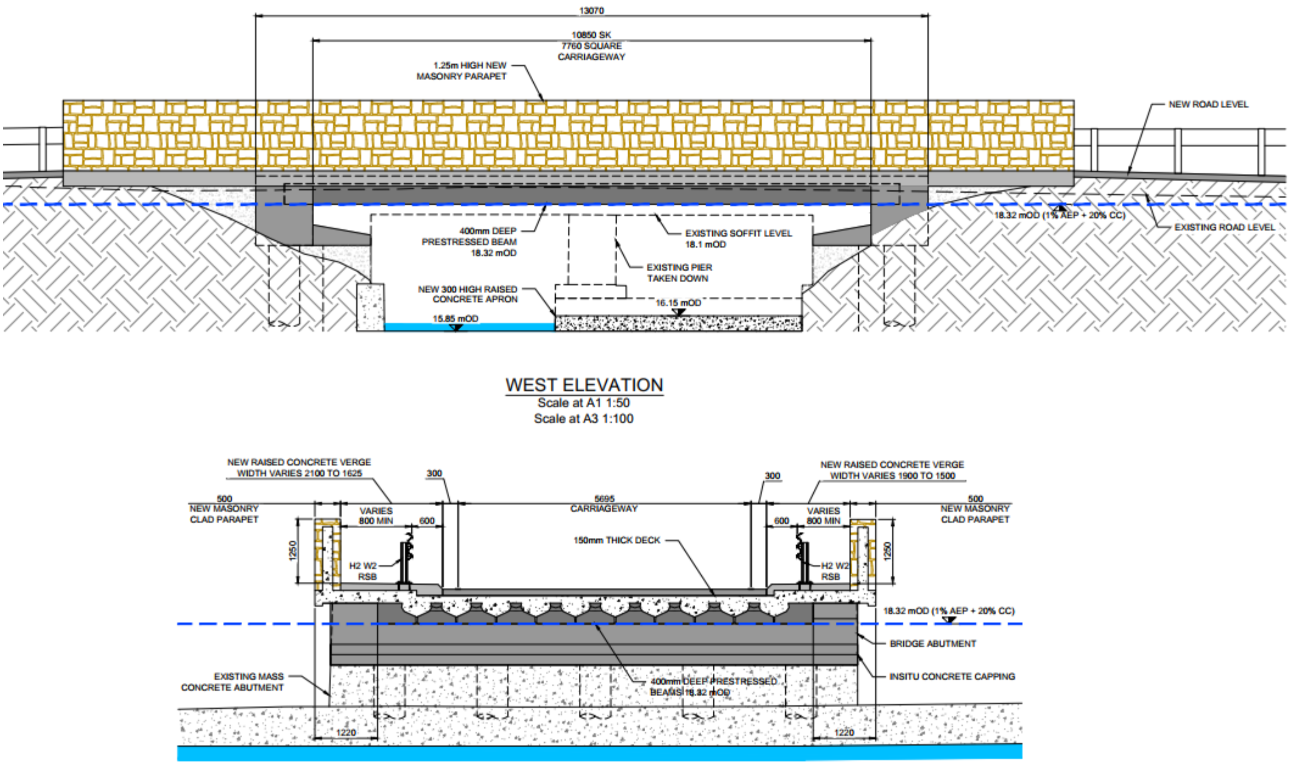


Figure 3-6 – Option 1 Elevation and Section

3.5.2 Option 2 - In-situ Concrete Slab

Option 2 comprises an insitu reinforced concrete slab with a structural depth of 500mm. The structure would be of integral construction with the substructure comprising reinforced concrete piled foundations located behind the existing abutment walls. The piles would require partial isolation to accommodate thermal movement of the new superstructure.

The existing abutment walls would be reduced in height to allow for the inspection and maintenance access to the full extent of the deck.

See Figure 3-7 below for the general arrangement of the option. See drawing no. 0088572-ATK-02-XX-DR-CE-900205 in Appendix B of this report.

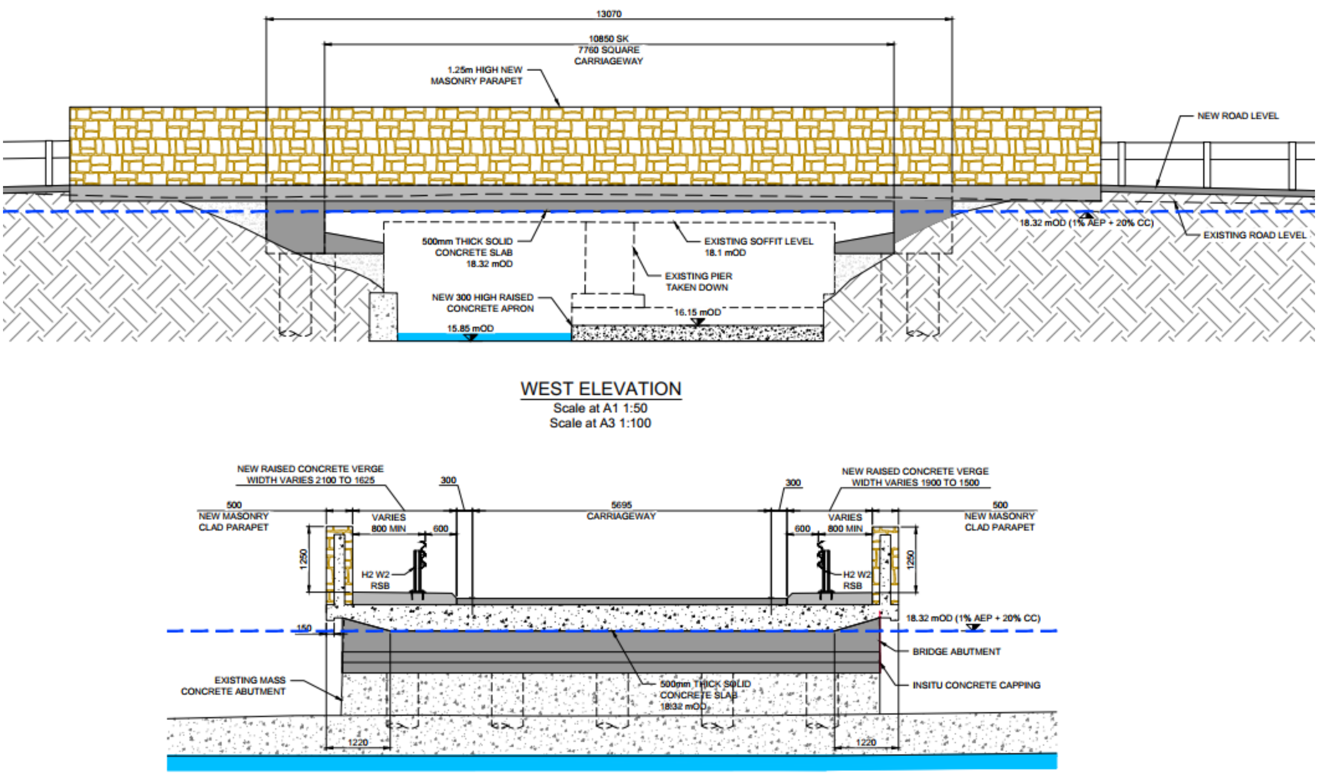


Figure 3-7 – Option 2 Elevation and Section

3.5.3 Option 3 - Composite Beams & Slab

Option 3 comprises longitudinal steel beams acting compositely with a reinforced concrete deck slab. The structural depth is estimated as 700mm, comprising a 200mm deep deck slab and 500mm deep steel I beams, connected to the deck slab using shear studs. The structure will be of integral construction with the substructure comprising reinforced concrete piled foundations located behind the existing abutment walls. The piles would require partial isolation to accommodate thermal movement of the new superstructure.

The existing abutment walls would be reduced in height to allow for the inspection and maintenance access to the full extent of the deck.

See Figure 3-8 below for the general arrangement of the option. See drawing no. 0088572-ATK-02-XX-DR-CE-900206 in Appendix B of this report.

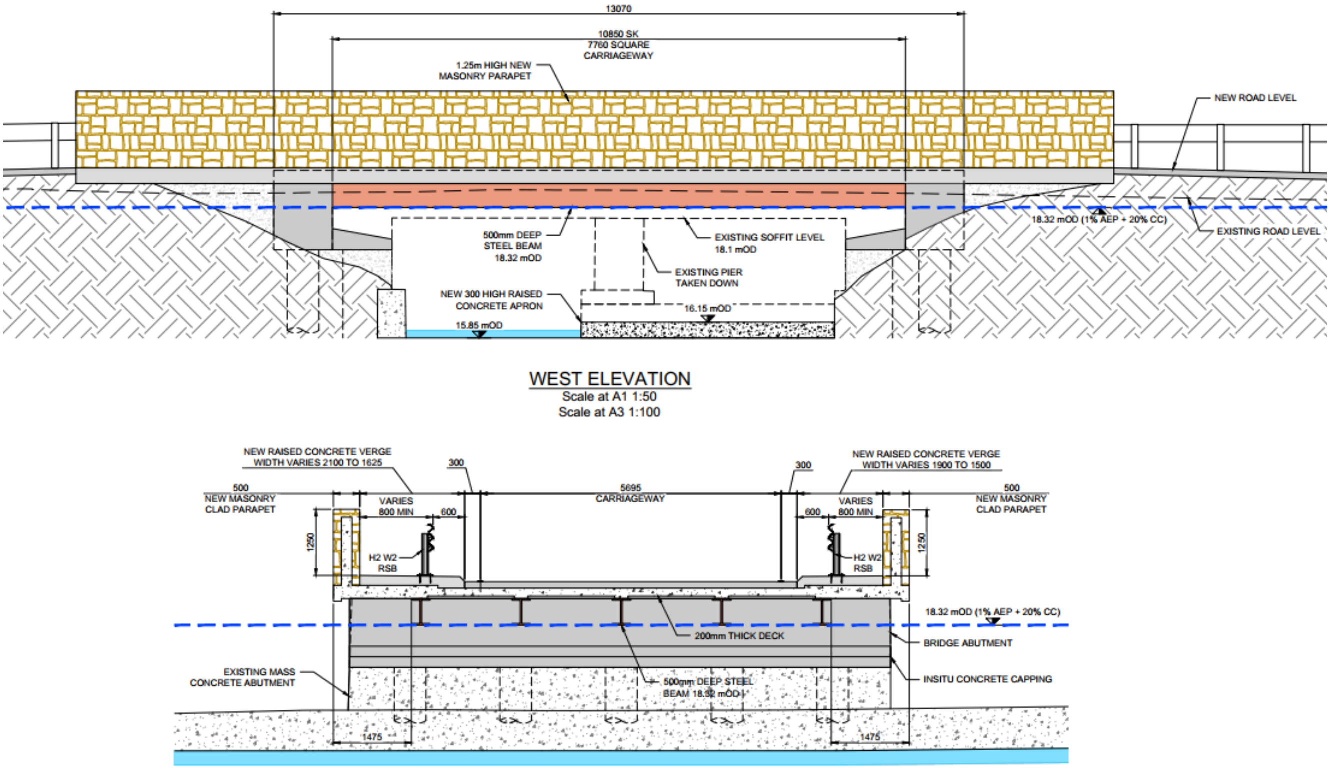


Figure 3-8 – Option 3 Elevation and Section

4. Technical Evaluation

The proposed options are largely similar from a technical perspective but there are minor variations as outlined in the sections below. The variations across the options are better covered in the subsequent evaluation criteria of aesthetics, durability & maintenance and constructability.

The existing deck slab and parapet walls are to be demolished and replaced with a new superstructure. The options are all structurally independent from the existing structure with new piled foundations constructed behind the existing abutment walls. Each of the options provide a single span structure.

The structure has an overall span length of 12.5m and is to be of integral construction for all options. The proposed parapets for all options comprise a reinforced concrete wall with masonry cladding on both parapet faces.

Option 1 - Prestressed Concrete Beams and Slab

The prestressed concrete beams and slab option is of integral construction with the prestressed beams cast into the supports behind the existing abutment walls. The estimated construction depth is 550mm, based on a 150mm deck infill above the precast beams with the construction depth increasing to 650mm at the cantilever sections of the slab.

The use of prestressed reinforced concrete in the construction increases the design complexity compared to reinforced concrete. Prestressed concrete beams are a familiar construction form used on many previous projects however with their production by a specialist precast beam manufacturer reducing the technical complexity further.

The beams would be lifted into position in multiple lifts with an in situ concrete deck infill then poured to complete the deck slab.

Option 2 - In-situ Concrete Slab

The in-situ reinforced concrete slab option also has an integral connection at the supports behind the existing abutment walls and is of reinforced concrete construction, which is a less complex design than the other 2no. options. The estimated structural depth for this option is 500mm. The construction would require temporary formwork to be erected across the full width of the structure.

Option 3 - Composite Beams and Slab

The composite beams option also has an integral connection at the supports behind the existing abutment walls with composite action increasing the complexity of the design.

The need to consider the different stages of construction in the design prior to achieving composite action and an integral connection adds to the technical requirements. The structural depth of this option is 700mm, comprising 500mm deep beams and a 200mm deep deck slab, increasing to 250mm for the cantilever deck sections.

Summary

	Option 1 – Prestressed Beams and Slab	Option 2 – In-Situ Concrete Slab	Option 3 – Composite Beams and Slab
Scoring 1 (worst) to 3 (best)	3	2	1

Option 1 – Prestressed Beams and Slab is deemed the best technical option as the structural behaviour is less technical than the composite beams and the construction of the option is easier achieved than the significant formwork needed for Option 2

5. Economic Evaluation

As the wider scheme including the foundation details and demolition of the existing superstructure is repeated across all options there is not a significant cost variation across the various structure options. Option 2 – In-Situ Concrete Slab has the least construction cost followed by Option 1 – Prestressed Beam and Slab. The composite beams option has the highest cost across the options.

The whole life costs for the structure options show a variation across the options as the concrete options are expected to incur minor maintenance costs while the composite option will require maintenance of the protection system to the steel beams.

The table below presents construction cost estimates for the various structure options, and a ranking of 1 (worst) to 3 (best). It excludes the cost of purchasing private property which is the same across all options.

	Option 1 – Prestressed Beams and Slab	**Option 2 – In-situ Concrete Slab**	**Option 3 – Composite Beams and Slab**
Construction Cost	€450,000	€425,000	€475,000
Expected Maintenance	Low maintenance expected due to concrete durability	Low maintenance expected due to concrete durability	Medium maintenance required for renewal of protective coatings
Ranking 1 (worst) to 3 (best)	2	3	1

6. Aesthetic Evaluation

The existing Strade River Bridge is considered to have limited architectural value due to its 1980's concrete construction with the aesthetic value provided by the surrounding location which includes both the protected masonry arch structure upstream and also the adjacent Abbey ruins.

It is therefore considered important that the new bridge deck ties into these existing surroundings as best as possible, with masonry clad parapets proposed for all options as a result. The aesthetics of the options are evaluated in the following sections.

Option 1 - Prestressed Concrete Beams and Slab

The taking down of the central pier would provide a more open structure and give a more slender appearance for the deck. The use of masonry cladding on the faces of the parapet would reduce the visual impact of the concrete also. The masonry parapet coursing and stone is to match the upstream masonry structure where possible.

Option 2 - In-situ Concrete Slab

The in-situ concrete slab option has the lowest structural depth and would allow for a tapered cantilever edge to enhance its depth ratio visually. Similar to Option 1, the single span structure giving a more slender appearance and the use of masonry cladding on the faces of the parapet would reduce the visual impact of the concrete. The masonry parapet coursing and stone is to match the upstream masonry structure where possible.

The quality of finish on the deck soffit will be important in order to achieve an aesthetic appearance to the concrete surface both in the short term and long term.

Option 3 - Composite Beams and Slab

The composite beams option provides a visual contrast between the steel, concrete and masonry which can have an aesthetic appeal if used in the right proportions. The steel beams protective coating also allows for a colour to best suit the surrounding environment. However, without proper maintenance, there is high potential for corrosion and weathering which can detract from its appearance over time.

Summary

	Option 1 – Prestressed Beams and Slab	**Option 2 - In-situ Concrete Slab**	**Option 3 – Composite Beams and Slab**
Scoring 1 (worst) to 3 (best)	3	2	1

Option 1 – Prestressed Beams and Slab is deemed the most aesthetic option due to the nature of its construction providing a more consistent finish than Option 2 due to the higher quality control of precast concrete production.

7. Evaluation of Durability and Maintenance Requirements

The durability and maintenance requirements of the various options are outlined below.

Option 1 - Prestressed Concrete Beams and Slab

Concrete can achieve a 120-year design life with nominal maintenance, particularly precast concrete with greater control at fabrication stage. As the structure is fixed at both supports there is no bearings or movement joints to be maintained. The precast beams for this option would allow for higher quality control in the manufacturing of the beams compared to the insitu construction of Option 2 with increased durability expected as a result.

Option 2 - In-situ Concrete Slab

Similar to Option 1, apart from the reduced quality control for the insitu construction compared to the precast construction of Option 1.

Option 3 - Composite Beams and Slab

The composite option can achieve a 120-year design life providing maintenance of the protective coating to the steel beams is periodically undertaken, with major renewal required after 30 to 50 years depending on the protective system. To minimise the need for paintwork maintenance and reduce potential ecology impacts, the use of high-performance coatings such as fluoropolymer paint systems or Duplex (hot dip galvanised plus paint system coating) would maximise the working life of the protective system. As the structure is fixed at both supports there is no bearings or movement joints to be maintained.

Summary

	Option 1 – Prestressed Beams and Slab	**Option 2 - In-situ Concrete Slab**	**Option 3 – Composite Beams and Slab**
Scoring 1 (worst) to 3 (best)	3	2	1

Options 1 is deemed the best option for durability and maintenance with the composite beams option requiring the maintenance of the protective coating to the steel beams.

8. Hydraulic Considerations

The hydraulic considerations for the proposed structure are a significant consideration for the project with the existing bridge being the primary hydraulic constraint in the river channel at the bridge location. A 3 span protected masonry arch structure located 40m upstream is also providing a primary hydraulic constraint in the upstream river channel.

Figure 8-1 below shows the medium probability fluvial mapping for the area surrounding Strade River Bridge. A 1995 flood event is also recorded in the vicinity of the structure although the available information is limited. A more recent flood event occurred upstream of the structure on 23rd November 2024, causing flooding to the houses and church hall upstream of the existing masonry arch bridge. On review of available information the national road does not appear to have flooded at the bridge location (levels c. 18.6mOD) but flooding did occur on the south approach, adjacent to the public house and residential premises where road levels are lower (levels c. 18.2mOD). See Figure 8-2 below for the flooding at the masonry arch bridge upstream with Strade River Bridge visible in the background.

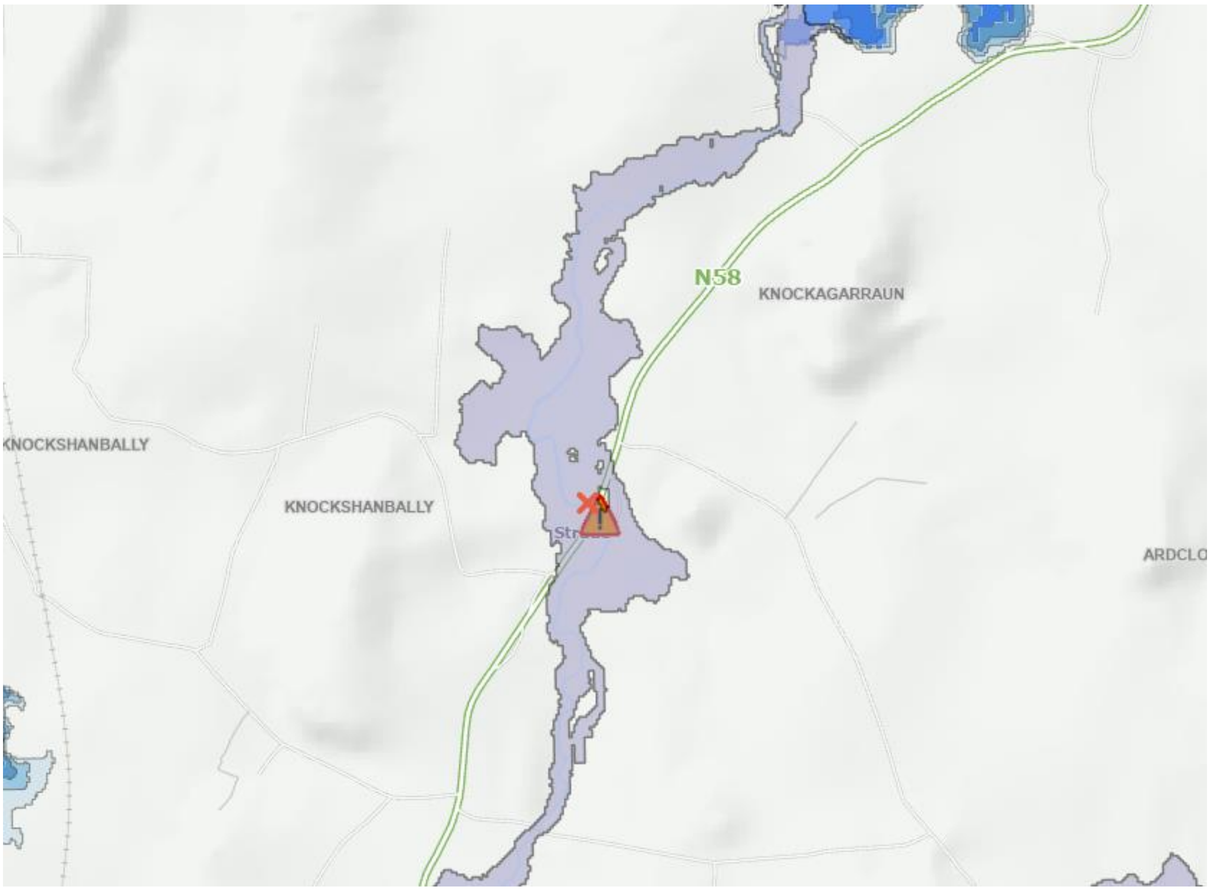


Figure 8-1 – Medium Probability Flood Risk Map for the area surrounding Strade River Bridge

Figure 8-2 – Flooding upstream of Strade River Bridge on 23rd November 2024

The hydraulic assessment of the existing structure determined a design flood level of 18.38mOD at the existing bridge, with the bridge soffit level of 18.1moD below the design flood level.

The location of the new bridge supports behind the existing abutment walls maintains the existing river channel width through the structure with the conveyance improved by the removal of the existing pier and raised concrete apron. A new reduced height raised concrete apron of 300mm to maintain the existing low flow channel has been agreed with Inland Fisheries Ireland.

The design flood level for the proposed structure arrangement is 18.31mOD with the bridge soffit level of 18.32mOD agreed following consultation with OPW. The omission of the 300mm freeboard requirement for the structure allows for the required vertical realignment of the carriageway to remain within acceptable gradients in the available length on both approaches.

The proposed options all meet the required soffit level with the varying construction depths affecting the height the road requires to be raised. The options have therefore been scored based on their construction depth and the impact on the required gradients for the new road surface.

A Section 50 application has been submitted for the proposed structure with a soffit level of 18.32mOD.

Summary

	Option 1 – Prestressed Beams and Slab	Option 2 – In-situ Concrete Slab	Option 3 – Composite Beams and Slab
Scoring 1 (worst) to 3 (best)	2	3	1

All options are evaluated in accordance with their expected carriageway level with Option 2 having the smallest construction depth and therefore requires the least vertical realignment of the carriageway.

9. Environmental Considerations

Potential environmental impacts from the proposed works will be mitigated where possible. The proposed substructure for all options is set back from the watercourse with differing levels of potential environmental impact across the options during construction stage.

Due to the location of the structure within the 20m buffer zone of the River Moy SAC a Natura Impact Statement is considered to be required for all options. All mitigation measures outlined in the Natura Impact Statement for the preferred option will be implemented prior to commencement of the works.

The existing structure requires the same demolition works for each option comprising the removal of the deck slab, parapets, pier and raised concrete apron with measures required to protect the watercourse during the demolition and removal of the material from site.

Another variation across the options is the potential environmental impact from the required maintenance to the structure.

Option 1 - Prestressed Concrete Beams and Slab

The prestressed beams would be lifted into place and supported on the new foundations located behind the existing abutments with the beams abutting one another to remove the need for formwork for the in- situ concrete deck infill. The cantilever sections of the structure will require temporary formwork to be provided however. The joint between the beam faces will be caulked/sealed to prevent grout leakage during construction

Minimal maintenance is required for the option due to the high durability of concrete which will reduce instream access and maintenance works.

Option 2 - In-situ Concrete Slab

The in-situ concrete slab option would require full temporary formwork to be erected below the structure supported from the riverbed to construct the replacement deck. The large volume of in-situ concrete required is considered a significant environmental concern with an increased risk of wet concrete entering the watercourse.

Minimal maintenance is required for the option due to the high durability of concrete which reduces the need for instream access and maintenance works.

Option 3 - Composite Beams and Slab

The steel beams would be lifted into place and supported on the new foundations located behind the existing abutments with permanent non participating formwork spanning between the beams to construct the deck slab. The permanent formwork would reduce the risk of concrete entering the watercourse, however temporary formwork would be required for the construction of the cantilever sections.

The maintenance for the steel beam protective coatings would require access from the watercourse and also measures to protect the watercourse during the renewal of protective coatings.

Summary

	Option 1 – Prestressed Beams and Slab	Option 2 - In-situ Concrete Slab	Option 3 – Composite Beams and Slab
Scoring 1 (worst) to 3 (best)	3	1	2

All options consider environmental protection during construction by reducing the works adjacent to the watercourse through the retention of the existing substructure. Option 1 is deemed the best option environmentally due to the need for limited maintenance over the structure lifecycle compared to Option 3 and the reduced risk of wet concrete entering the watercourse compared to Options 2 & 3.

10. Health & Safety Considerations

The construction works shall be carried out in accordance with the 'Safety, Health and Welfare at Work (Construction) Regulations 2013'. All works shall be carried out with approval from the Project Supervisor Design Process (PSDP) and Project Supervisor Construction Stage (PSCS) as required by the above-mentioned regulations.

Health and Safety (H&S) considerations are evaluated over 3no. stages, construction, operation and maintenance. The following is applicable to all options:

- Construction: New substructure foundations would be located behind the existing abutment walls set back from the watercourse to reduce the instream works required. Existing abutments would be retained to provide protection from the watercourse to operatives
- Maintenance: Inspection and maintenance access to the underside of the new deck replacement will require access from the river below.
- Operation: All options improve the safety of vehicle users over the structure by providing a structure with adequate 40t load capacity

Further H&S considerations specific to the various structure options are described below.

Option 1 - Prestressed Concrete Beams and Slab

Construction: The individual precast beams require separate lifts for their installation. In-situ concrete construction required over water but sufficient safety measures can be easily implemented.

Maintenance: Concrete requires little maintenance, reducing the need to enter the watercourse below the structure.

Option 2 - In-situ Concrete Slab

Construction: In-situ concrete construction required over water with significant temporary works required for the formwork.

Maintenance: Concrete requires little maintenance, reducing the need to enter the watercourse below the structure.

Option 3 - Composite Beams and Slab

Construction: The individual steel beams require separate lifts for their installation but the number and weight of the beams are less than Option 1. In-situ concrete construction is required over water but the use of permanent formwork between the beams is a safer solution than the temporary formwork of Option 2.

Maintenance: Steel requires regular maintenance, increasing the need to enter the watercourse below the structure.

Summary

	Option 1 – Prestressed Beams and Slab	Option 2 - In-situ Concrete Slab	Option 3 – Composite Beams and Slab
Scoring 1 (worst) to 3 (best)	3	1	2

Option 1 is deemed the best option for health & safety considerations due to the reduction in temporary works and maintenance to be undertaken from the watercourse. The health and safety risks from the extent of temporary formwork required for Option 2 and the need for maintenance of the steel beams of Option 3 were considered in their scoring.

11. Construction and Buildability

The bridge substructure is the same for all options and comprises the construction of a piled foundations behind the existing abutment walls at the bridge location with the superstructure connected integrally to the new substructure. The construction process for all options also comprises the demolition of the existing deck slab, pier, and raised concrete apron with the existing abutments are also to be reduced in height to enable inspection and maintenance access to the full extent of the new deck.

Option 1 - Prestressed Concrete Beams and Slab

The prestressed concrete elements are standard beams available from precast beam manufacturers with no variation required. The beams are short and can be transported to site as single units and lifted into position in multiple lifts which reduces the weight of the lift.

In-situ concrete deck infill is required following the beam installation increases the construction complexity with in-situ cantilever sections and parapets also to be formed over the watercourse. Provision to support the cantilever slab construction can be incorporated in the edge beams negating the requirement to enter the watercourse to erect formwork.

Option 2 - In-situ Concrete Slab

The in-situ concrete slab requires temporary formwork to be erected fully across the slab, increasing the extent of temporary works in the riverbed. Quality control would be particularly important to ensure a durable and aesthetic finish. In-situ concrete parapets are also to be formed over the watercourse.

Option 3 - Composite Beams and Slab

The steel beams would be fabricated off site and transported to site and lifted into position in multiple lifts. The steel beams would require permanent formwork to span between the beams to support the concrete deck during construction with in-situ concrete parapets also to be formed over the watercourse similar to the other options.

Summary

	Option 1 – Prestressed Beams and Slab	**Option 2 - In-situ Concrete Slab**	**Option 3 – Composite Beams and Slab**
Scoring 1 (worst) to 3 (best)	3	1	2

Option 1 is deemed the best option for constructability due to easier transportation of prefabricated elements and reduced formwork compared to other options. The extent of temporary formwork required for Option 2 results in it receiving the lowest score.

12. Sustainability Considerations

The overall sustainability of the scheme is improved by the retention of the existing bridge abutments in their current form. The evaluation of sustainability across the options focuses on the sustainability of the replacement deck options as the wider scheme is the same for all options.

Option 1 - Prestressed Concrete Beams and Slab

The embodied carbon of the concrete material is quite large due to the carbon intensive calcination process where one ton of cement typically emits about 0.9 tons of CO2. The type of cement used can largely affect the CO_2e, with 50-70% Ground Granulated Blast Furnace Slag (GGBS) content being preferred in the mix design to reduce the carbon footprint.

The concrete can be recycled as aggregate at the end of the structure life with the steel reinforcement also recycled to promote sustainability.

Option 2 - In-situ Concrete Slab

Similar to Option 1 with the use of GGBS preferred in the mix design to reduce carbon footprint and the concrete can be recycled as aggregate at the end of the structure life with the steel reinforcement also recycled in order to promote sustainability.

Option 3 - Composite Beams and Slab

Steel production is highly carbon intensive. However, steel is highly recyclable and therefore has a lower total embodied carbon than concrete, particularly when considering the volume of material required. The overall carbon footprint can be reduced by optimizing the production process, increasing the use of recycled steel and minimizing transportation distances.

A concrete deck is also required for this option with the reduction in the volume of concrete compared to the first 2no. options is offset by the steel production needed for the steel beams. Both the concrete and steel components can be recycled at the end of the structure life cycle to promote sustainability.

Summary

	Option 1 – Prestressed Beams and Slab	**Option 2 - In-situ Concrete Slab**	**Option 3 – Composite Beams and Slab**
Scoring 1 (worst) to 3 (best)	2	1	3

Option 3 is deemed the best option due to the reduced concrete volume compared to the other options.

13. Ground Conditions

Ground Investigations are to be undertaken to inform the ground conditions and the required foundation arrangements.

The proposed substructure and foundations are the same for all options and comprise reinforced concrete bored cast in place piled foundations located behind the existing river walls.

14. Consultation with Relevant Authorities

The following authorities have been and will be consulted as part of the scheme development.

Mayo County Council

Mayo County Council Transportation section were liaised with for feedback on the proposed scheme layout with the comments considered in the options development. The planning and environmental sections are also to be liaised with during the preliminary design of the structure.

Mayo County Council advised of a future bypass scheme for the area but this is in early stages of development and remote from the bridge location.

Transport Infrastructure Ireland

Transport Infrastructure Ireland Bridges Management team also provided feedback on the proposed scheme layout and bridge options with the comments considered in the options development.

Office of Public Works (OPW)

The OPW were consulted regarding the soffit height of the proposed bridge deck replacement with a soffit level of 18.32mOD agreed, omitting the requirement for a 300mm freeboard. A Section 50 application was submitted for the new bridge structure layout with the agreed soffit level. The hydraulic considerations of the options are as presented in section 8 of this report.

Inland Fisheries Ireland (IFI)

IFI have been consulted on the proposed works and agreed to a reduction in the height of the existing raised concrete apron to improve conveyance through the structure.

Utility Providers

A PAS128 utility survey was undertaken for the structure to determine the layout of services across the structure, with records also sought from the utility providers prior to the survey being carried out. The required diversion of the Eir service duct running across the north abutment is the same for all options with liaison with Eir ongoing regarding the relocation of the duct.

The overhead ESB lines crossing the carriageway above the north abutment will also require to be relocated to facilitate the works. Liaison is ongoing with ESB with the lines recommended to be permanently buried below the carriageway.

National Monuments Service

As the bridge location is within the zone of notification for the nearby monuments we will liaise with the National Monuments Service and submit licence applications as required for the monitoring of the works. Richard Gillespie of Mayo County Council / TII was also contacted for guidance on assessments required for the scheme, with Richard preparing a Cultural Heritage Impact Assessment.

15. Conclusions & Recommendations

The summary of the evaluation scoring (1 is worst and 3 is best) for each of the criteria is summarised in Table 15-1 below.

Table 15-1 – Multi criteria assessment of the options

Evaluation Criteria	Option 1 – Prestressed Beams and Slab	Option 2 – In-situ Concrete Slab	Option 3 – Composite Beams
Technical Evaluation	3	2	1
Economic Evaluation	2	3	1
Aesthetic Evaluation	3	2	1
Durability and Maintenance	3	2	1
Hydraulic Considerations	2	3	1
Environmental Considerations	3	1	2
Health & Safety	3	1	2
Construction and Buildability	3	1	2
Sustainability Considerations	2	1	3
Total score out of 27	**24**	**16**	**14**
Overall ranking:	**1st**	**2nd**	**3rd**

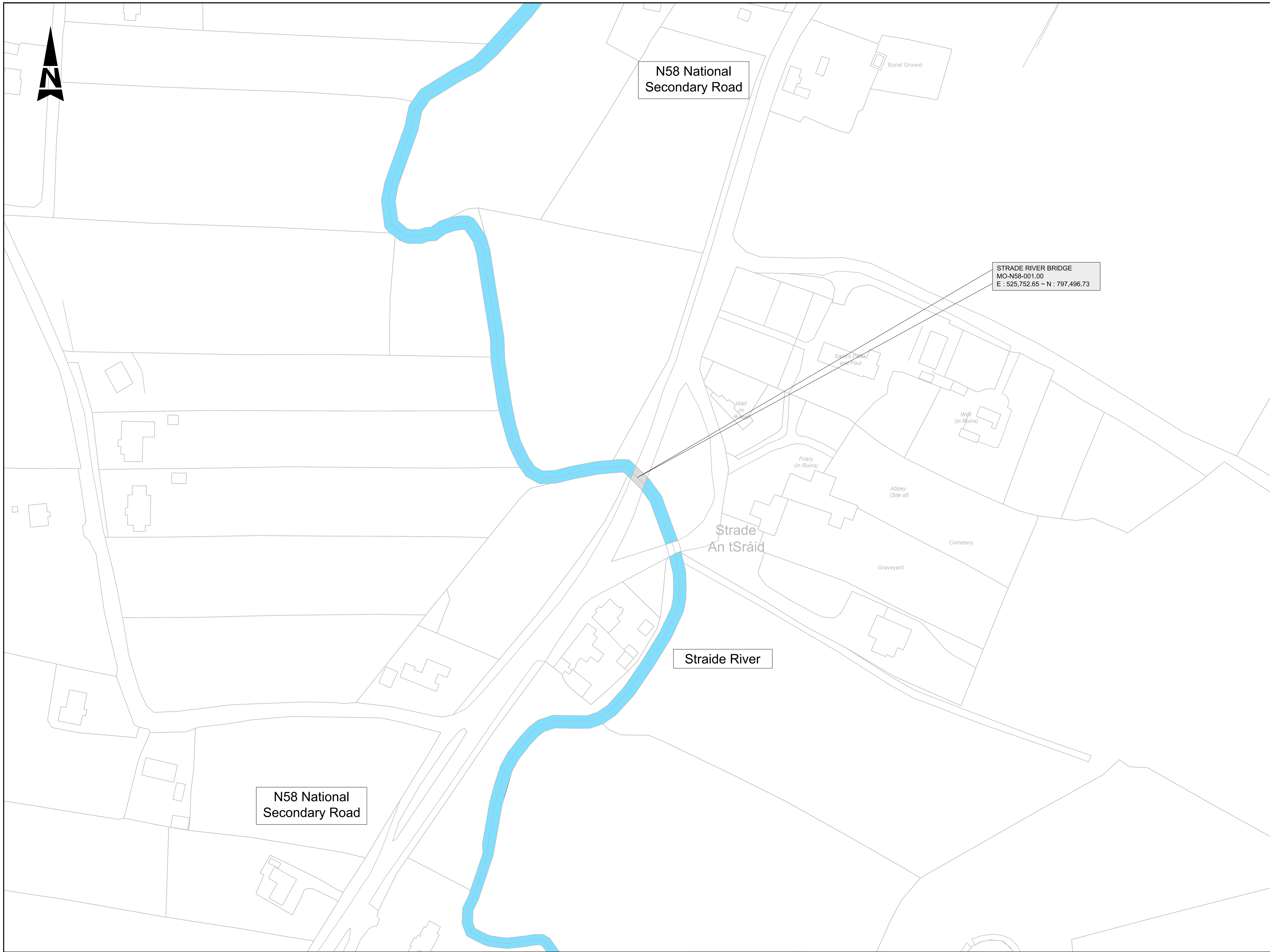
As per the summary table above the preferred option is Option 1 - Prestressed Concrete Beams and Slab with the overall ranking of the options as follows:

- 1st Place – Option 1 Prestressed Concrete Beams and Slab
- 2nd Place – Option 2 In-situ Concrete Slab
- 3rd Place – Option 3 Composite Beams

It is therefore recommended that Option 1 – Prestressed Concrete Beams and Slab is progressed to preliminary design.

APPENDICES

Appendix A. Site Location Plan



A1

DO NOT SCALE

GENERAL NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE
2. ONLY WRITTEN DIMENSIONS SHALL BE USED. NO DIMENSIONS SHALL BE SCALED FROM THE DRAWINGS
3. ALL LEVELS ARE IN METRES AND ARE TO MALIN HEAD DATUM
4. ALL COORDINATES ARE IN METRES AND ARE TO IRISH TRANSVERSE MERCATOR
5. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION

Risk Level		
	X	Atkins Base Line - Low Risk
		Atkins Sensitive - Medium Risk
		Atkins Private - High Risk
		Client Critical - Already Marked

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Oifig Bóithre Náisiúnta Dhún na nGall

Rev	Description	By	Date	Chk'd	Rev'd	Auth
P0	ISSUED FOR INFORMATION	AOS	02.24	MG	CP	MJ

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1st Floor Technology House Parkmore Technology Park, Galway
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Fax (+353) 091 779 830

Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: ISSUED FOR INFORMATION

Title: Strade River Bridge
MO-N58-001.00
Existing Site Location Plan

Original Scale	Drawn	Checked	Reviewed	Authorised
1:1000	AOS	MG	CP	MJ
	Date 02.02.24	Date 02.02.24	Date 02.02.24	Date 02.02.24

Status	Drawing Number	Rev
S2	0088572-ATK-XX-XX-DR-CE-900102	P0

File: 0088572-ATK-XX-XX-DR-CE-900101 to 900110.dwg Plotted by: aosullivan
Date: Mar 12, 2024 - 3:53pm

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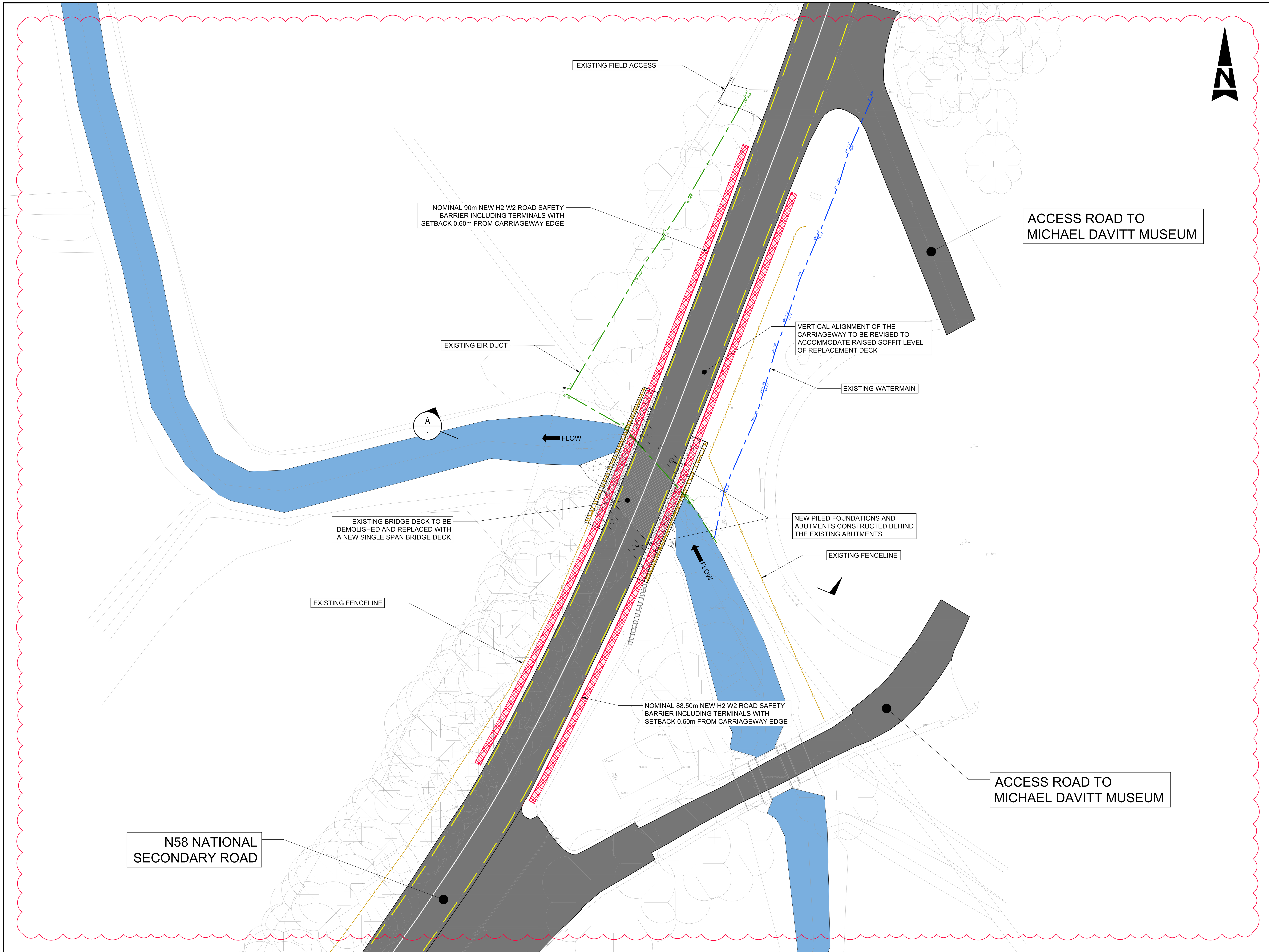
Appendix B. General Arrangement Drawings

A1

DO NOT SCALE



GENERAL NOTES

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5. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION

DRAWING NOTES

1. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH 0088572DG0046 - Strade River Bridge Options Report

Risk Level		
	X	Atkins Base Line - Low Risk
		Atkins Sensitive - Medium Risk
		Atkins Private - High Risk
		Client Critical - Already Marked

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Transport Infrastructure Ireland

Donegal NRO
Oifig Bóithre Náisiúnta Dhún na nGall

Rev	Description	By	Date	Chk'd	Rev'd	Auth
P01	REVIEW COMMENTS INCORPORATED	AOS	03.25	MG	MJ	MJ
P0	ISSUED FOR REVIEW	AGL	01.25	MG	MJ	MJ

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Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Proposed Site Layout Plan

Original Scale	Drawn	Checked	Reviewed	Authorised
1:250	AGL	MG	MJ	MJ
	Date 03.01.25	Date 03.01.25	Date 03.01.25	Date 03.01.25

Status	Drawing Number	Rev
S0	0088572-ATK-02-XX-DR-CE-900203	P01

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Date: Mar 25, 2025 - 11:46am

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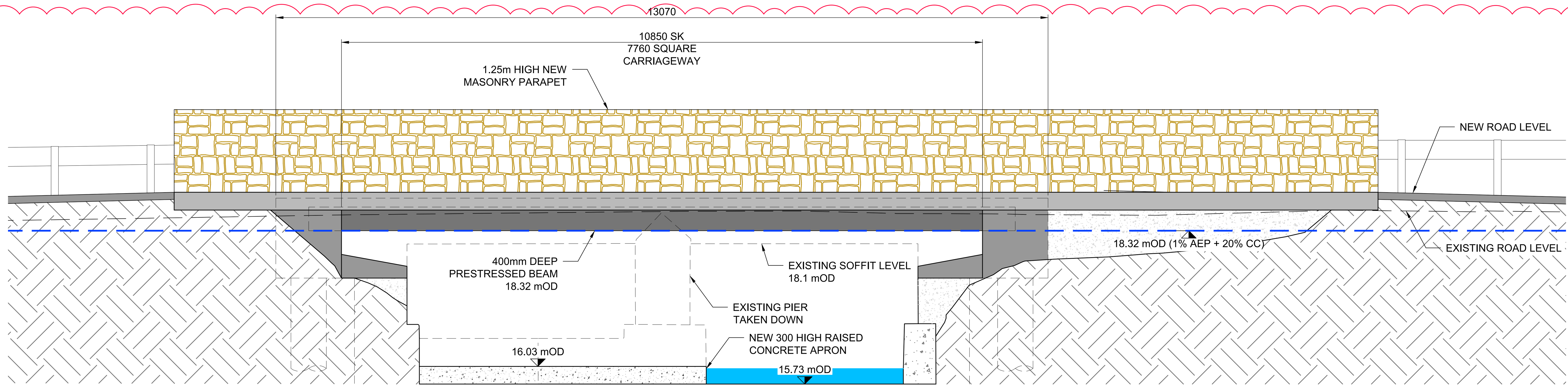

EAST ELEVATION

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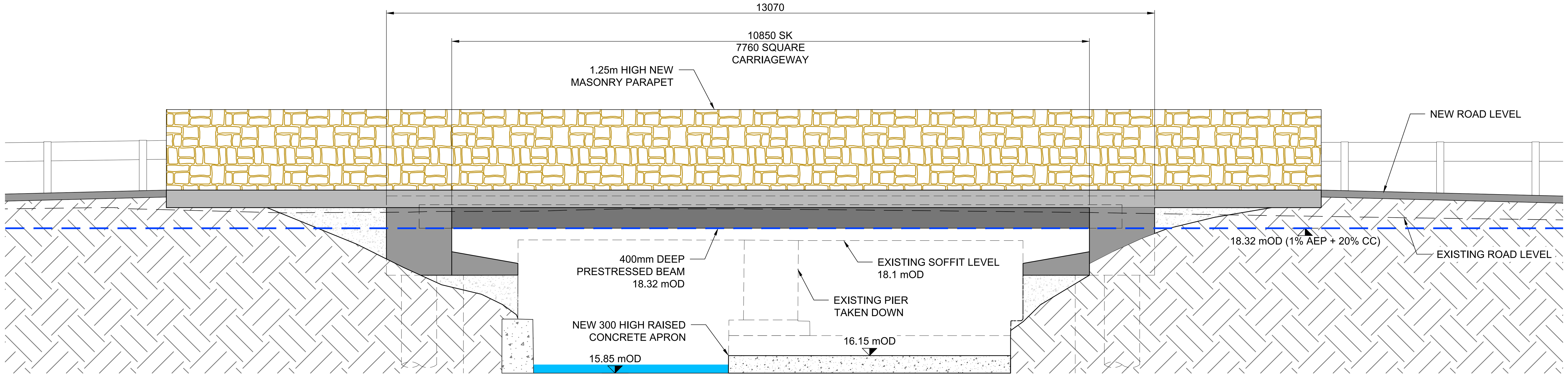
Scale at A3 1:100



WEST ELEVATION

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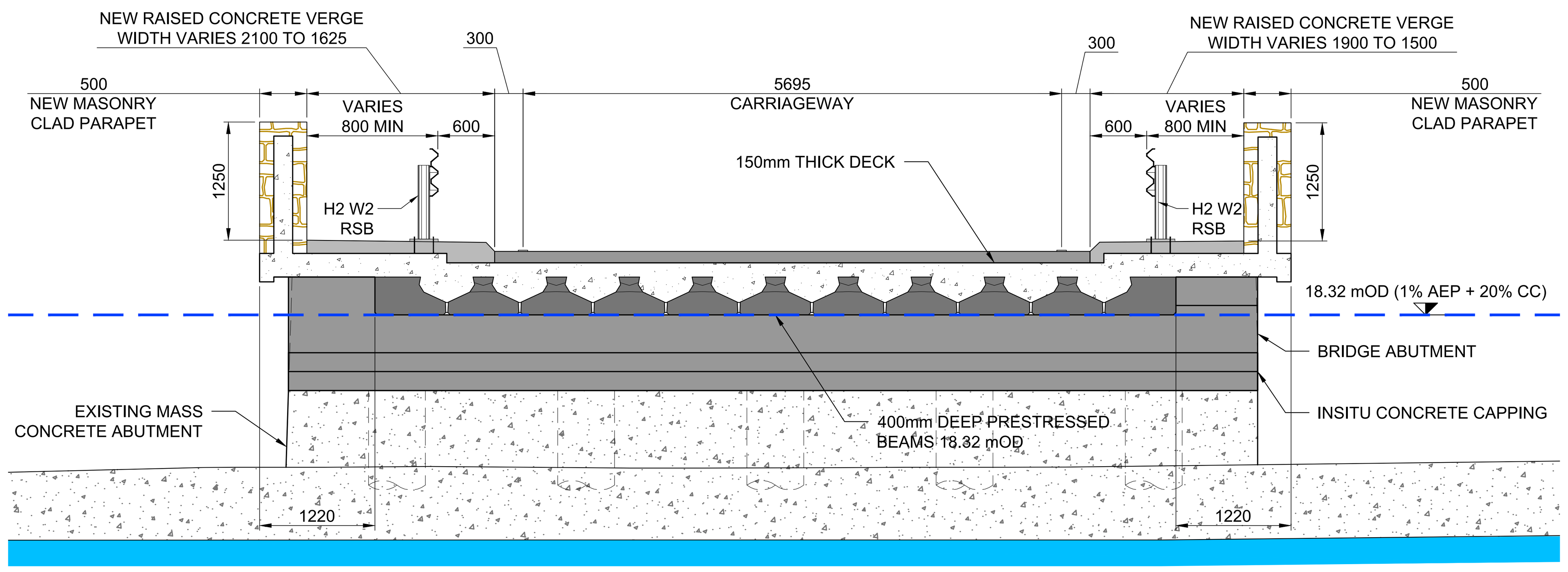
Scale at A3 1:100



SECTION A

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3. ALL LEVELS ARE IN METRES AND ARE TO MALIN HEAD DATUM
4. ALL COORDINATES ARE IN METRES AND ARE TO IRISH TRANSVERSE MERCATOR
5. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH THE SPECIFICATION

DRAWING NOTES

1. DRAWINGS ARE TO BE READ IN CONJUNCTION WITH 0088572DG0046 - Strade River Bridge Options Report

Risk Level
- X Atkins Base Line - Low Risk
- Atkins Sensitive - Medium Risk
- Atkins Private - High Risk
- Client Critical - Already Marked

Rev	Description	By	Date	Chk'd	Rev'd	Auth
P01	REVIEW COMMENTS INCORPORATED	AOS	03.25	MG	MJ	MJ
P0	ISSUED FOR REVIEW	AGL	01.25	MG	MJ	MJ

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1st Floor Technology House Parkmore Technology Park, Galway Tel (+353) 091 786 050 Fax (+353) 091 779 830

Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Option 1 - Prestressed Concrete Beam and Slab

Original Scale	Drawn	Checked	Reviewed	Authorised
1:50	AGL, Date 03.01.25	MG, Date 03.01.25	MJ, Date 03.01.25	MJ, Date 03.01.25

Status	Drawing Number	Rev
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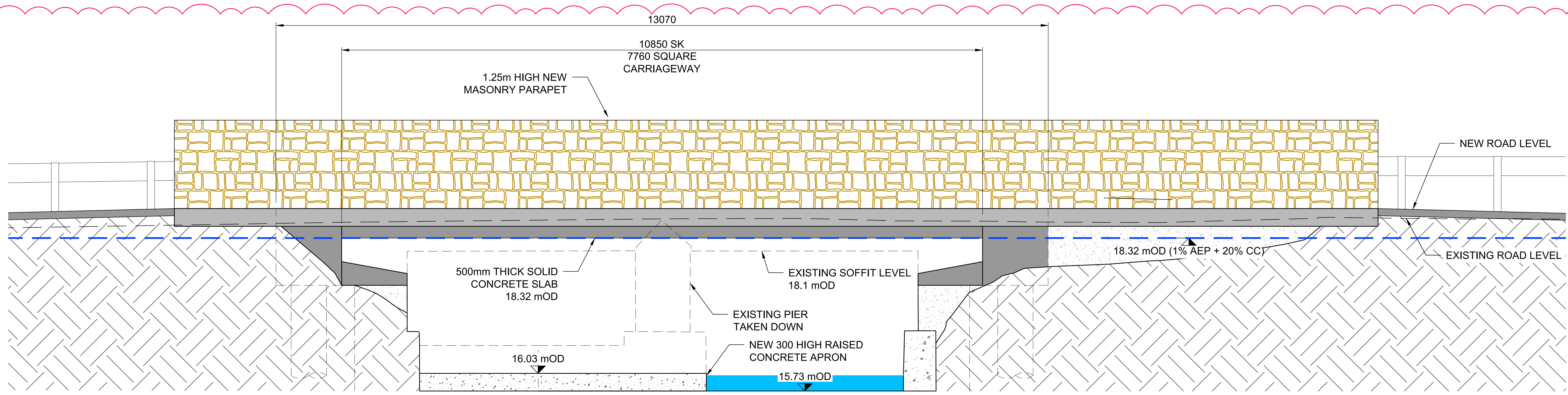

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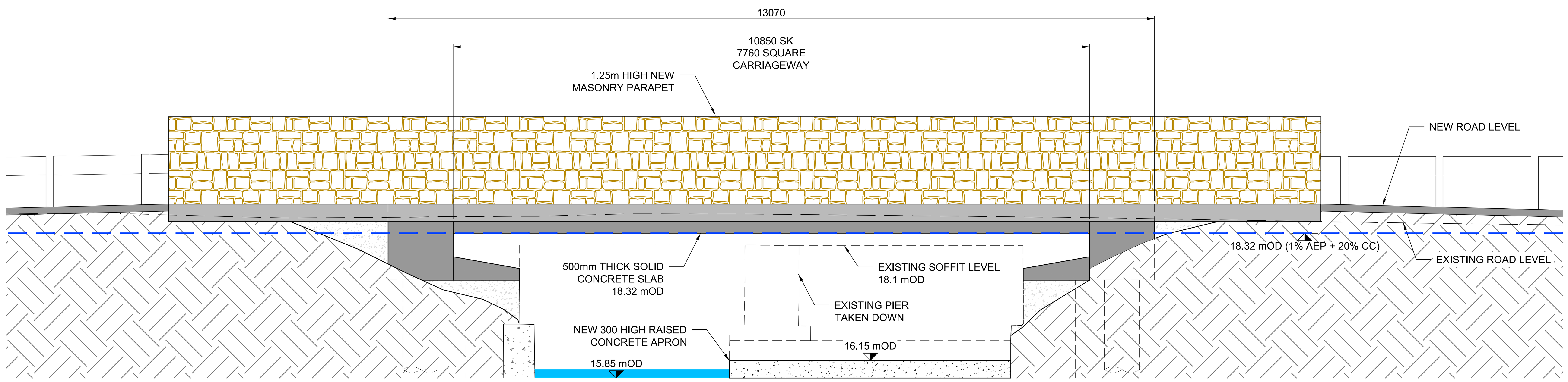

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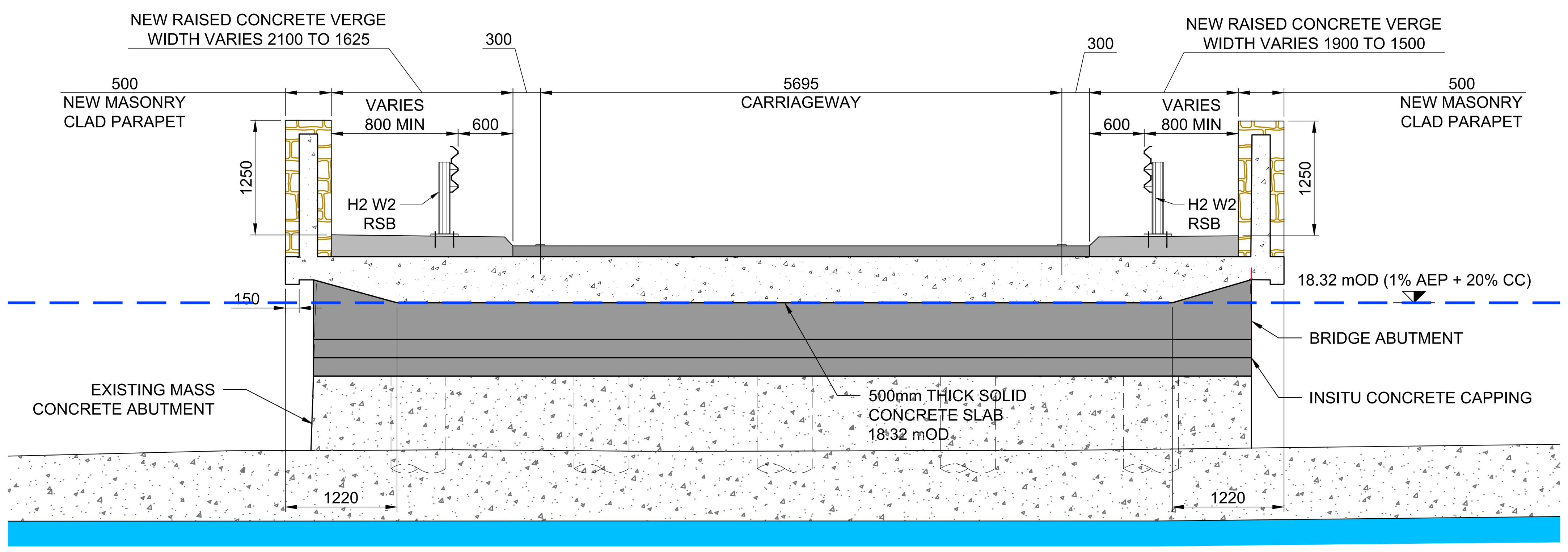

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A1

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Risk Level		
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Client: Comhairle Contae Mhaigh Eo
Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Option 2 - In-situ Concrete Slab

Original Scale	Drawn	Checked	Reviewed	Authorised
1:50	AGL	MG	MJ	MJ
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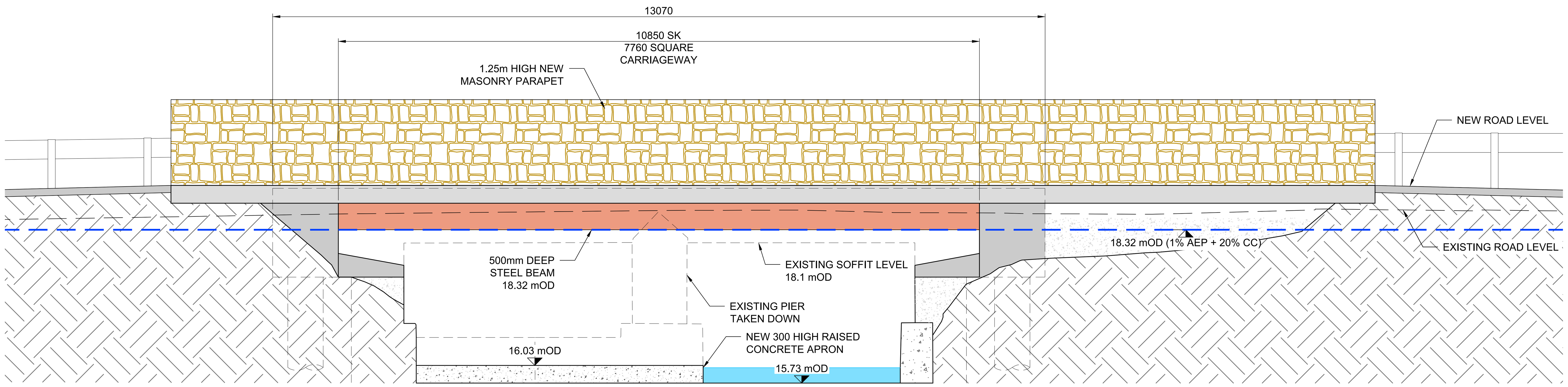

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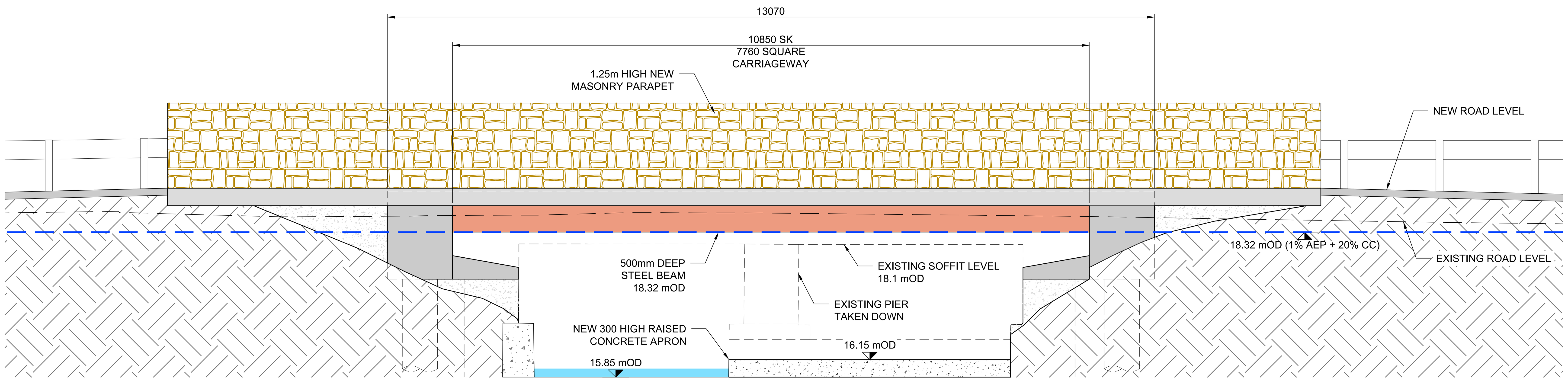

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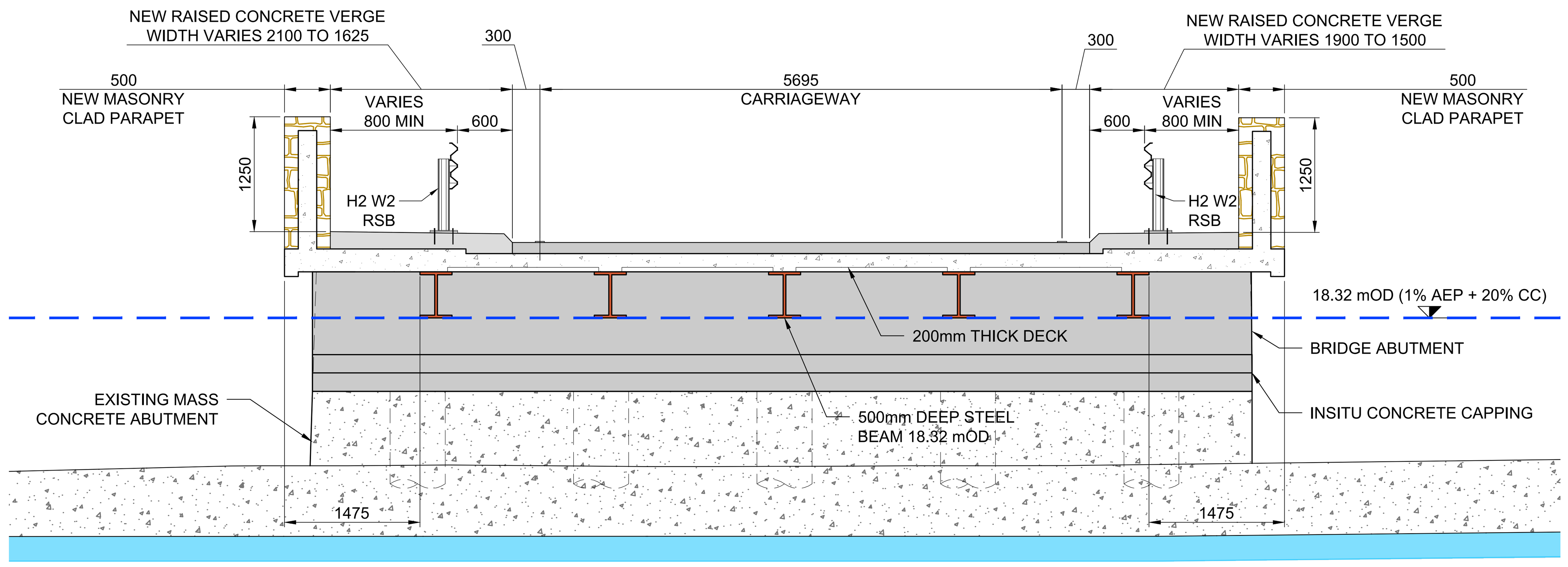

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		Atkins Private - High Risk
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Rev	Description	By	Date	Chk'd	Rev'd	Auth
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Client: Comhairle Contae Mhaigh Eo / Mayo County Council

Project: TO315 - MAYO BRIDGE ASSESSMENTS AND STRENGTHENING 2023

Purpose: PRELIMINARY ISSUE

Title: Strade River Bridge
MO-N58-001.00
Option 3 - Composite Beam and Slab

Original Scale	Drawn	Checked	Reviewed	Authorised
1:50	AGL 03.01.25	MG 03.01.25	MJ 03.01.25	MJ 03.01.25

Status	Drawing Number	Rev
S0	0088572-ATK-02-XX-DR-CE-900206	P01

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Appendix C. Structural Investigation Report

Structural Investigation Report

MO-N58-001.00 - STRUCTURAL INVESTIGATION REPORT – [REV 1]

12TH December 2024

PREPARED FOR

Comhairle Contae Mhaigh Eo
Mayo County Council

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

CONTENTS

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2. GENERAL DESCRIPTION OF STRUCTURE 2
3. INVESTIGATION WORKS 2
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6 REINSTATEMENT WORKS
7. PHOTO REPORT 18
7. APPENDIX 1 – BRIDGE LAYOUT DRAWING
8. APPENDIX 2 - LAB TEST REPORT

1. INTRODUCTION

TRIUR Construction LTD carried out structural investigation works on Strade River Bridge (MO-N58-001.00) from the 8th to the 12th of July 2024
The Scope of the work included the following:
The site works were to consist of the following:

- Mobilization and site set up
- Installation of traffic management measures (traffic lights)
- Excavation of 2no. trial pits in the concrete verges for depth of fill and deck exposure. One trial pit was excavated above the Northeastern abutment support while the second trial pit was excavated above the western pier support.
- Coring of 4x samples for strength testing of deck soffit (2no. in each span).
- The drilling of pilot holes in both the deck and the abutments, as required.
- Expose the deck slab and cleaning of the deck surface in adhesion test area.
- Carry out waterproofing adhesion test in Test Area 1
- Delamination survey to both spans
- Ferroscan and Concrete breakout of Test area 1-7.
- Chloride, cement content and carbonation samples obtained for BHP to lab test.
- Half-cell potential and Resistivity testing conducted by BHP.
- Detailed sketches made of breakout areas to include reinforcement sizing, location, spacing and cover.
- Reinstatement of the breakout and coring areas using PLANITOP RASA AND RIPARA R4 cementitious mortar.
- Reinstatement of any road openings as per *Guidelines for Managing Openings in Public Roads (Guidelines on the Opening, Backfilling and Reinstatement of Openings in Public Roads) Second Edition Rev 1 (2017).*
- Preparation of a detailed factual report on the investigation work undertaken at each bridge, i.e. one no. report required per bridge
- Removal of traffic management measures
- Demobilization
- The Bridge was reinstated on the 15th July 2024
- A detailed sketch was prepared, see below.
- A digital photographic record was carried out throughout the investigation works, see below.

2. GENERAL DESCRIPTION OF STRUCTURE

The Strade River Bridge is a 2 span filler beam bridge. Each span is approx. 3.8m in length with a width of 11m.The Strade River predominantly flows in the northern span while the southern span consists of an elevated concrete floor which at the time of testing was above the river water level and completely dry. It carries the N58 national secondary road over the Strade Rriver which flows from east to west.

Location

Strade River Bridge
Co-ordinates: 53.921444, -9.130361 MO-N58-001.00, Strade

3. INVESTIGATION WORKS

- The excavation of the Trial pits above the deck comprised of the breakout and removal of 2no. concrete rubbing strip located on the eastern and western verges. A layer of mesh and fill was also removed from each trial pit until the deck was exposed. Test area 1 (TA1) was located over the northeastern abutment while Test area 2 (TA2) was located over the western pier. No waterproofing layer was found above the concrete deck. No services or ducting were located in each respective trial pit.
- The excavation of a Trial pit (Test Area 01), located above the northeastern abutment to expose the RC slab for depth of fill and deck exposure. In this Trial Pit, a Covermeter and GPR survey was conducted to an area of the deck surface followed by concrete breakout to confirm cover and sizing of reinforcement members. The material covering this RC slab was observed to be 804 over layed with a concrete rubbing strip. A concrete core (C1) was also extracted for strength testing along with a pilot hole to obtain deck thickness. Durability testing was carried out by BHP.

- The excavation of a Trial pit (Test Area 02), located above the western end of the bridge pier to expose the RC slab for depth of fill and deck exposure. In this Trial Pit, a Covermeter and GPR survey was conducted to an area of the deck surface. No Steel was found on the deck side of the slab. A concrete core (C2) was also extracted for strength testing. A 25mm diameter pilot hole was drilled through the deck to obtain a value for the depth of the slab in this location. Durability testing was carried out by BHP.
- The investigation of Test Area 03, located in the the centre of the southern span on the western fascia. The area was scanned for reinforcement, samples acquired for testing and broken out to expose reinforcement.
- The investigation of Test area 3.1 located on the southeastern corner of the soffit of the southern span. In this area, a Concrete core (C3) was extracted for strength testing. A pilot hole was drilled to obtain measurements for deck thickness. A scan and breakout of the soffit in this area was undertaken to expose internal reinforcement.
- The investigation of Test Area 04, was located at the centre of the northern span on the western fascia. The area was scanned for reinforcement, samples acquired for testing and broken out to expose reinforcement.
- The investigation of Test area 4.1 located on the northwestern corner of the soffit on the Northern span. In this area, a Concrete core (C4) was extracted for strength testing. A pilot hole was drilled to obtain measurements for deck thickness. A scan and breakout of the soffit in this area was undertaken to expose internal reinforcement.
- The investigation of Test Area 05 located in the southern abutment approx. 3 meters from the the western edge. In this area, a Covermenter and GPR survey was conducted. 2no. durability tests were also conducted. This was followed by the drilling of a pilot hole to obtain the abutment thickness.
- The investigation of Test Area 06 located on the southern face of the pier at the midpoint. In this area, a Covermenter and GPR survey was conducted. 2no. durability tests were also conducted.
- The investigation of Test Area 07 located in the northern abutment approx. 3 meters from the eastern edge. In this area, a Covermenter and GPR survey was conducted. 2no. durability tests were also conducted. This was followed by the drilling of a pilot hole to obtain the abutment thickness.
- Adhesion pull off test on the deck top surface in Test Area 1 to determine the suitability of deck to a spray applied deck waterproofing system.
- Reinforcement was found via breakouts in both the deck and in the soffit. Both longitudinal and transverse members were located and exposed on the deck and the soffit. The longitudinal reinforcement consisted of asymmetrical I-beams wherein the top flange was found to be narrower and thicker than the bottom flange. The transverse support consisted of smaller rectangular length of steel located close to the soffit. No conncection observed between the traverse reinforcement and the beams. Placed rebar detail.
- A delamination survey of both the southern and northern soffits was conducted. In the southern span, significant delamination was found across the whole width of the bridge. The areas where delamination had occurred were generally in the area covering each section of longitudinal reinforcement. The delamination ran in the direction of the longitudinal reinforcement while being consistent with the longitudinal reinforcement spacing.

  In the northern span, delamination was present in the midsection of the bridge between 5m and 7.5m in from the eastern facia. There was evidence to suggest that this northern span had previously experienced delamination and been repaired.

4. INVESTIGATION RESULTS

TEST AREA 1	mm
DeckTrial hole (east)	
cover of fill	420
cover on longitudinal bars	148
cover on transverse bars	124
Longitudinal bar sizing	125mm high rail
Transverse bar sizing	23x13mm bar
pilot hole 1	300
pilot hole 2	315
pilot hole 3	320
pilot hole 4	300
Core 1 – Area 1 – Deck	18.9 N/mm2
Core 2 – Area 1 – Deck	21.1 N/mm2

TEST AREA 2	mm
DeckTrial hole (west)	
cover of fill	315
cover on longitudinal bars	n/a
cover on transverse bars	n/a
Longitudinal bar sizing	n/a
Transverse bar sizing	n/a
No reinforcement found above rail girders	

TEST AREA 3	mm
FACIA (south west)	
side cover on Web	129
cover on bottom flange	32
side cover bottom flange	68
side cover on top flange	105

TEST AREA 3.1	mm
soffit (south east)	
cover of fill	n/a
cover on longitudinal bars	34
cover on transverse bars	59
Longitudinal bar sizing	125 high rail
Transverse bar sizing	23x13mm bar
Core 3 – Area 3.1 – Soffit 1	49.6 N/mm2

TEST AREA 4	mm
FACIA (north west)	
side cover on Web	132
cover on bottom flange	37
side cover bottom flange	80
side cover on top flange	104
Core 4 – Area 4.1 – Soffit 2	57.1 N/mm2

TEST AREA 4.1	mm
soffit (north west)	
cover of fill	n/a
cover on longitudinal bars	47
cover on transverse bars	51
Longitudinal bar sizing	125 high rail
Transverse bar sizing	23x13mm bar

TEST AREA 5	mm
Southern Abutment	
pilot hole	740
cover on longitudinal bars	n/a
cover on transverse bars	n/a
Longitudinal bar sizing	n/a
Transverse bar sizing	n/a
No reinforcement found	

TEST AREA 6	mm
Pier mid support (south west side)	
pilot hole	n/a
cover on longitudinal bars	n/a
cover on transverse bars	n/a
Longitudinal bar sizing	n/a
Transverse bar sizing	n/a
No reinforcement found	

TEST AREA 7	mm
Northern Abutment	
pilot hole	890
cover on longitudinal bars	n/a
cover on transverse bars	n/a
Longitudinal bar sizing	n/a
Transverse bar sizing	n/a
No reinforcement found	

5.DETAILED SKETCHES

Plan of works area – Test Area locations – see Appendix 1 for more details.

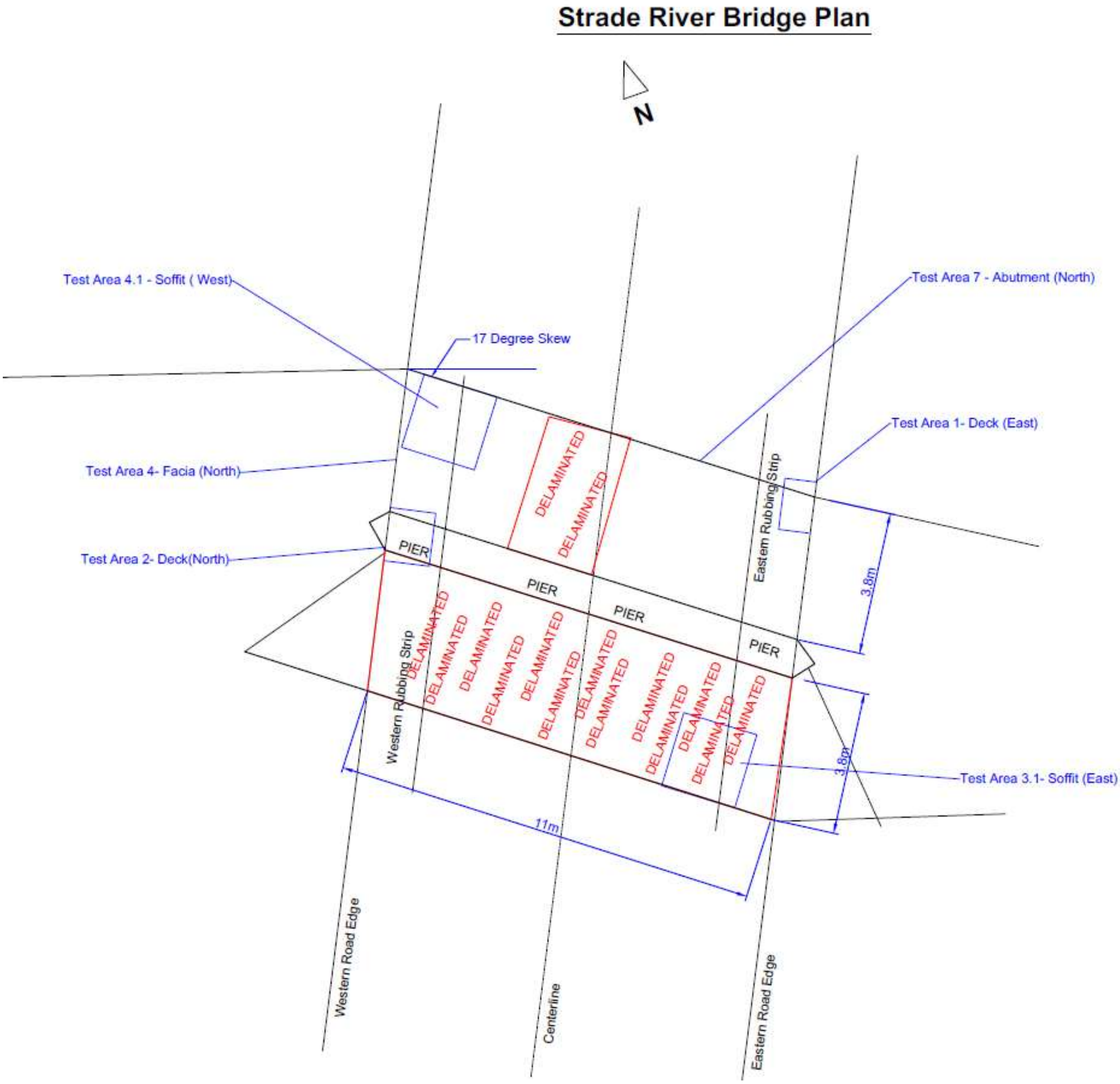


Figure 1: Strade Bridge Plan

Test area 1

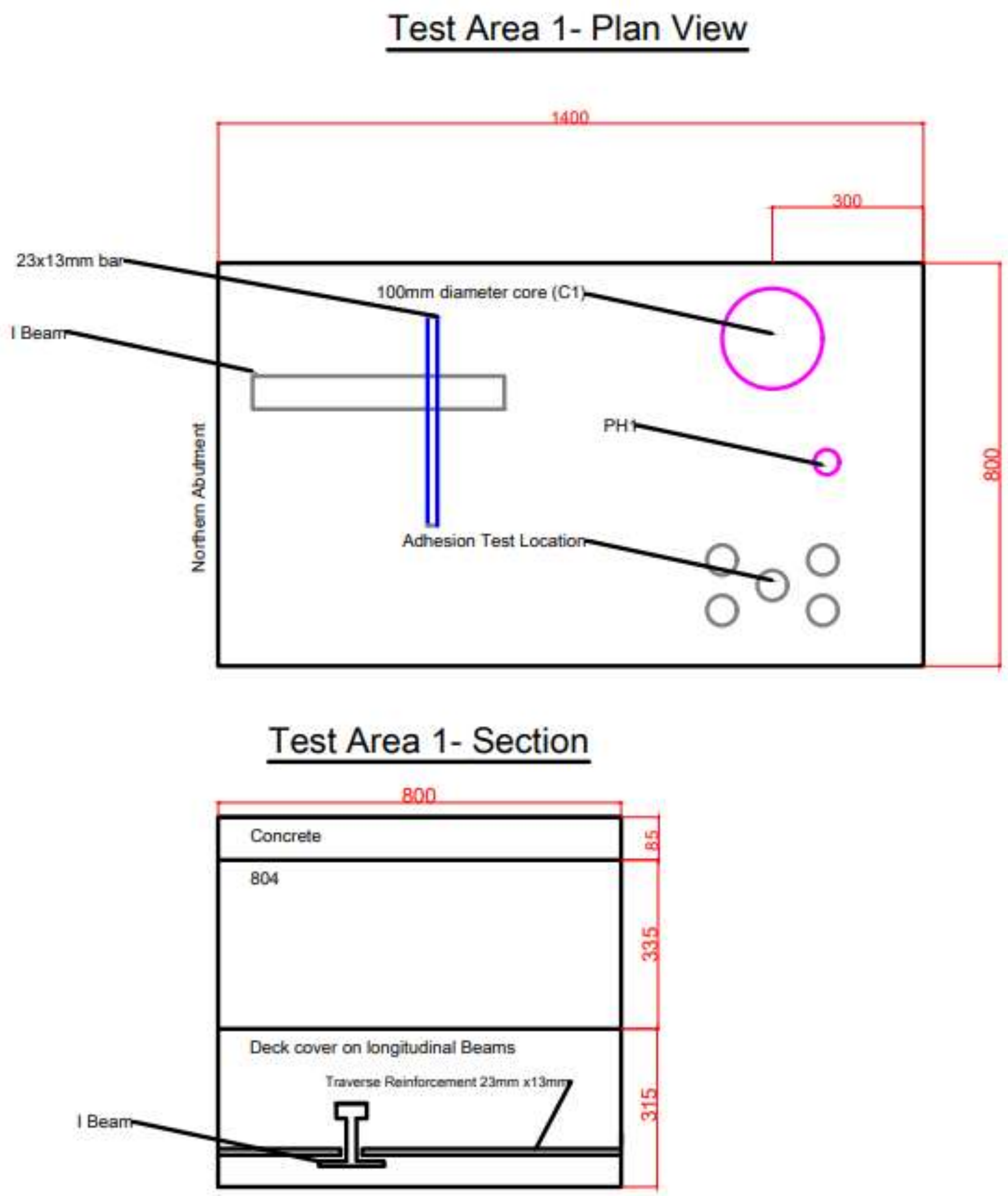


Figure 2: Test area 1 drawing

Test area 2

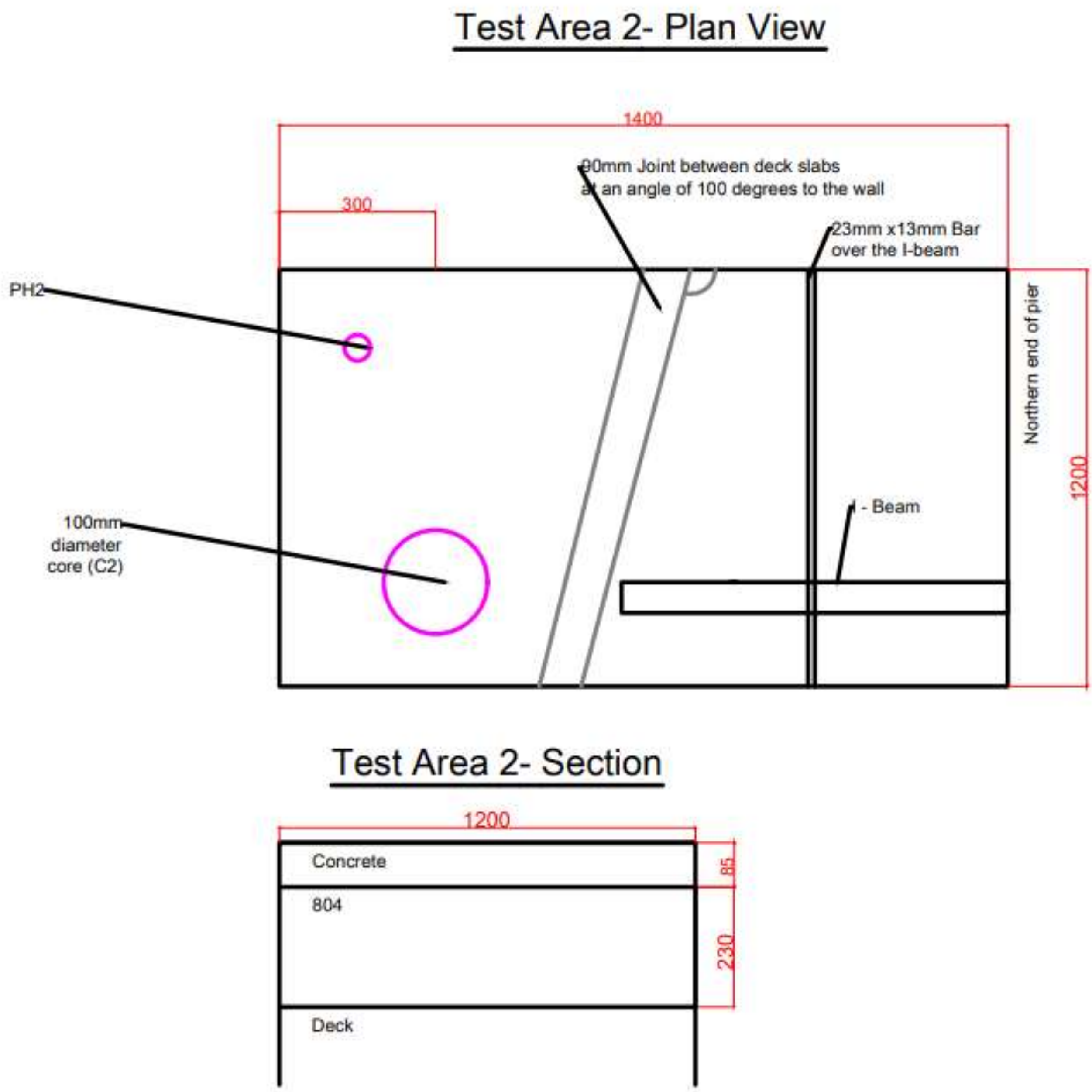


Figure 3: Test area 2 drawing

Test area 3

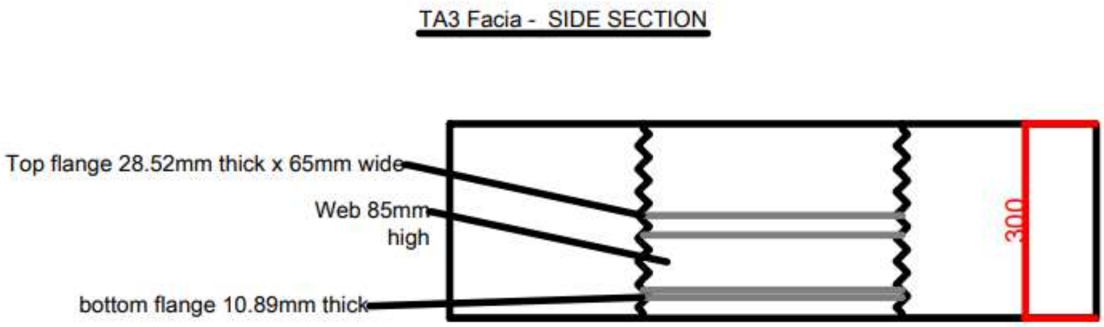


Figure 4:Facia side section

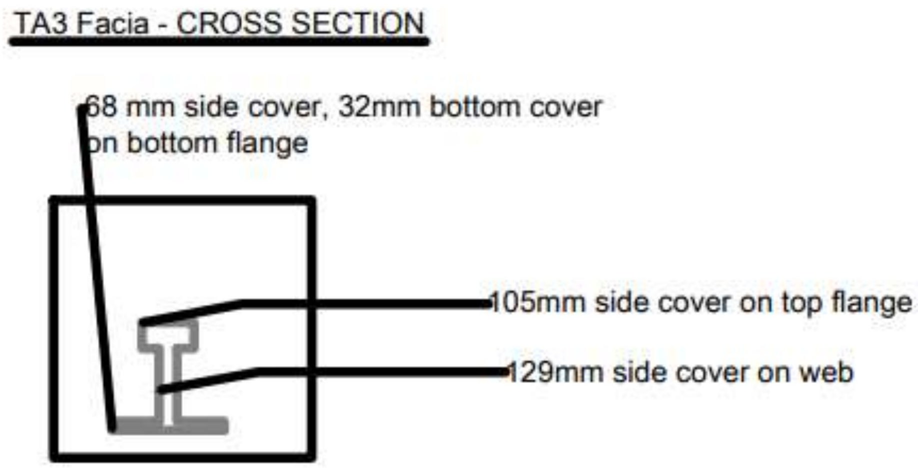


Figure 5: TP3 Facia cross section

TA3 Beam dimensions (mm)

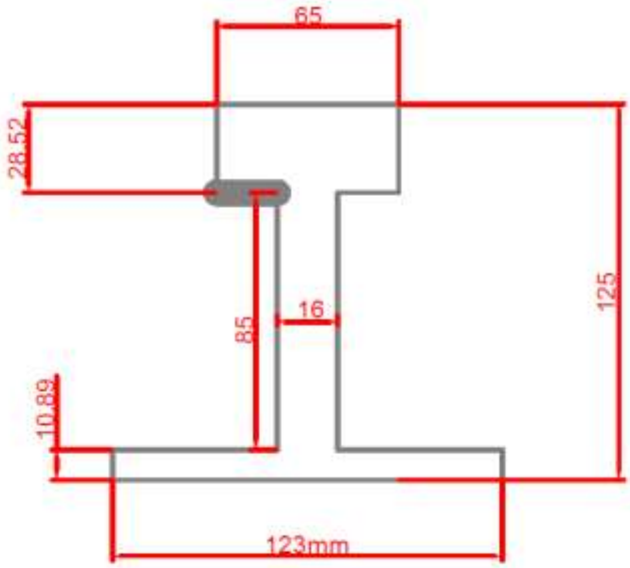


Figure 6 : External Beam Dimensions

Test area 3.1

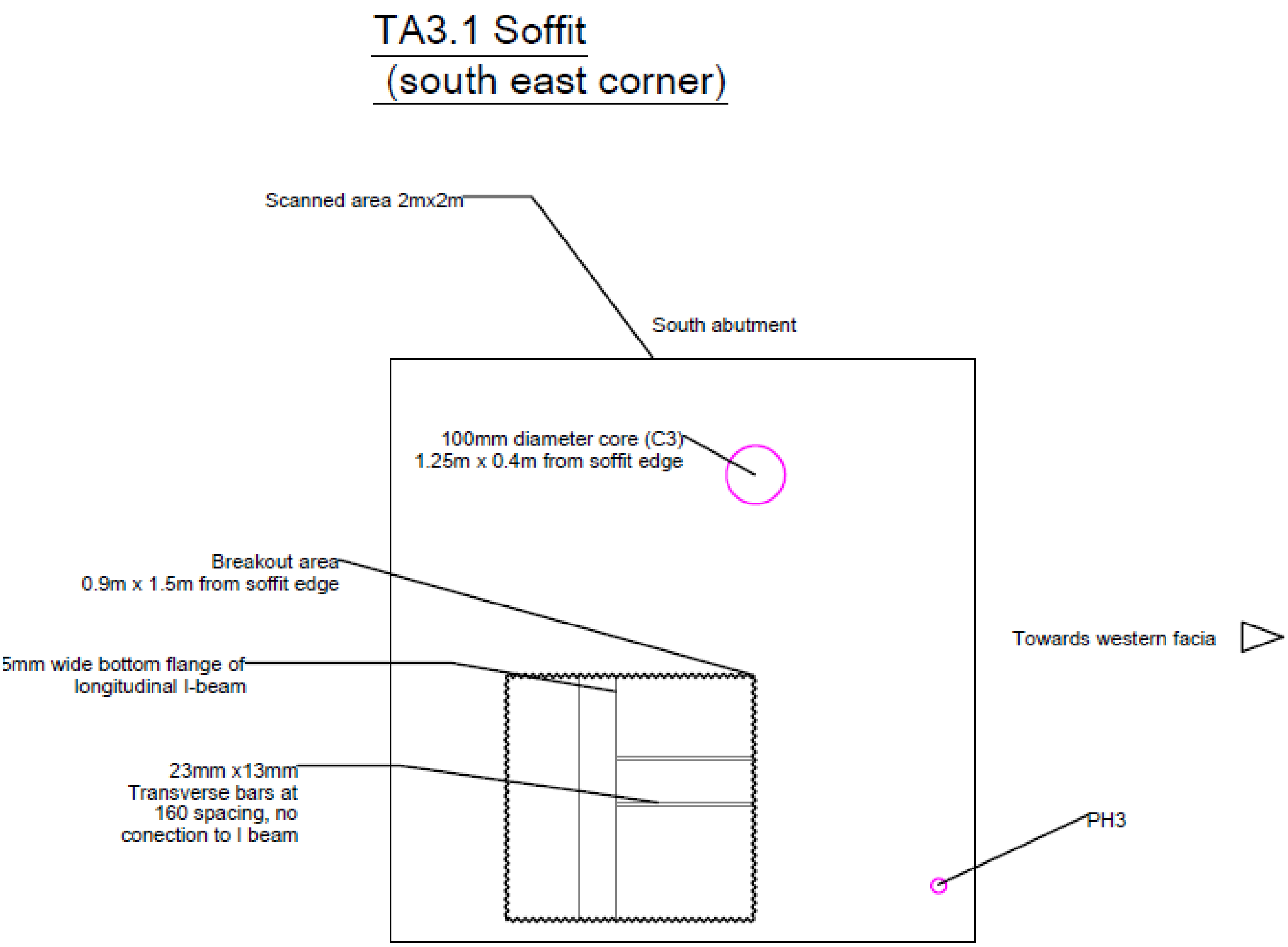


Figure 7: Test area 3.1 Soffit

Test area 4

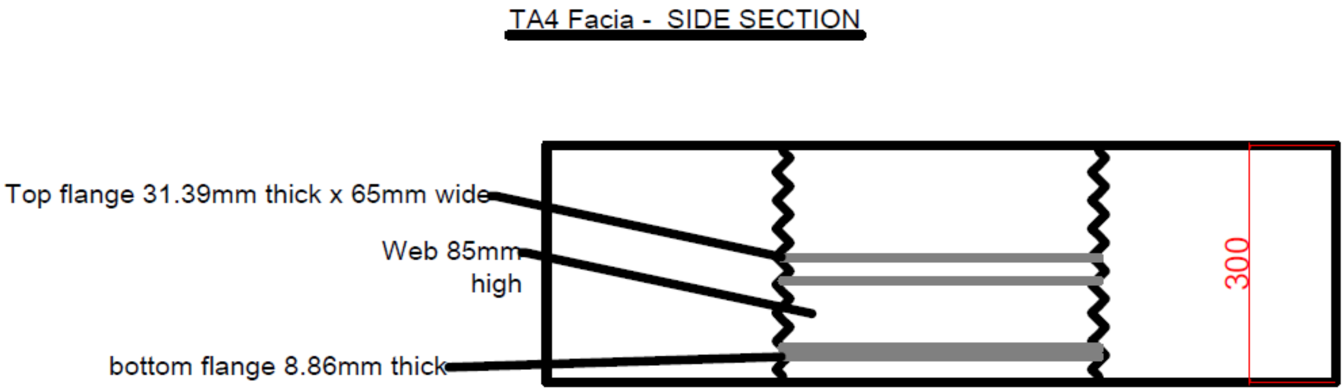


Figure 8:TA4 Facia - Side Section

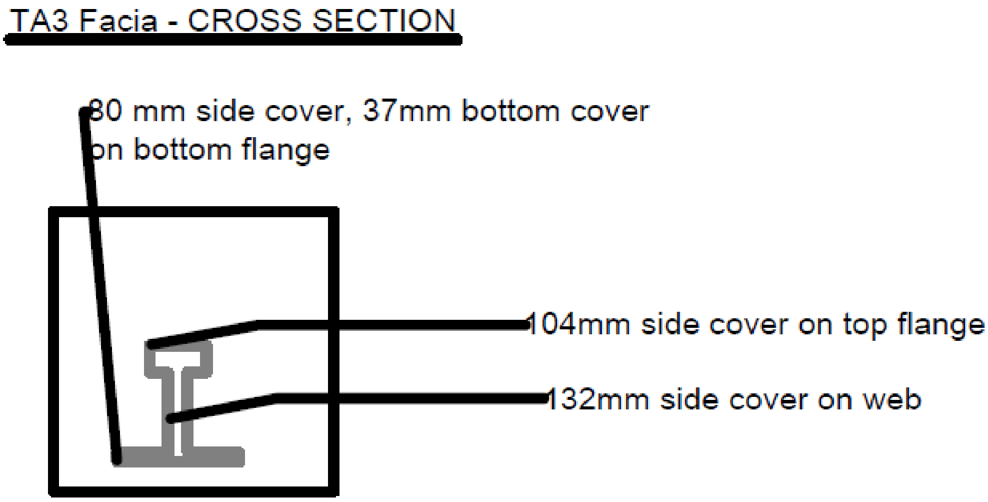


Figure 9 : TA4 Facia - Cross Section

TA4 Beam dimensions (mm)

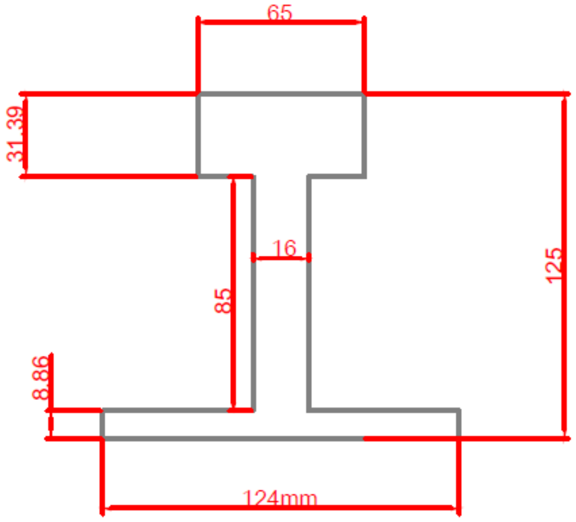


Figure 10: TA4 Beam Dimensions

Test area 4.1

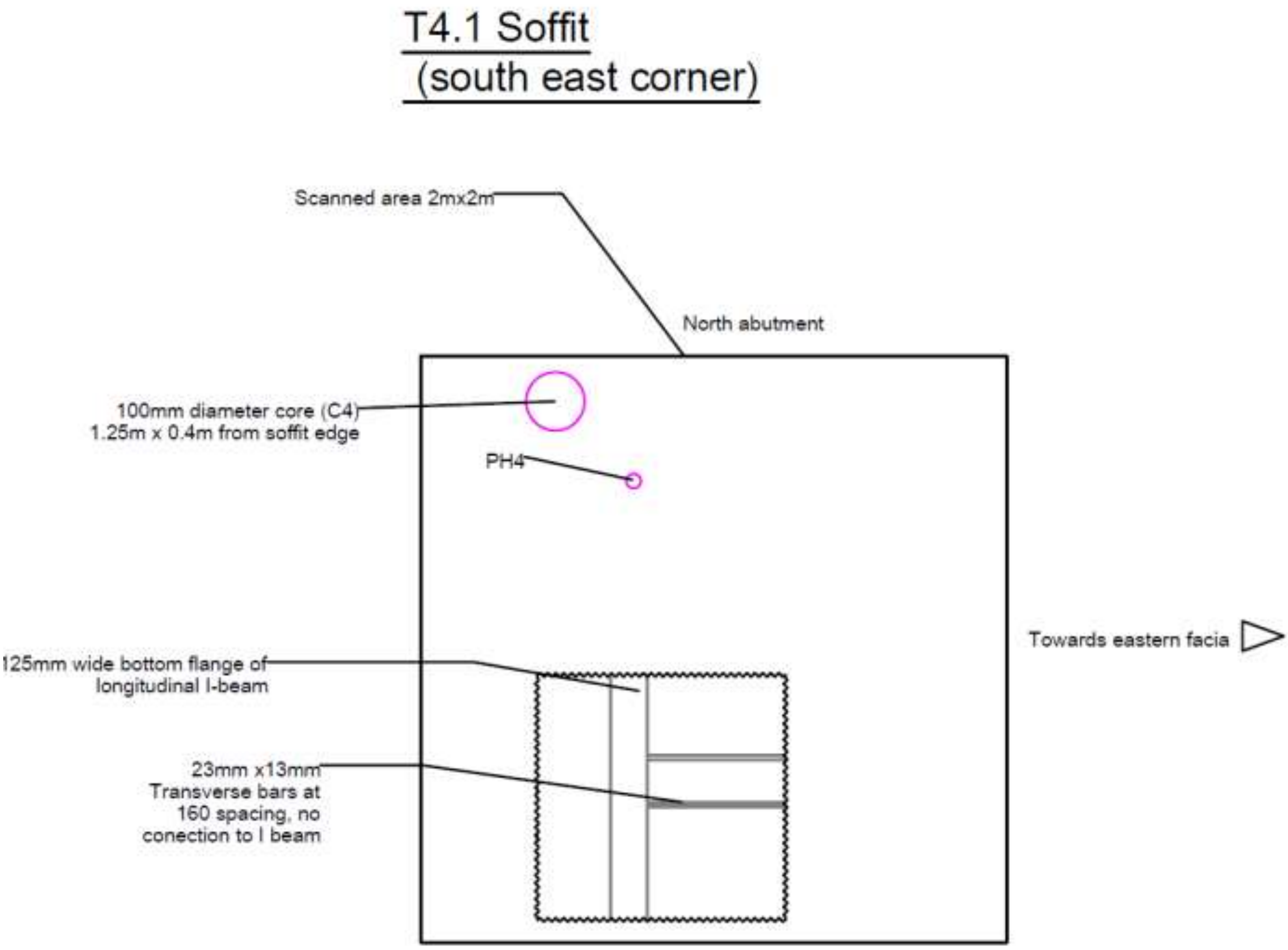
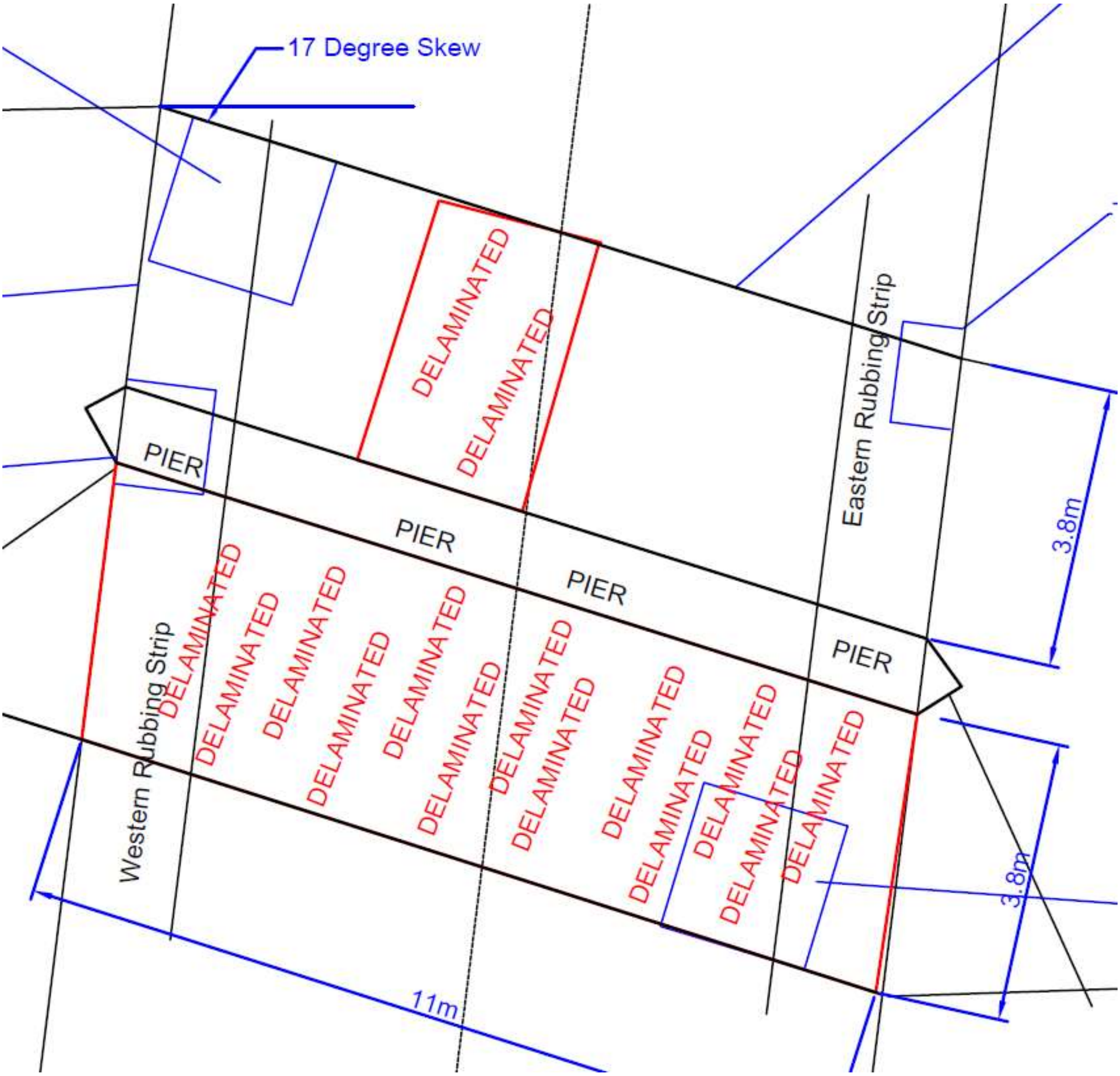


Figure 11: Test Area 4.1

Delamination – shown in Red



6.REINSTATEMENT DETAIL

- Rubbing strip cutouts were backfilled with UGM A and infilled with 35N 10mm agg

- Fosroc Renderoc HB45 was used to carry out concrete repairs to breakouts.

7.PHOTO REPORT

General bridge overview

TEST AREA 1

Figure 12: Test area 1 containing pilot hole, core sample hole and breakout.

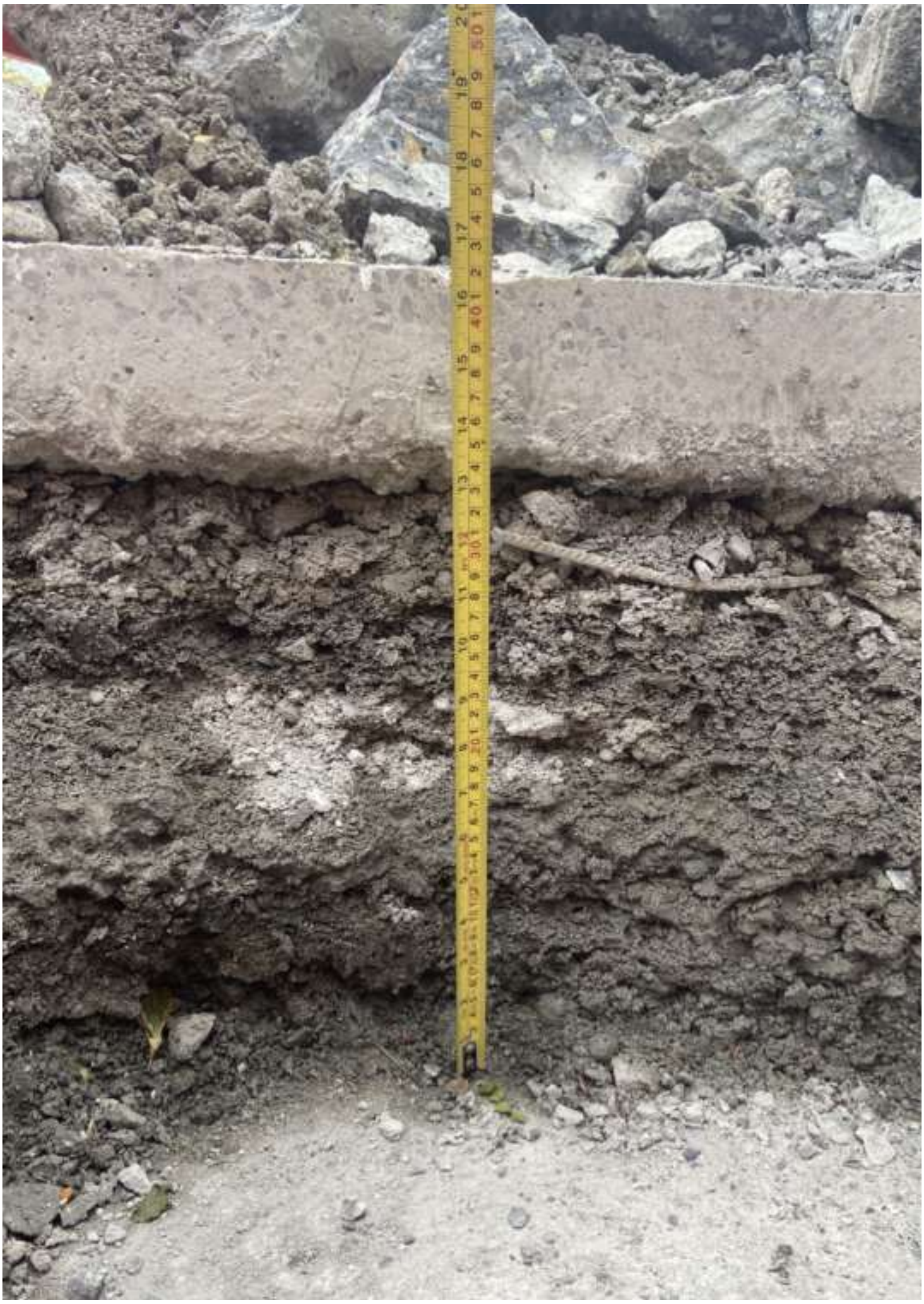


Figure 13: Trial Pit layers

Figure 14: Deck cover on longitudinal steel

Figure 15: Concrete core hole (C1)

Figure 16: Adhesion testing

Test Area 2

Figure 17: Trial pit on western edge

Figure 18: Trial pit layers


Figure 19: 90mm cutout in deck surface

Test area 3

Figure 20: Breakout of external beam

Figure 21: Wide angle view of test area including drill holes for dust samples

Figure 22: Half cell potential testing

Figure 23: Carbonation test sample extracted to the left of breakout

Test Area 3.1

Figure 24: Core hole from C3

Figure 25: Measurement of longitudinal beam flange

Figure 26: Transverse steel members running perpindicular to longitudinal members at 160mm spacing

Figure 27: Longitudinal cover was 39mm, Transverse cover wad 54mm


Figure 28: Delamination survey showed significant delamination underneath longitudinal sections on south arch

Figure 29: Further delamination on south arch

Figure 30: Exposed beams due to delamination of concrete cover

Figure 31: Delamination denoted by white x chalk marks

Test Area 4

Figure 32: Half cell potential testing of TP04

Figure 33: Resistivity testing of TP04

Figure 34: Breakout at test area 4 exposing external beam

Test Area 4.1

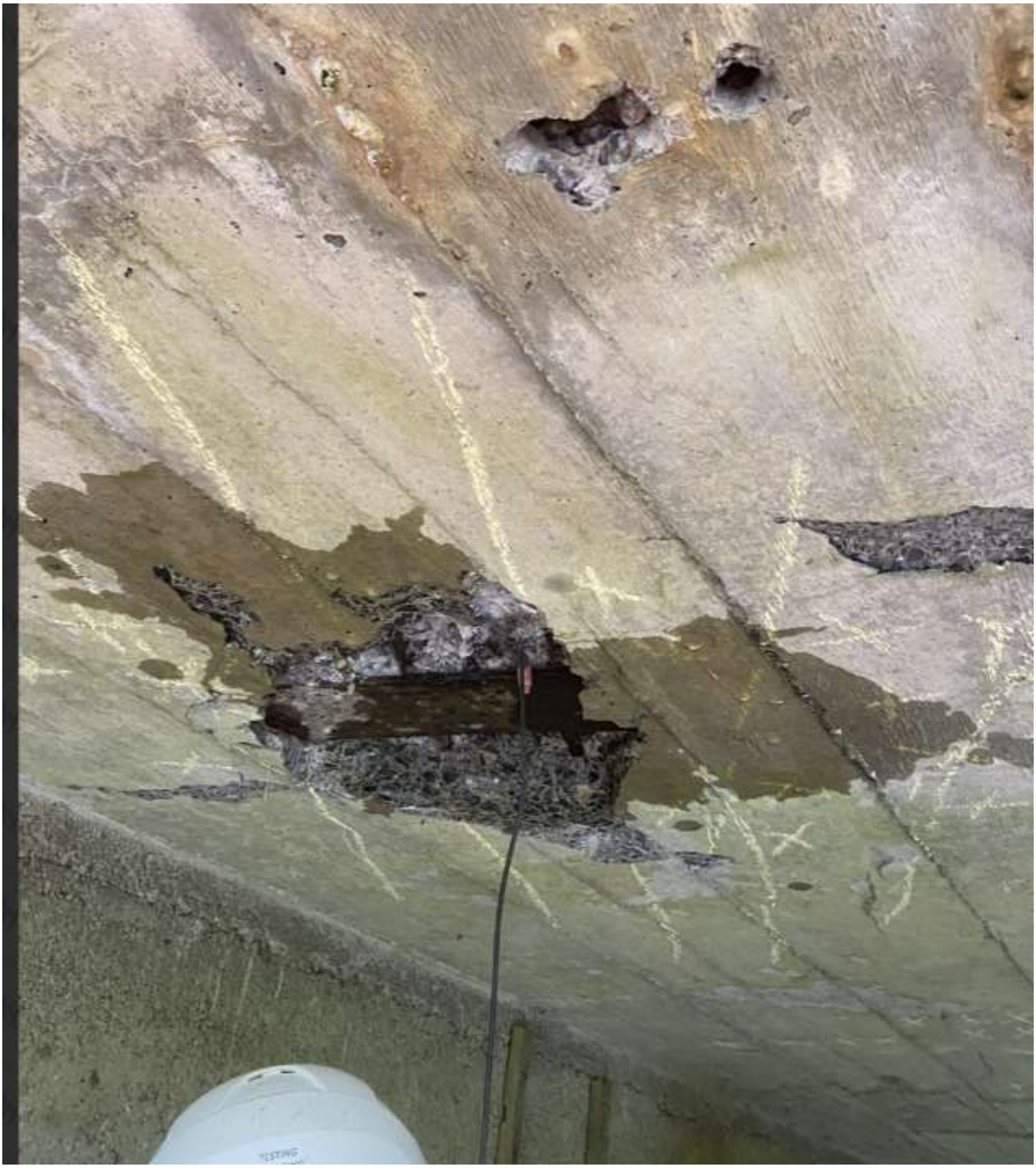


Figure 35: Breakout of internal beam showing transverse spacing marked via GPR

Figure 36: Half cell potential testing


Figure 37: Delamination found in northern arch

Figure 38: Delamination survey in Northern arch wide angle view

Figure 39: Core hole C4

Figure 40: Longitudinal bottom flange thickness

Figure 41: Cover of Transverse steel

Figure 42: 125mm wide bottom flange of internal beam

Figure 43: Wide angle view of breakout area

Test Area 5

Figure 44: Pilot hole reinstatement along with dust sample holes

Figure 45: Pilot hole depth measurement

Figure 46: Outline of scanned area

Test Area 6

Figure 47: Outline of scanned area with carbonation sample removed

Figure 48: Carbonation sample consisted of 100mm x 100mm x 80mm cuboid

Figure 49: TA6 carbonation sample depth into pier

Test Area 7

Figure 50: Wide angle view of test area

Figure 51: Pilot hole reinstatement

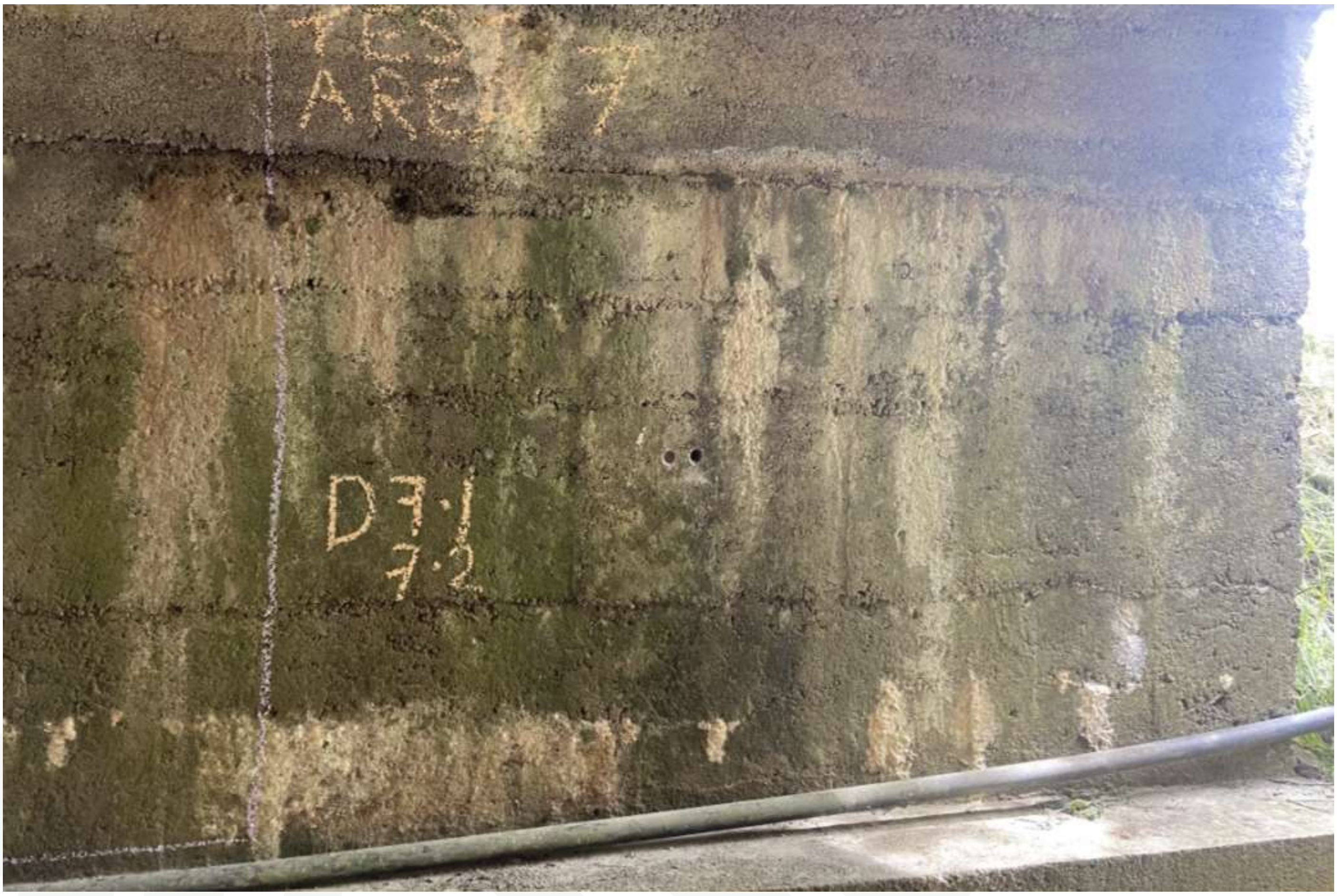
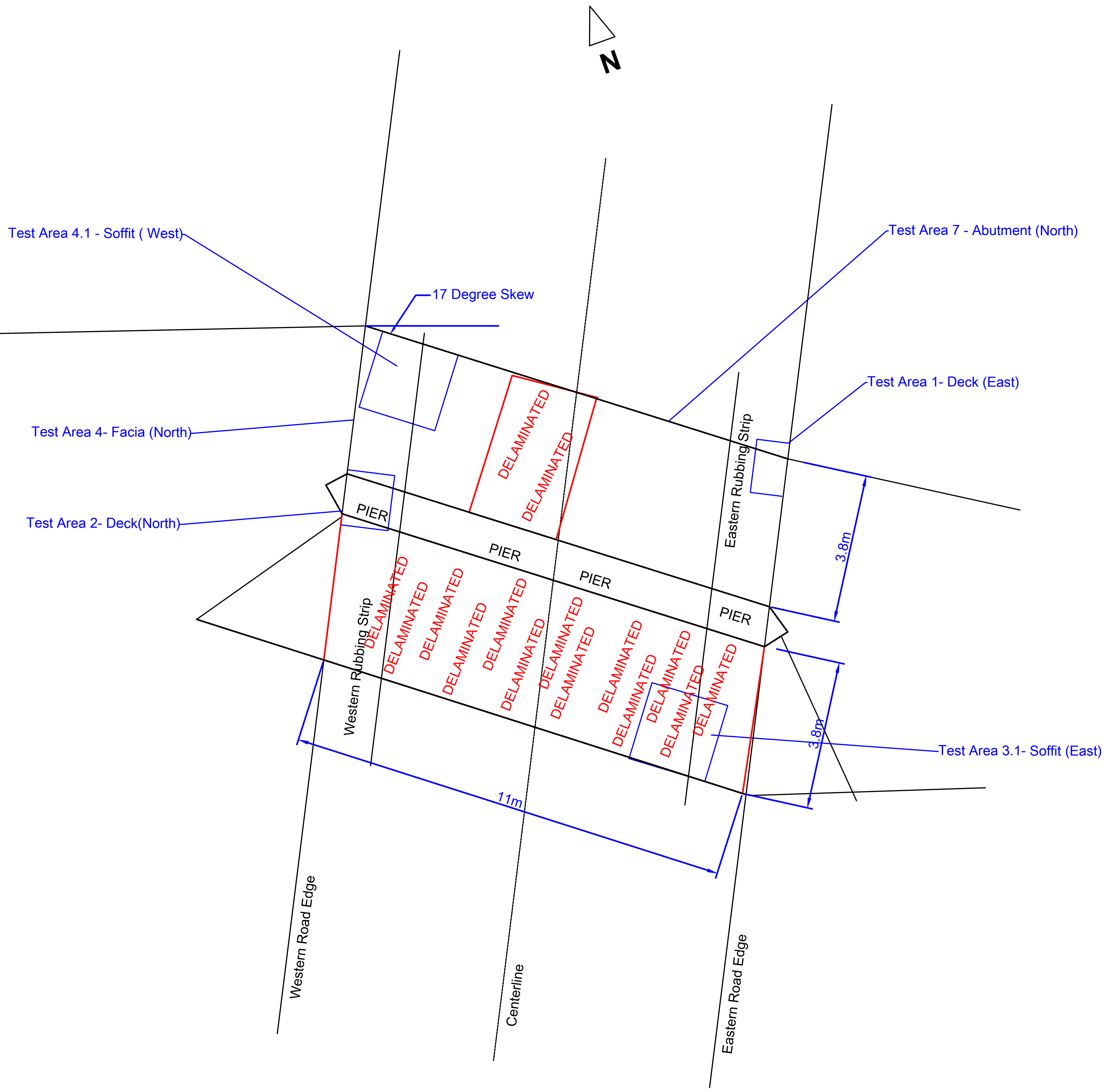


Figure 52:Drill holes used for dust collection located on the northesatern end of the abutment

Appendix 1 – Bridge Layout

Strade River Bridge Plan



Appendix 2 – Lab Test report

Mayo Bridges Inspection – Strade River Bridge

Concrete Testing Report

2024

Document Issue Register

Distribution	Report Status	Revision	Date of Issue	Prepared by	Approved by
Lurcan Donnellan Triur Construction	Final	A	27th August 2024	Anton Hajek	James Purcell

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2.0	**Project Requirements**	**Page 4**
3.0	**Location of Works**	**Page 4**
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Concrete Strength Test Report	**Appendix A**
Pull Off Test Report	**Appendix B**
Carbonation Test Report	**Appendix C**
Reinforcement Test Report	**Appendix D**
Chloride Ion Test Report	**Appendix E**
Cement Content Test Report	**Appendix F**
Half Cell and Resistivity Test Report	**Appendix G**

1.0 Project Overview

BHP was contracted by Lurcan Donnellan of Triur Construction to provide a survey of the concrete bridge.

The investigation is intended to provide information for the employer in respect of the structural condition of the concrete deck and parapets and to assess the existing condition to enable evaluation of the proposed need for strengthening/rehabilitation works.

2.0 Project Requirements

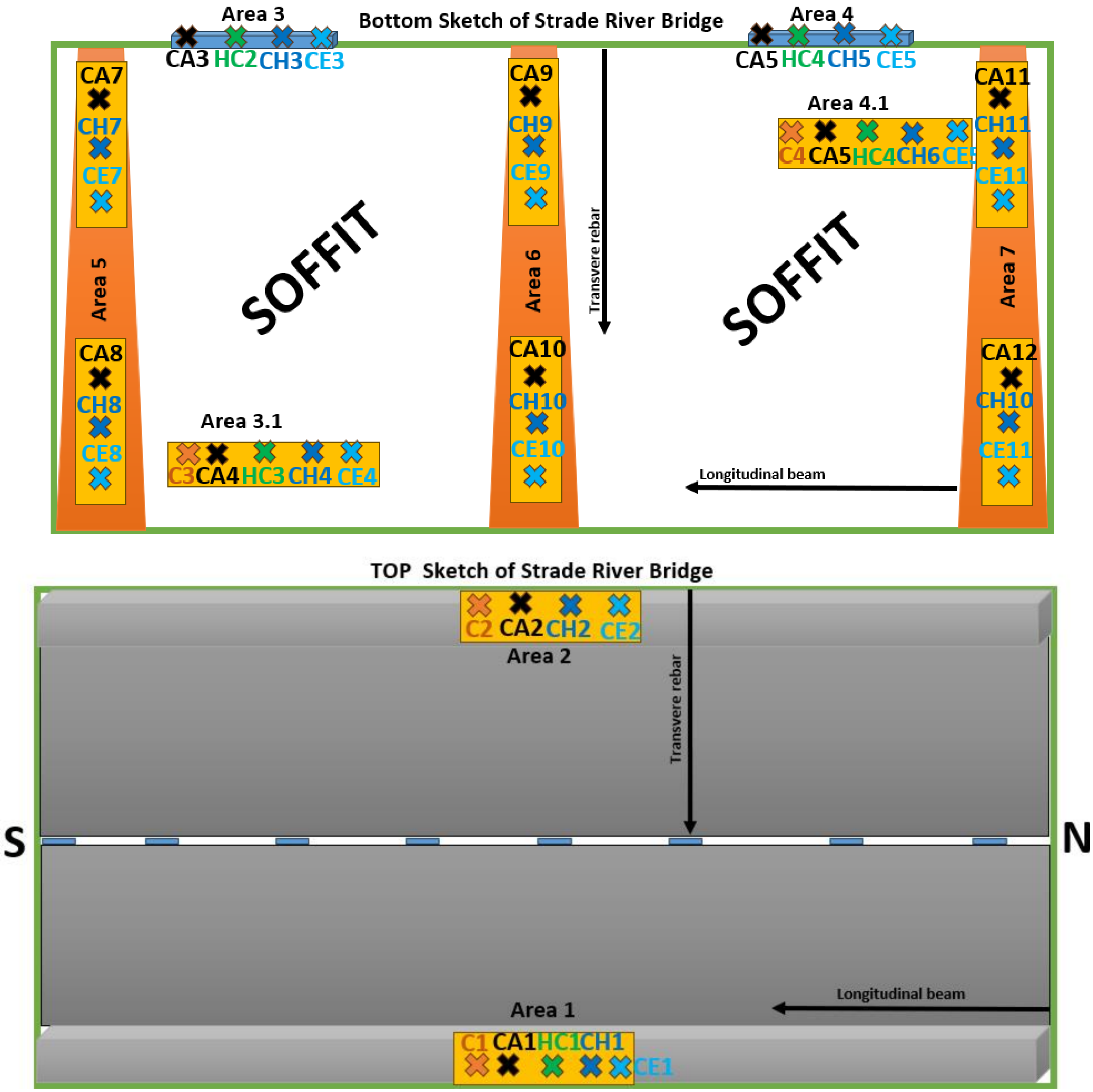
As directed by the project specification the requirements of the works included:

- Drill 4No. 100 diameter cores.
- Test for Density, Compressive strength and Visual examination.
- Chemical testing includes chloride content, cement content and depth of carbonation.
- Pull off testing on the concrete deck.
- Reinforcement scanning of concrete deck and parapets.
- Half-cell potential and concrete resistivity.

3.0 Location of Works

Site Location / Works Area

4.0 Summary of Results



*Key
- Cores
- Half-cell
- Pull test
- Chloride
- Carbonation
- Cement

4.1 Concrete Cores – Compressive Strength

In line with the project specification, BHP removed several cores from the reinforced concrete elements. These were cored using a water-cooled diamond drill. The cores were individually marked and placed in sealed plastic bags for transportation to the laboratory.

The concrete cores were visually assessed by BHP's technical manager Seamus O'Connell.

A summary of the results with photographs is contained below:

BHP Ref:	**Core Ref.**	**Details**	**Density kg/m3**	**Compressive Strength N/mm2**
24/07/072-1	Core 1 – Area 1 – Deck	20mm Crushed Rock, 1.5% Voids	2280	18.9
24/07/072-2	Core 2 – Area 1 – Deck	20mm Crushed Rock, 2.5% Voids	2300	21.1
24/07/072-3	Core 3 – Area 3.1 – Soffit 1	20mm Crushed Rock, 0.5% Voids	2610	49.6
24/07/072-4	Core 4 – Area 4.1 – Soffit 2	20mm Crushed Rock, 0.5% Voids	2380	57.1

The mean result for compressive strength for the deck cores is 20.0N/mm² with a standard deviation of 1.56. The mean density of the test specimens is 2290kg/m³.

The mean result for compressive strength for all the cores is 53.4N/mm² with a standard deviation of 5.3. The mean density of the test specimens is 2500kg/m³.

4.2 Pull Off Test

In accordance with the project specification, the pull off test was to be performed at one location in the concrete deck.

A summary of the results is contained below with full reports contained in Appendix B of this report.

Test Reference	**Max Applied Load (MPa)**	**Depth of failure (mm)**	**Failure occurred in**
Area 1 top deck	1.4	3	Below adhesive in concrete substrate (cohesion failure)
Area 1 top deck	1.7	4	Below adhesive in concrete substrate (cohesion failure)
Area 1 top deck	2.3	5.0	Below adhesive in concrete substrate (cohesion failure)
Area 1 top deck	0.9	0	Below adhesive on top of concrete surface (adhesion failure)
Area 1 top deck	2.6	4.0	Below adhesive in concrete substrate (cohesion failure)
Mean	**1.78**		

4.3 Carbonation

In accordance with the project specification, the carbonation testing was to be performed at seven locations.

Carbonation testing is carried out to determine the depth of concrete affected due to a combined attack of atmospheric carbon dioxide and moisture causing a reduction in the level of alkalinity in concrete. Cement paste has a pH of approximately 13 which provides a protective layer (passive coating) to the steel reinforcement against corrosion. Loss of passivity occurs at about pH 9.

A 3% phenolphthalein indicator is used for the test. This is applied to freshly exposed concrete surface as detailed above.

Once the indicator is applied to the concrete surface, the change of colour of concrete to pink indicates that the concrete is in good health/condition. Where no change in colour takes place, it is suggestive of carbonation-affected concrete.

The results of the tests performed at Knockavrony Bridge, Co. Mayo are contained in Appendix C of this report.

A summary of the results is contained below:

Location	**Depth of Carbonation (mm)**
Carbonation Test 1 – Area 1 Top Deck	<1
Carbonation Test 2 – Area 2 Top Deck	<1
Carbonation Test 3 – Area 3 Face deck	<1
Carbonation Test – Area 3.1 Soffit	16
Carbonation Test 5 – Area 4 Face deck	<1
Carbonation Test 6 – Area 4.1 Soffit	<1
Carbonation Test 7 – Area 5 Abutment	>20
Carbonation Test 8 – Area 5 abutment	<1
Carbonation Test 9 – Area 6 abutment	<1
Carbonation Test 10 – Area 6 abutment	<1
Carbonation Test 11 – Area 7 abutment	<1
Carbonation Test 12 – Area 7 abutment	<1

There was no obvious reason for the differing levels of carbonation other than different locations. The two locations of high carbonation can be viewed as isolated instances of carbonation. All other results had negligible carbonation. At both soffit locations (3.1 and 4.1), there was clear visual spalling of concrete. However, the carbonation at 4.1 did not show high carbonation like at location 3.1. To understand a full assessment of carbonation, further samples would have to be taken at a number of locations throughout to ascertain the consistency. It must be noted that the chloride ingress into the concrete is very low, so refurbishment works including the application of protection paint/similar material should limit any increase in carbonation and reduce long-term risks of corrosion occurring.

4.4 Reinforcement Details

In following page, a summary of reinforcement investigation on deck, parapet sections and information on the reinforcement found in breakouts have been compiled from the survey conducted in Strade River Bridge, Co. Mayo

Full details are in Appendix D of this report.

Scan Location	Rebar direction	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)	Minimum Spacing (mm)	Maximum Spacing (mm)
Area 1 top deck longitudinal scan 001	T	153	n/a	n/a	n/a	n/a	n/a
Area 1 top deck transverse scan 001	L	164	158	170	180	n/a	n/a
Area 2 top of deck longitudinal scan 001	T	160	137	183	640	n/a	n/a
Area 2 top of deck longitudinal scan 002	T	156	150	162	620	n/a	n/a
Area 2 top of deck transverse scan 001	L	204	144	238	405	130	680
Area 3 deck face vertical scan 001	L	142	136	148	60	n/a	n/a
Area 3 deck face horizontal scan 001	T	135	n/a	n/a	n/a	n/a	n/a
Area 3.1 soffit longitudinal scan 001	T	38	28	48	684	560	710
Area 3.1 soffit longitudinal scan 002	T	42	37	48	657	620	690
Area 3.1 soffit transverse scan 001	L	46	42	55	166	140	198
Area 3.1 soffit transverse scan 002	L	62	54	68	165	140	196
Area 4 Deck Face Vertical scan 001	L	106	92	120	120	n/a	n/a

Area 4 Deck Face Horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 4.1 Soffit longitudinal scan 001	T	48	42	51	666	640	700
Area 4.1 Soffit longitudinal scan 002	T	51	42	56	707	640	750
Area 4.1 Soffit transverse scan 001	L	60	44	69	227	120	330
Area 4.1 Soffit transverse scan 002	L	65	55	76	216	120	319
Area 5 Abutment vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a
Area 5 Abutment horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 6 Pier horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 6 Pier Vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a
Area 7 Abutment Vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a
Area 7 Abutment Horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a

Rebar directions: L- longitudinal, T- transverse
* In Area 1(TP1), Area 2 (TP2) were not enough space to get more reinforcement readings due to lack of access for GPR as the Trail hole area only allowed for coring and breakouts
* In Area 5 – Area 7 GPR did not find any reinforcement

Reinforcement found by completing a breakout	**Actual cover (mm)**	**Diameter (mm)**	**Width(mm)**
Area 1 top of deck top flange	150	N/A	N/A
Area 1 top of deck transverse rebar square	109	14.3 / 25.7	N/A
Area 3 face deck web	129	N/A	N/A
Area 3 face deck bottom flange	32	10.89	123
Area 3 face deck bottom side flange	68	N/A	N/A
Area 3 face deck top flange	104	N/A	N/A
Area 3 face deck distance top-bottom flange	117	N/A	N/A
Area 3.1 soffit bottom flange	34	N/A	N/A
Area 3.1 soffit transverse rebar square	59	15.3 / 28.9	N/A
Area 4 face deck top side flange	104	31.39	N/A
Area 4 face deck web	132	N/A	N/A
Area 4 face deck bottom flange	80	N/A	N/A
Area 4 face deck bottom flange	37	8.86	N/A
Area 4.1 soffit bottom flange	47	N/A	N/A
Area 4.1 soffit transverse rebar square	51	13.5 / 23.6	N/A

4.5 Chloride Ion Testing

Corrosion of reinforcing steel and other embedded metals is the leading cause of deterioration in concrete. When steel corrodes, the resulting rust occupies a greater volume than the steel. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination and spalling.

Steel corrodes because it is not a naturally occurring material. Rather, iron ore is smelted and refined to produce steel. The production steps that transform iron ore into steel add energy to the metal. Steel, like most metals except gold and platinum, is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural state – iron oxide, or rust. This process is called corrosion.

Corrosion is an electrochemical process involving the flow of charges (electrons and ions). At active sites on the reinforcement bar, called anodes, iron atoms lose electrons and move into the surrounding concrete as ferrous ions. This process is called a half-cell oxidation reaction, or anodic reaction.

Corrosion of embedded metals in concrete can be greatly reduced by placing crack-free concrete with low permeability and sufficient concrete cover. Additional measures to mitigate corrosion of steel reinforcement in concrete include the use of corrosion inhibiting admixtures, coating of reinforcement, and the use of sealers and membranes on the concrete surface.

As noted in section 4.3 carbonation, the breakdown in the protection of reinforcement bars leads to concrete spalling. The depth of carbonation provides a guide as to the risk of corrosion on a particular bar. Concrete that is not carbonated (or has very low levels of carbonation) protects the embedded steel reinforcement.

Exposure of reinforced concrete to chloride ions is the primary cause of premature corrosion of steel reinforcement. The intrusion of chloride ions present in deicing salts, seawater and other associated sources, into reinforced concrete can cause steel corrosion if oxygen and moisture are available to sustain the reaction. Chlorides dissolved in water can penetrate through sound concrete or reach the steel through cracks.

No other contaminant is documented as extensively in the literature as a cause of corrosion of metals in concrete than chloride ions. The risk of corrosion increases as the chloride content of concrete increases. For Strade River bridge, Co. Mayo, the major concern is the extent of any existing chloride within the various concrete structural elements. While the levels are assessed during this survey, as the concrete is continually exposed to the natural environments and weathering, the level of chloride in the concrete could increase with time.

To assess potentially chloride-contaminated concrete, it is necessary to determine the concentration of chloride ions at various depths in order to determine the likelihood of corrosion of the reinforcement steel. To do this dust samples are taken from incremental depths. As specified, this was to be carried out in four depths (5-30mm, 30-55mm, 55-80mm & 80-105mm). Note the first 5mm drilling are normally discarded as being non-representative. Care was taken to ensure all drilling dust was collected. This is important as studies have shown that more chloride is contained in the finer component of the dust.

In line with the Irish concrete standard (EN 206), the chloride content as a percentage of cement is to be below the maximum allowable of 0.4% for concrete mixes containing embedded steel. At all twelve locations, the chloride content as a percentage of cement is below this value.

A summary table of the results is found below:

Location Reference	Sample Reference	Depth (mm)	Chloride Content % by mass of Sample	Chloride Content % by mass of Cement
Area 1 - Car 1	24/07/072-1	5-30	0.01	0.08
		30-55	0.01	0.08
		55-80	0.02	0.15
		80-105	0.01	0.08
Area 2 - Car 2	24/07/072-2	5-30	0.04	0.20
		30-55	0.03	0.15
		55-80	0.03	0.15
		80-105	0.01	0.05
Area 3 - Car 3	24/07/072-3	5-30	0.02	0.13
		30-55	0.02	0.13
		55-80	0.02	0.13
		80-105	0.02	0.13
Area 3.1 - Car 4	24/07/072-4	5-30	0.03	0.20
		30-55	0.02	0.13
		55-80	0.03	0.20
		80-105	0.03	0.20
Area 4 - Car 5	24/07/072-5	5-30	0.04	0.19
		30-55	0.02	0.10
		55-80	0.02	0.10
		80-105	0.02	0.10
Area 4.1 - Car 6	24/07/072-6	5-30	0.04	0.33
		30-55	0.03	0.25
		55-80	0.03	0.25
		80-105	0.04	0.33

Location Reference	Sample Reference	Depth (mm)	Chloride Content % by mass of Sample	Chloride Content % by mass of Cement
Area 5 - Car 7	24/07/072-7	5-30	0.02	0.20
		30-55	0.01	0.10
		55-80	0.01	0.10
		80-105	0.01	0.10
Area 5 - Car 8	24/07/072-8	5-30	0.02	0.25
		30-55	0.01	0.13
		55-80	0.01	0.13
		80-105	0.01	0.13
Area 6 - Car 9	24/07/072-9	5-30	0.01	0.07
		30-55	0.01	0.07
		55-80	0.01	0.07
		80-105	0.01	0.07
Area 6 - Car 10	24/07/072-10	5-30	0.03	0.21
		30-55	0.03	0.21
		55-80	0.03	0.21
		80-105	0.03	0.21
Area 7 - Car 11	24/07/072-11	5-30	0.01	0.08
		30-55	0.01	0.08
		55-80	0.01	0.08
		80-105	0.01	0.08
Area 7 - Car 12	24/07/072-12	5-30	0.03	0.17
		30-55	0.03	0.17
		55-80	0.02	0.11
		80-105	0.02	0.11

4.6 Cement Content

The determination of the cement content (mix proportions) is undertaken largely for two reasons. The first is in the cases of problems to identify the reason for concrete failure or lack of quality. The second is to investigate old structural concrete for redevelopment and improvement works. This is the case in this project. The cement content analysis will also allow BHP to provide chloride and sulphate results as a percentage of cement for clear comparison with standard allowances.

We start by describing the raw materials that go into mortar and concrete and by defining some terms. Cement is a generic term meaning "glue." Portland cement is a gray powder that when mixed with water forms a paste that hardens and gains strength with time. This is the glue that holds mortar and concrete together. When sand or fine aggregate is added to paste the mixture is known as mortar which is suitable for thin cross sections. Grouts, plasters and stuccos are generally special mortars and contain much the same raw materials. Stone added to mortar makes concrete which can be used in structural or massive applications.

The cement most often used in construction is known as Portland cement. There are other types of construction cements, some used in masonry construction and other special cements used for repairs or high temperature applications. This paper addresses Portland cement and its derivatives only. The predominant chemical compounds in Portland cement are based upon oxides of calcium (lime), silicon (silica), aluminium (alumina) and iron. There are other compounds present in smaller quantities such as magnesia and carbon dioxide and a number of trace elements. The principal chemical compounds that combine with water (hydrate) to provide strength are calcium silicates. However, in all reported chemical analyses, the constituents of cement and concrete are reported simply as the appropriate oxides. Modern Portland cements, by definition, all tend to contain these compounds in a fairly tight range of values even if they come from different manufacturing facilities. Hydrated Portland cement has the unusual, and desirable, property that it will continue to gain strength (albeit at a decreasing rate) when in the presence of water. This complicates chemical analysis because the system is continually changing from the time of first mixing to the time of test.

The cement content analysis for Strade River bridge, Co. Mayo was undertaken on twelve samples. The samples came from deck, abutments and soffits in different levels. The mean cement content results for the twelve samples is 14% with a range of 8% – 20%. A summary table of the results is found below.

Location	**Cement Content (%)**	**Compressive Strength (N/mm2) – from core test**
Area 1 Top Deck	13	18.9
Area 2 Top Deck	20	21.1
Area 3 Face deck	16	-
Area 3.1 Soffit	15	49.6
Area 4 Face deck	21	-
Area 4.1 Soffit	12	57.1
Area 5 Abutment	10	-
Area 5 Abutment	8	-
Area 6 Pier	14	-
Area 6 Pier	14	-
Area 7 Abutment	12	-
Area 7 Abutment	18	-

A cement content of 16-17% would normally indicate an approximate in-situ compressive strength of 50N. The values found here find that the expected cement content for the soffit is a little lower than expected. The biggest different is the cement content in the top deck versus the actual compressive strength. Albeit one of the cores in the soffit contained reinforcement, the density of these concrete versus the concrete in the deck is much higher.

4.7 Half Cell and Resistivity

Corrosion of steel in concrete is one of the major problems with respect to the durability of reinforced concrete structures. Most concrete structures perform well even after a long period of use in normal environments. However, there are various reinforced concrete structures important for our infrastructure, especially bridges and buildings, which exhibit premature damage due to environmental actions (EN 206).

In contrast to mechanical actions (load, wind, etc.) the environmental actions are not reversible and accumulate hazardous components (such as chloride ions) in the concrete. A high percentage of the damage is caused by insufficient planning, wrong estimation of severity of environmental actions and by bad workmanship and this many of these structures need to be repaired after a short service life.

Half-cell potential measurements can be performed on structures with ordinary or stainless-steel reinforcement. Corrosion of prestressing steel in concrete can be assessed in the same way. Prestressing steel in the ducts of posttensioned cables cannot be assessed.

Half-cell potential measurements are suitable mainly on reinforced concrete structures exposed to the atmosphere. The method can be applied regardless of the depth of concrete cover and the rebar size. Half-cell potential measurements will indicate corroding rebars not only in the most external layers of reinforcement facing the references electrode but also in greater depth. The method can be used at any time during the life of a structure and in any kind of climate providing the temperature is higher than +2°C. Hal-cell potential measurements should be taken only on a free concrete surface. The presence of isolating layers (asphalt, organic coatings or paints etc.) may make measurements erroneous or impossible.

In the assessment of the half-cell results, ASTM C876 uses a numeric technique to assess the half-cell potential results.

Table 1: Relationship between the potential values and corrosion probability (adapted from ASTM C876)

Measured Potential(mV CSE)	Probability of steelcorrosion activity
>-200	Less than 10%
-200 to -350	Uncertain
<-350	More than 90%

Half Cell Potential Results

Location	Mean (mV)	Lowest (mV)	Highest (mV)	Standard Deviation (mV)
Area 1 Top deck	-239	-268	-207	19.8
Area 3 Face deck	-54.9	-97	-27	21
Area 3.1 Soffit	-333.5	-368	-320	13.2
Area 4 Face deck	-237.7	-283	-198	28.3
Area 4.1 Soffit	-165.8	-179	-129	13

Based on this, it sets our three phases of corrosion activity – Initial Phase, Transient Phase, and the Final Phase. For any half-cell potential results that are > -200 it is deemed to be in the initial phase where the probability of corrosion activity is less than 10%. Where the half-cell potential results that are in the range of -200 to -350 (Transient Phase), the probability of corrosion activity is uncertain. Where the half-cell potential results that are <-350 (Final Phase), the probability of corrosion activity is more than 90%. Based on the results and visual examination of the bars on site when broken out, the likelihood of corrosion based on half-cell results is moving from the initial phase to the transient phase.

In addition to half-cell potential surveying of concrete, resistivity measurements of the same concrete material provide further information on the potential for further corrosion taking or to take place. Corrosion of reinforcing steel is an electro-chemical process. For corrosion of the steel to occur a current must pass between the anodic and cathodic regions of the concrete. The electrical resistivity of the concrete affects the flow of ions and the rate at which corrosion can occur. A higher concrete resistivity decreases the flow; an empirical relationship between corrosion rate and resistivity has been determined from measurements on actual structures.

Electrical resistivity measurement techniques are becoming popular among consulting / design engineers for the quality assessment and durability assessment of concrete. The concept of durability of concrete depends largely on the properties of its microstructure, such as pore size distribution and the shape of the interconnections (that is, tortuosity). A finer pore network, with less connectivity, leads to lower permeability. A porous microstructure with larger degree of interconnections, on the other hand, results in higher permeability and reduced durability in general. The principal idea behind most electrical resistivity techniques is to somehow quantify the conductive properties of the microstructure of concrete. Overall, the electrical resistivity of concrete can be described as the ability of concrete to withstand the transfer of ions subjected to an electrical field. In this context, resistivity measurement can be used to assess the size and extent of the interconnectivity of pores.

Various approaches for measuring resistivity are available but the four-probe device is the most suitable. Modern devices are spring-loaded and are applied directly to the surface. A current is applied between the two outer probes and the potential difference measured between the two inner probes. Resistivity measurement is useful for identifying areas of reinforced concrete at risk from corrosion. It should not be considered in isolation but used in conjunction with other techniques such as half-cell potential. BHP employed the use of the latest version of Proceq's Resipod with 50mm spacings between the four probes.

From the testing undertaken at this structure, we found that there was a negligible risk of corrosion based on the resistivity results.

Location	**Result 1**	**Result 2**	**Result 3**	**Result 4**	**Result 5**
Area 1 Top deck	106	112	172	185	190
Area 3 Face deck	69	55	72	-	-
Area 3.1 Soffit	285	278	303	256	272
Area 4 Face deck	186	156	194	-	-
Area 4.1 Soffit	196	206	209	255	272

Appendix A

BHP/MTIField/F058 V1 29/05/24

COMPRESSIVE STRENGTH OF A CONCRETE CORE TEST REPORT

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-1
		Order No:	Not Supplied
		Date Tested:	09/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Core

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 1 C1 Deck
Test Standard: EN 12504-1:2019

Core Details			
Coring Date	12/07/2024	Age of specimen	Not Specified
End of core used as datum	Top	Reinforcement in test Specimen: Size (mm)	N/A
Drilling Direction	Vertical	Reinforcement in test Specimen: Position (mm)	N/A
Visual Assessment			
Condition of specimen when received	Good	Maximum nominal size of aggregate (mm)	20
Compaction of concrete	Good	Distribution of materials	Even
Excess Voids	1.5%	Ribbing on core surface	None
Honeycombing	Yes	Flatness	Pass
Presence of cracks	None	Perpendicularity	Pass
Type of aggregate	Crushed Rock	Straightness	Pass
Test Information			
Preparation		Surface condition at time of test	Dry
Length after end preparation	102	Type of failure	Satisfactory
Diameter after end preparation	99	Average Diameter (mm)	99
Length / diameter ratio of specimen	1.03	Maximum length of specimen, as received	144
		Minimum length of specimen, as received	144
		Density of the specimen, as received (kg/m^3)	2280
		Max Load (KN)	144.8
		Compressive Strength (N/mm^2)	18.9

REMARKS:

Method of determining volume used was displacement. Method of end preparation used was sawn & capped. The sample was stored in a sealed container prior to testing.

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories

Issue Date: 19/07/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

COMPRESSIVE STRENGTH OF A CONCRETE CORE
TEST REPORT

BHP/MTIField/F058 V1 29/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-2
		Order No:	Not Supplied
		Date Tested:	09/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Core

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 2 C2 Deck
Test Standard: EN 12504-1:2019

Core Details			
Coring Date	12/07/2024	Age of specimen	Not Specified
End of core used as datum	Top	Reinforcement in test Specimen: Size (mm)	N/A
Drilling Direction	Vertical	Reinforcement in test Specimen: Position (mm)	N/A
Visual Assessment			
Condition of specimen when received	Good	Maximum nominal size of aggregate (mm)	20
Compaction of concrete	Good	Distribution of materials	Even
Excess Voids	2.5%	Ribbing on core surface	None
Honeycombing	Yes	Flatness	Pass
Presence of cracks	None	Perpendicularity	Pass
Type of aggregate	Crushed Rock	Straightness	Pass
Test Information			
Preparation		Surface condition at time of test	Dry
Length after end preparation	102	Type of failure	Satisfactory
Diameter after end preparation	99	Average Diameter (mm)	99
Length / diameter ratio of specimen	1.03	Maximum length of specimen, as received	123
		Minimum length of specimen, as received	123
		Density of the specimen, as received (kg/m^3)	2300
		Max Load (KN)	161.8
		Compressive Strength (N/mm^2)	21.1

REMARKS:

Method of determining volume used was displacement. Method of end preparation used was sawn & capped. The sample was stored in a sealed container prior to testing.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories — Issue Date: 19/07/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

COMPRESSIVE STRENGTH OF A CONCRETE CORE
TEST REPORT

BHP/MTIField/F058 V1 29/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-3
		Order No:	Not Supplied
		Date Tested:	09/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Core

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 3.1 C3 Soffit
Test Standard: EN 12504-1:2019

Core Details			
Coring Date	12/07/2024	Age of specimen	Not Specified
End of core used as datum	Top	Reinforcement in test Specimen: Size (mm)	Square (14x25mm)
Drilling Direction	Vertical	Reinforcement in test Specimen: Position (mm)	60
Visual Assessment			
Condition of specimen when received	Good	Maximum nominal size of aggregate (mm)	20
Compaction of concrete	Good	Distribution of materials	Even
Excess Voids	0.5%	Ribbing on core surface	None
Honeycombing	None	Flatness	Pass
Presence of cracks	None	Perpendicularity	Pass
Type of aggregate	Crushed Rock	Straightness	Pass
Test Information			
Preparation		Surface condition at time of test	Dry
Length after end preparation	102	Type of failure	Satisfactory
Diameter after end preparation	99	Average Diameter (mm)	99
Length / diameter ratio of specimen	1.03	Maximum length of specimen, as received	145
		Minimum length of specimen, as received	145
		Density of the specimen, as received (kg/m^3)	2610
		Max Load (KN)	380.9
		Compressive Strength (N/mm^2)	49.6

REMARKS:

Method of determining volume used was displacement. Method of end preparation used was sawn & capped. The sample was stored in a sealed container prior to testing.

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories — Issue Date: 28/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

COMPRESSIVE STRENGTH OF A CONCRETE CORE
TEST REPORT

BHP/MTIField/F058 V1 29/05/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-4
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	09/07/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Core

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 4.1 C4 Soffit
Test Standard: EN 12504-1:2019

Core Details			
Coring Date	12/07/2024	Age of specimen	Not Specified
End of core used as datum	Top	Reinforcement in test Specimen: Size (mm)	N/A
Drilling Direction	Vertical	Reinforcement in test Specimen: Position (mm)	N/A
Visual Assessment			
Condition of specimen when received	Good	Maximum nominal size of aggregate (mm)	20
Compaction of concrete	Good	Distribution of materials	Even
Excess Voids	0.5%	Ribbing on core surface	None
Honeycombing	None	Flatness	Pass
Presence of cracks	None	Perpendicularity	Pass
Type of aggregate	Crushed Rock	Straightness	Pass
Test Information			
Preparation		Surface condition at time of test	Dry
Length after end preparation	102	Type of failure	Satisfactory
Diameter after end preparation	99	Average Diameter (mm)	99
Length / diameter ratio of specimen	1.03	Maximum length of specimen, as received	135
		Minimum length of specimen, as received	120
		Density of the specimen, as received (kg/m^3)	2380
		Max Load (KN)	438.9
		Compressive Strength (N/mm^2)	57.1

REMARKS:
Method of determining volume used was displacement. Method of end preparation used was sawn & capped. The sample was stored in a sealed container prior to testing.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 28/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

Appendix B

BOND STRENGTH BY PULL OFF
TEST REPORT

BHP/MTIField/F045 V1 15/04/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072
		Order No:	Not Supplied
		Date Tested:	12/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Surface

Project: Mayo Bridges - Strade River Bridge
Location Reference: See below
Test Standard: BS EN 1542

Surface Condition	Wet
Deck Surface Condition	As Supplied
Test Direction	Vertical

Test Reference	Max Applied Load (MPa)	Depth of Failure (mm)	Failure Occurred In
Area 1 deck	1.4	3.0	Below adhesive on top of substrate
Area 1 deck	1.7	4.0	Below adhesive on top of substrate
Area 1 deck	2.3	5.0	Below adhesive on top of substrate
Area 1 deck	0.9	0.0	Below adhesive on top of substrate
Area 1 deck	2.6	4.0	Below adhesive on top of substrate
Mean	**1.78**		

REMARKS:
Elcometer 506 Pull - Off Adhesion Tester

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski (signed)

For and On Behalf of BHP Laboratories — Issue Date: 13/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

Appendix C

CARBONATION DEPTH OF CONCRETE
TEST REPORT

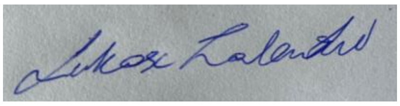
BHP/MTIField/F053 V1 15/05/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	09/07/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Core

Project: Mayo Bridges Investigation - Strade Rivei
Location Reference: See below
Test Standard: BS EN 14630

Location Reference	Carbonation (mm)	Notes
Car 1	<1.0	Area 1
Car 2	<1.0	Area 2
Car 3	<1.0	Area 3
Car 4	16	Area 3.1
Car 5	<1.0	Area 4
Car 6	<1.0	Area 4.1
Car 7	>20	Area 5
Car 8	<1.0	Area 5
Car 9	<1.0	Area 6
Car 10	<1.0	Area 6
Car 11	<1.0	Area 7
Car 12	<1.0	Area 7

REMARKS:
Nill

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Appendix D

TEST REPORT

Analysing
Testing
Consulting
Calibrating

BHP

New Road
Thomondgate
Limerick
Ireland
Tel +353 61 455399
Fax + 353 61 455447
E Mail: jamespurcell@bhp.ie

Account: Triur Construction Ltd,
13 Society Street,
Ballinasloe,
Galway

Customer: Mr. Lurcan Donnellan.

BHP Ref No.: 24/07/072
Order No.: Not Supplied
Date Received: Not Applicable
Date Tested: 12/07/2024
Specification: Client Specification

Customer Reference: Reinforcement Scanning at Strade River Bridge, Co. Mayo

Steel Reinforcement Survey

On Tuesday 9th July and Friday 12th July 2024, BHP Laboratories visited Strade River bridge, Co. Mayo. The purpose of these specific works was to conduct a series of reinforcement scans to determine the concrete cover and reinforcement layout in top deck, face deck and soffit of bridge.

BHP undertook scans of the top deck, face deck and soffit to ascertain the reinforcement position and cover. BHP conducted this reinforcement scanning using the latest from Proceq – Ground Penetrating Radar (GPR).

Site Location

The scanning of the top deck, face deck and soffit bridge has found the following information / key points:

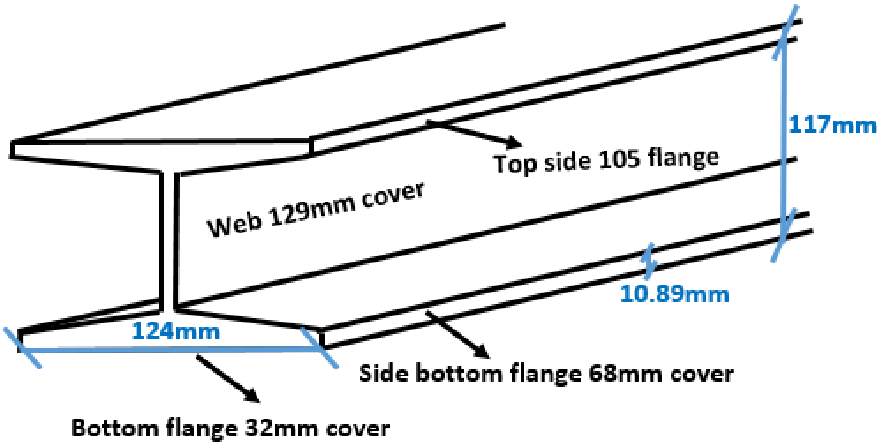
Scan Location	Rebar directions	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)	Minimum Spacing (mm)	Maximum Spacing (mm)
Area 1 top deck longitudinal scan 001	T	153	n/a	n/a	n/a	n/a	n/a
Area 1 top deck transverse scan 001	L	164	158	170	180	n/a	n/a
Area 2 top of deck longitudinal scan 001	T	160	137	183	640	n/a	n/a
Area 2 top of deck longitudinal scan 002	T	156	150	162	620	n/a	n/a
Area 2 top of deck transverse scan 001	L	204	144	238	405	130	680
Area 3 deck face vertical scan 001	L	142	136	148	60	n/a	n/a
Area 3 deck face horizontal scan 001	T	135	n/a	n/a	n/a	n/a	n/a
Area 3.1 soffit longitudinal scan 001	T	38	28	48	684	560	710
Area 3.1 soffit longitudinal scan 002	T	42	37	48	657	620	690
Area 3.1 soffit transverse scan 001	L	46	42	55	166	140	198
Area 3.1 soffit transverse scan 002	L	62	54	68	165	140	196
Area 4 Deck Face Vertical scan 001	L	106	92	120	120	n/a	n/a
Area 4 Deck Face Horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 4.1 Soffit longitudinal scan 001	T	48	42	51	666	640	700
Area 4.1 Soffit longitudinal scan 002	T	51	42	56	707	640	750
Area 4.1 Soffit transverse scan 001	L	60	44	69	227	120	330
Area 4.1 Soffit transverse scan 002	L	65	55	76	216	120	319
Area 5 Abutment vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a

Scan Location	Rebar directions	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)	Minimum Spacing (mm)	Maximum Spacing (mm)
Area 5 Abutment horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 6 Abutment horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a
Area 6 Abutment Vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a
Area 7 Abutment Vertical scan 001	L	n/a	n/a	n/a	n/a	n/a	n/a
Area 7 Abutment Horizontal scan 001	T	n/a	n/a	n/a	n/a	n/a	n/a

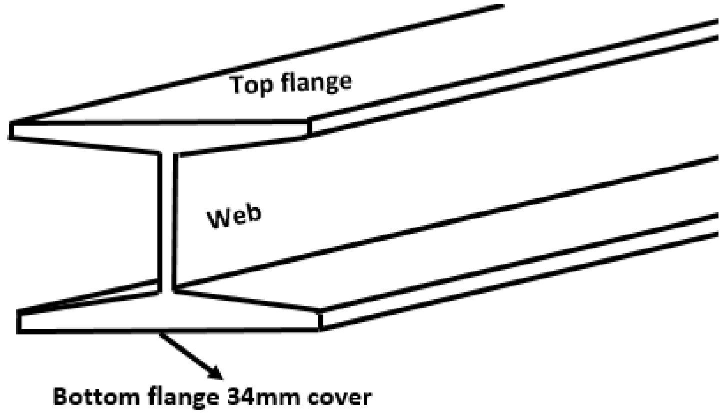
*Rebar directions: L- longitudinal, T- transverse
* In Area 1(TP1), Area 2 (TP2) were not enough space to get more reinforcement readings due to lack of access for GPR
* In Area 5 – Area 7 GPR did not find any reinforcement

Reinforcement found by completing a breakout	Actual cover (mm)	Diameter (mm)	Width(mm)
Area 1 top of deck top flange	150	n/a	n/a
Area 1 top of deck transverse rebar square	109	14.3/25.7	n/a
Area 3 face deck web	129	n/a	n/a
Area 3 face deck bottom flange	32	10.89	123mm
Area 3 face deck bottom side flange	68	n/a	n/a
Area 3 face deck top flange	104	n/a	n/a
Area 3 face deck distance top-bottom flange	117	n/a	n/a
Area 3.1 soffit bottom flange	34mm	n/a	n/a
Area 3.1 soffit transverse rebar square	59	15.3/28.9	n/a
Area 4 face deck top side flange	104	31.39	
Area 4 face deck web	132	n/a	n/a
Area 4 face deck bottom flange	80	n/a	n/a
Area 4 face deck bottom flange	37	8.86	n/a
Area 4.1 soffit bottom flange	47	n/a	n/a
Area 4.1 soffit transverse rebar square	51	13.5/23.6	

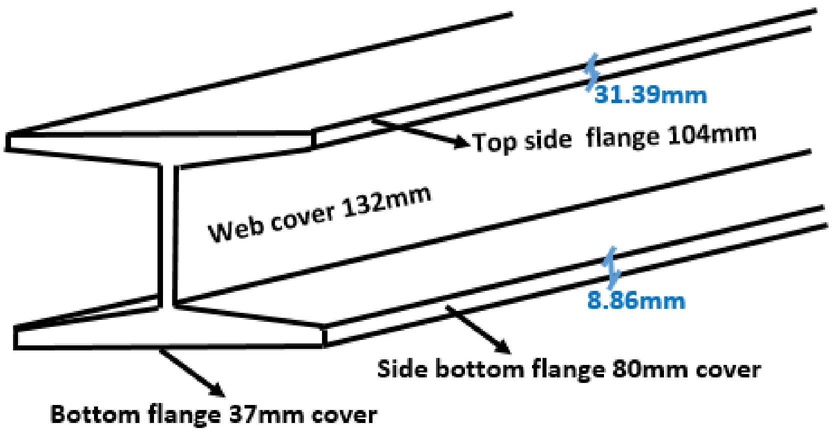
Area 3 beam sketch



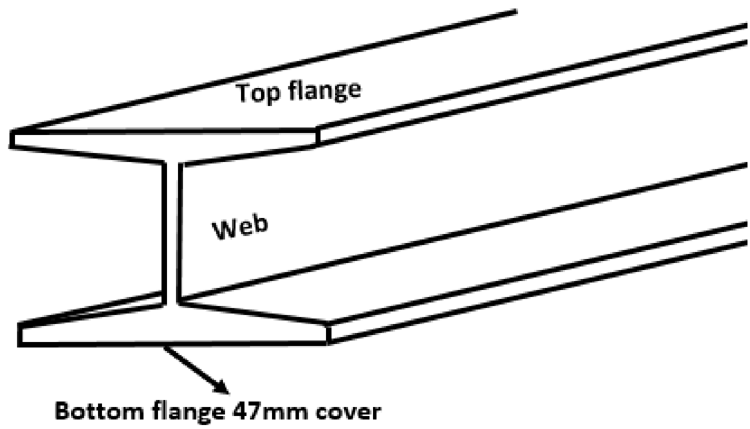
Area 3.1 beam sketch

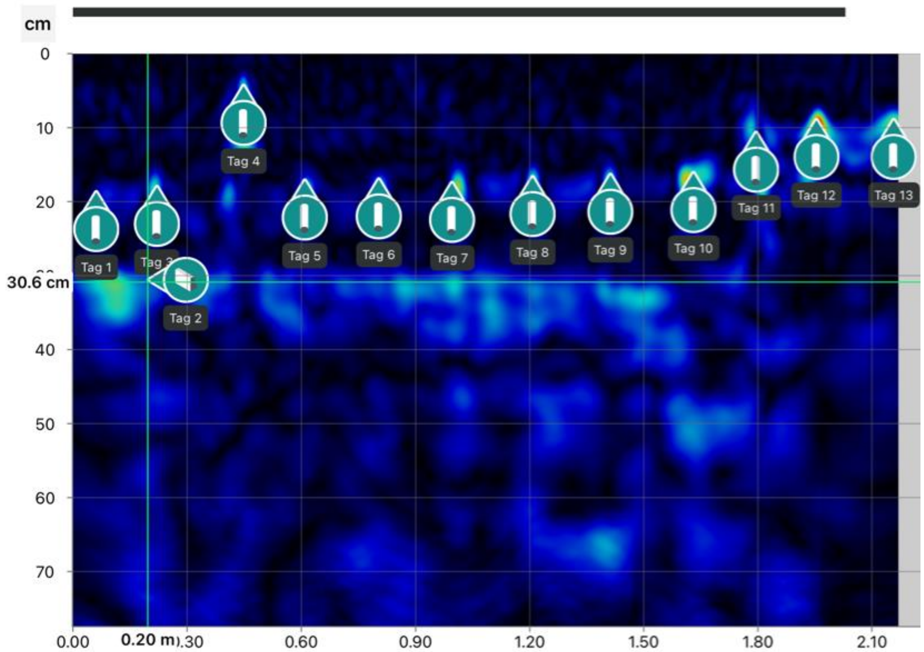


Area 4 beam sketch

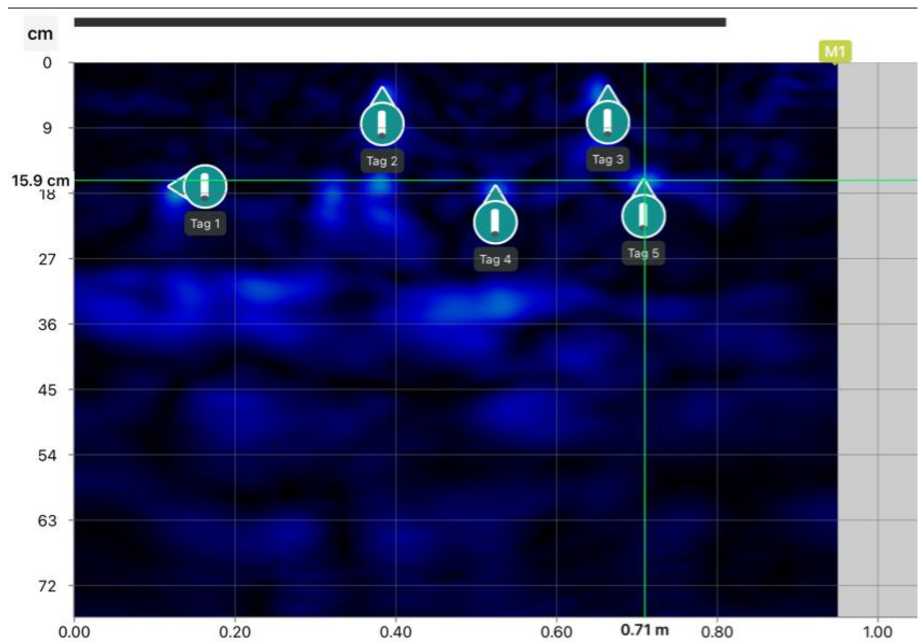


Area 4.1 beam sketch



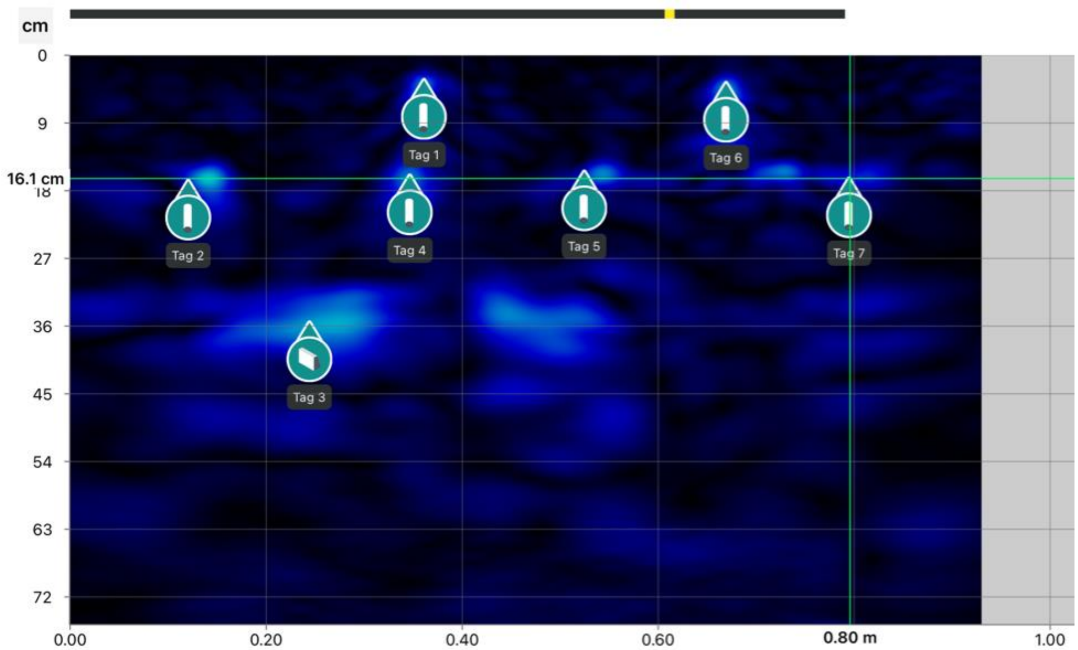


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top of footpath longitudinal scan	139	87	184	191



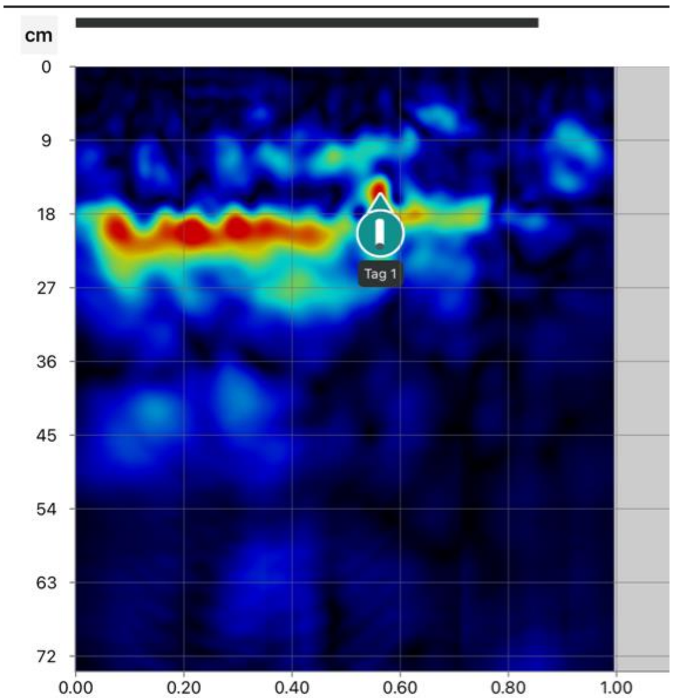
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top of footpath transverse scan first layer	31	30	32	290

Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top of footpath transverse l scan second layer	166	159	171	295

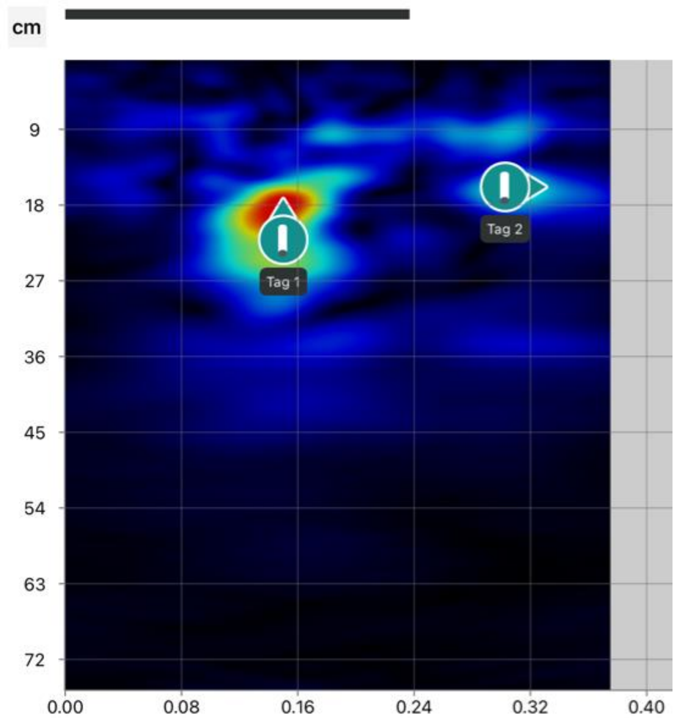


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top of footpath transverse scan first layer 002	32	30	34	310

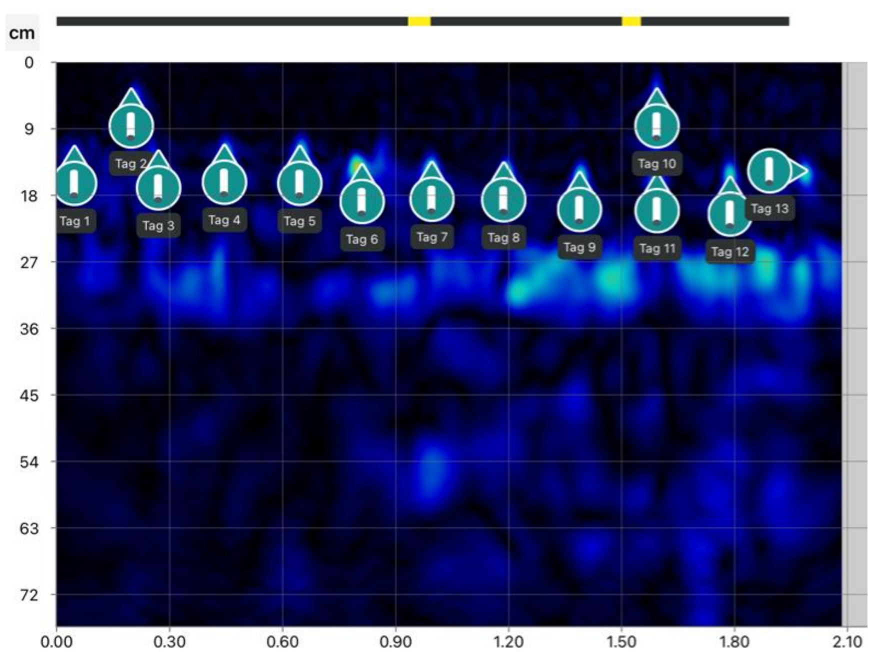
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top of footpath transverse scan second layer 002	159	152	164	227



Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top deck longitudinal scan 001	153	n/a	n/a	n/a

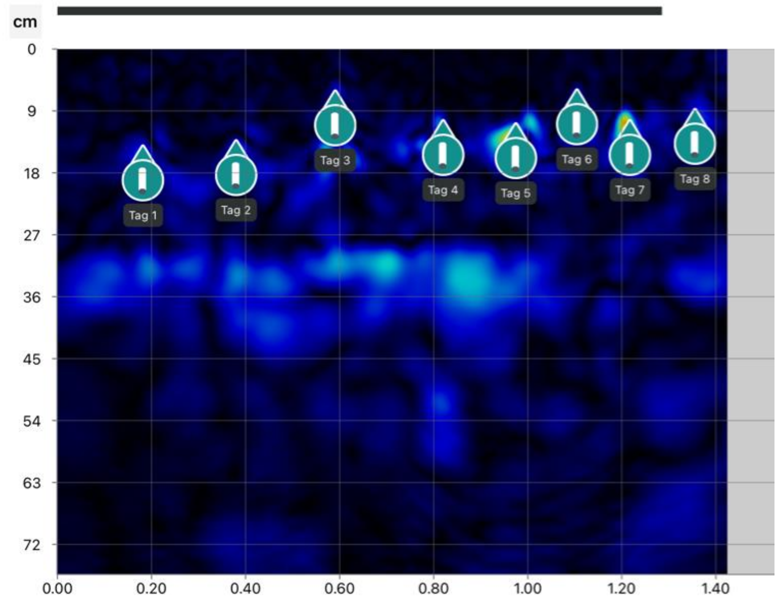


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 1 top deck transverse scan 001	164	158	170	180



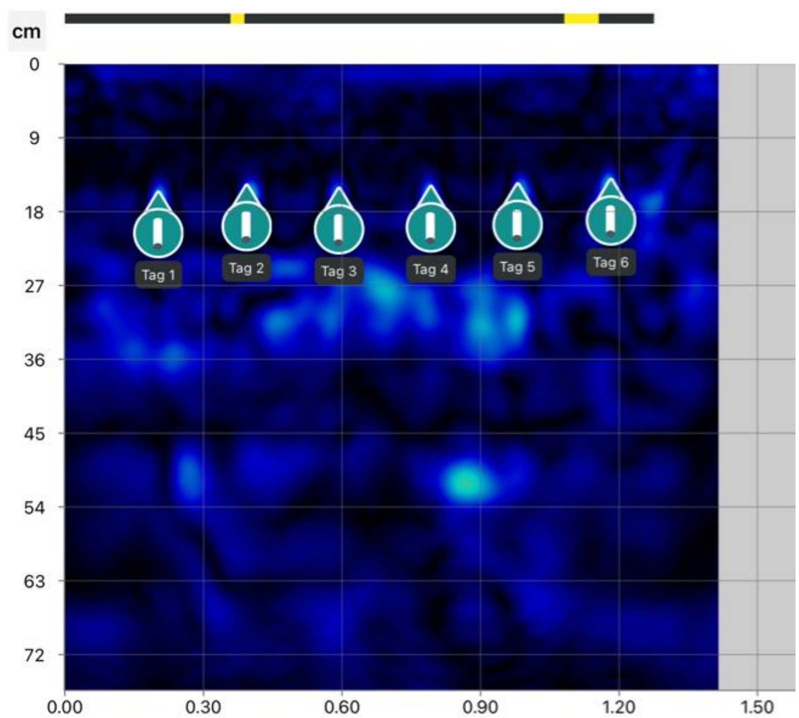
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of footpath longitudinal scan 001	34	34	34	1400

Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of footpath longitudinal scan 001	153	n/a	n/a	n/a

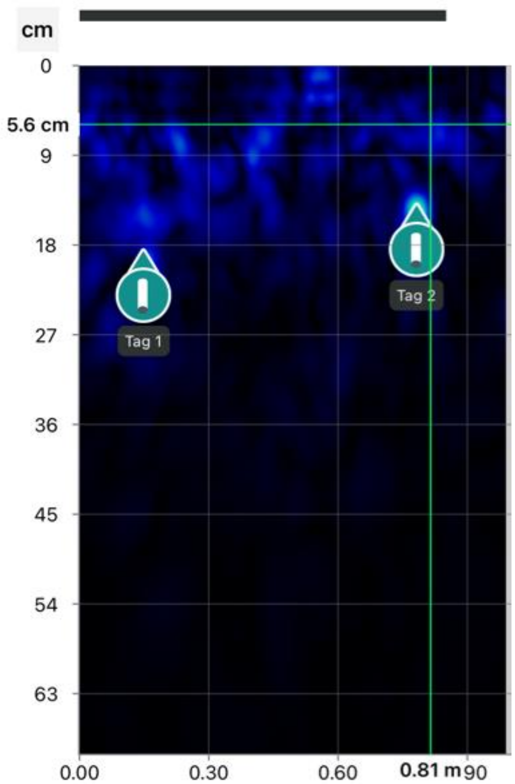


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of footpath transverse scan 001 first layer	67	57	85	385

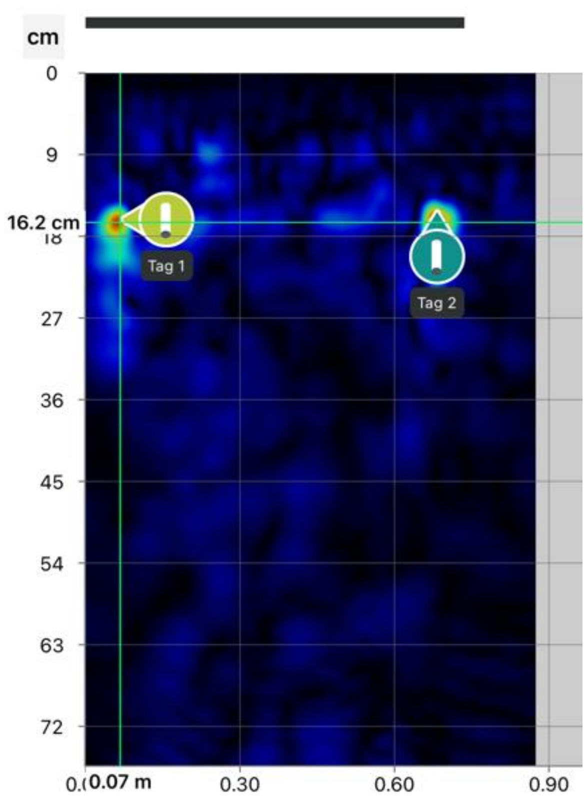
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of footpath transverse scan 001 second layer	116	102	138	260



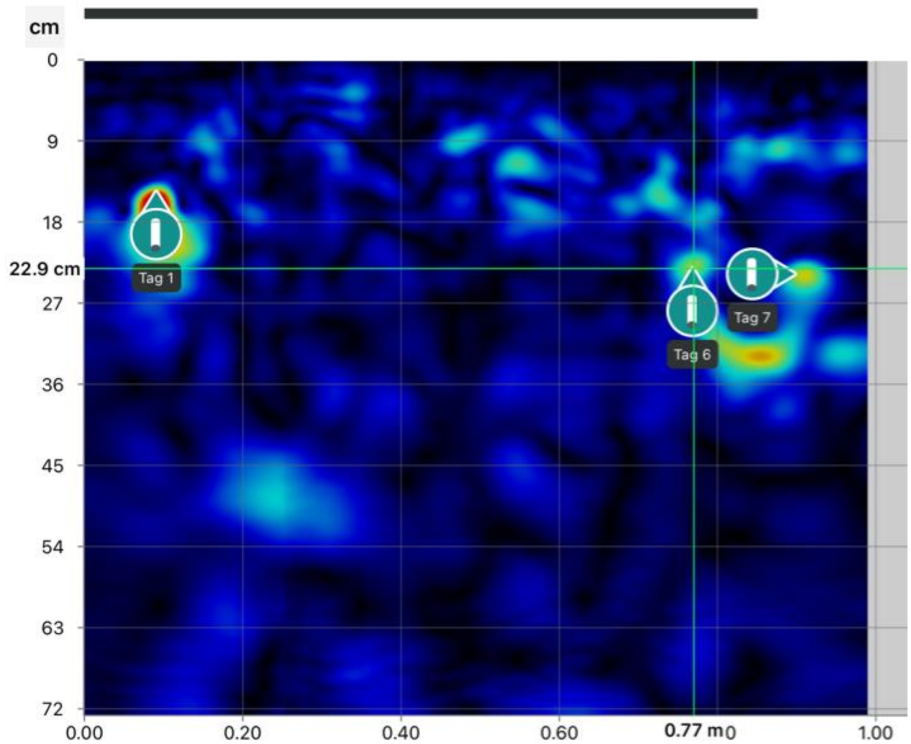
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of footpath transverse scan 002	146	138	154	196



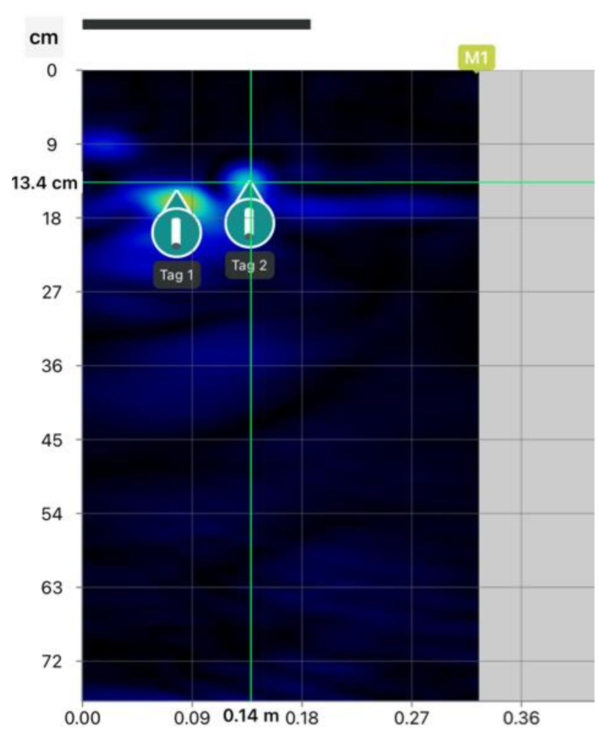
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of deck longitudinal scan 001	160	137	183	640



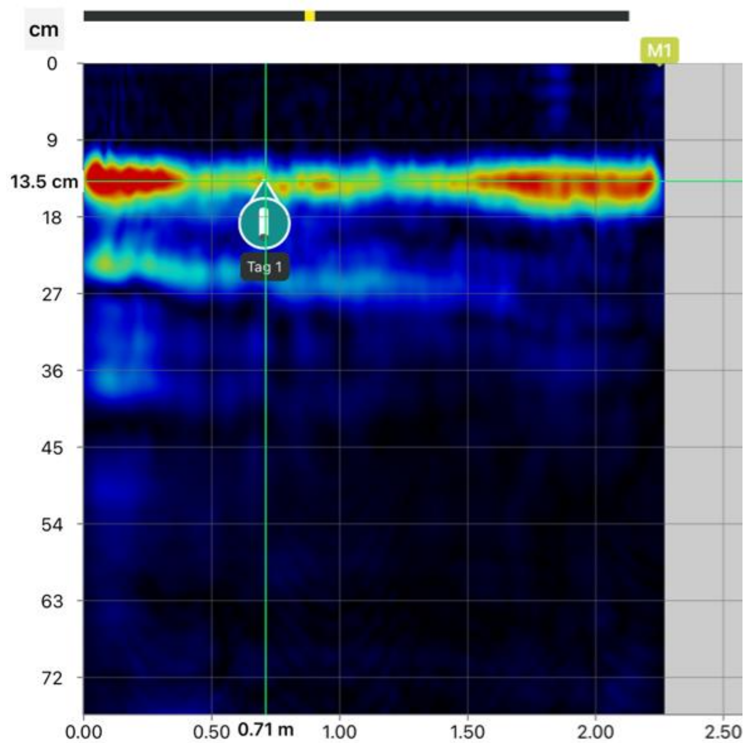
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of deck longitudinal scan 002	156	150	162	620



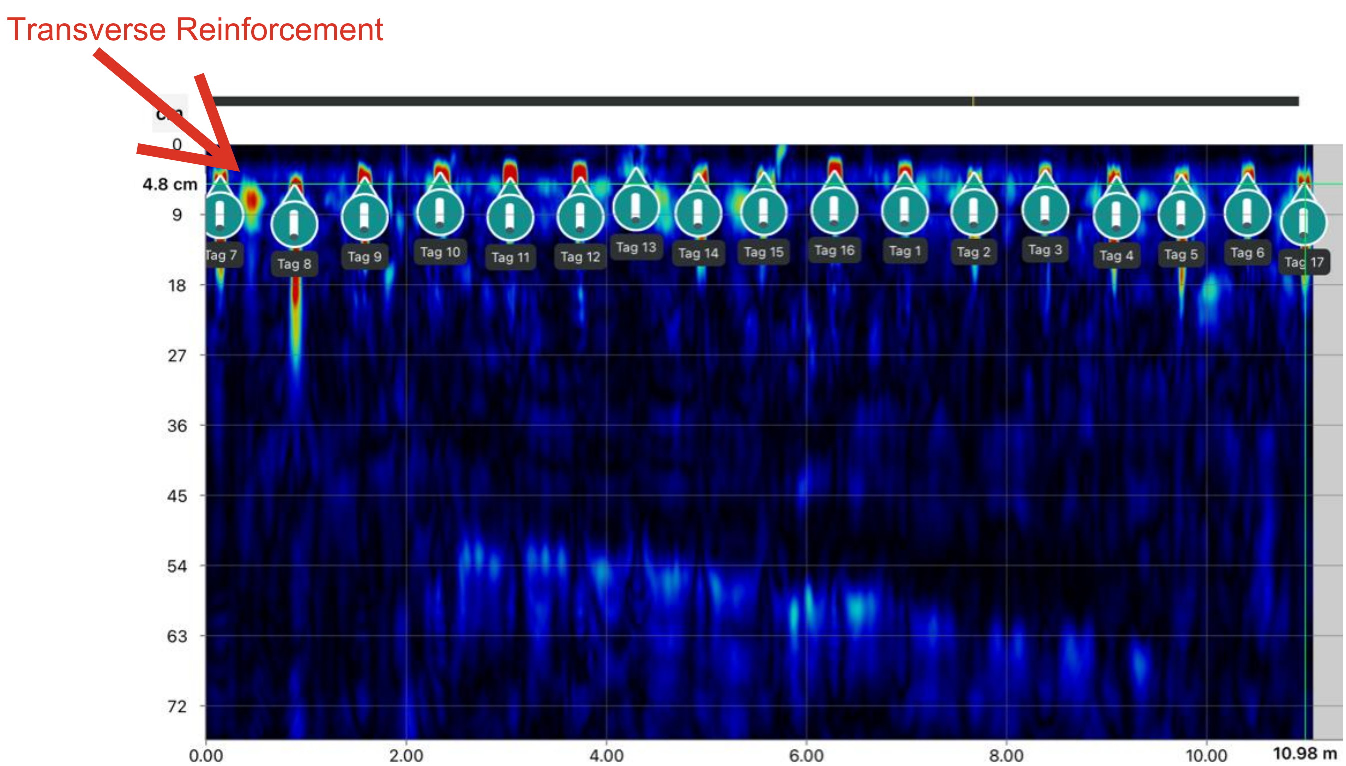
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 2 top of deck transverse scan 001	204	144	238	405



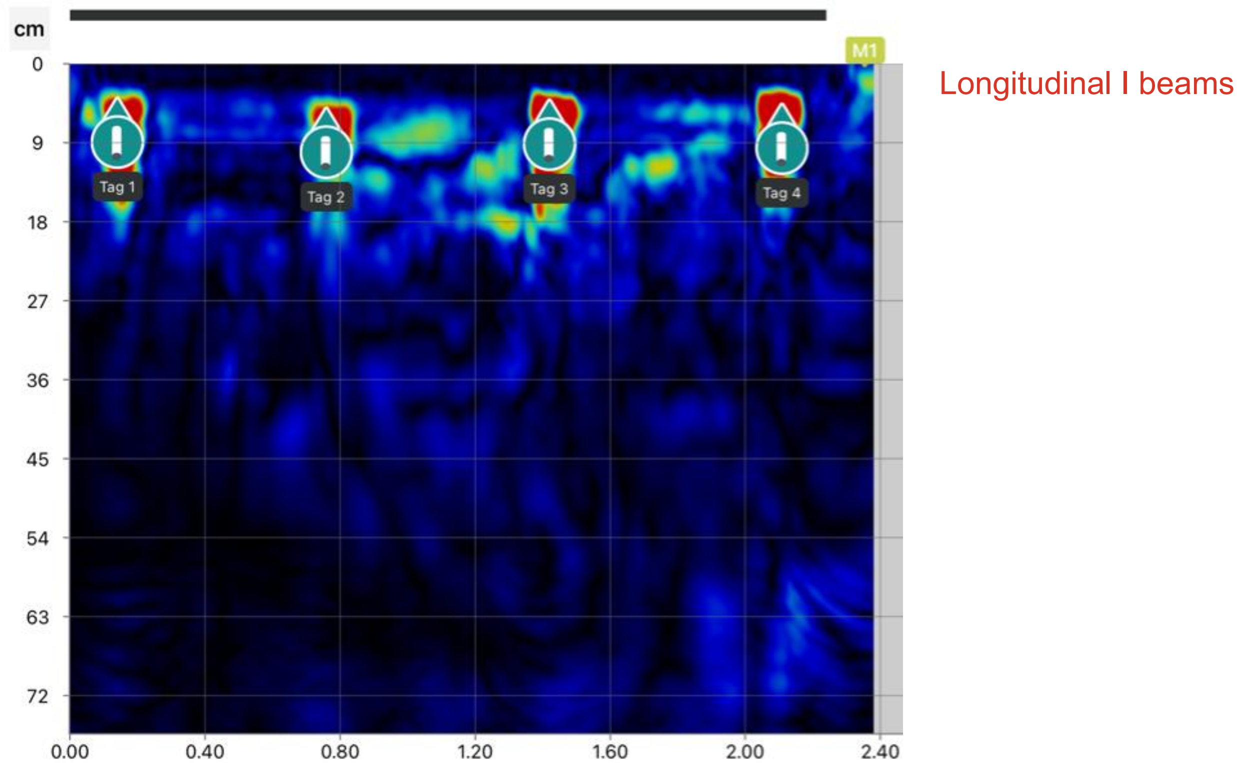
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3 deck face vertical scan 001	142	136	148	60



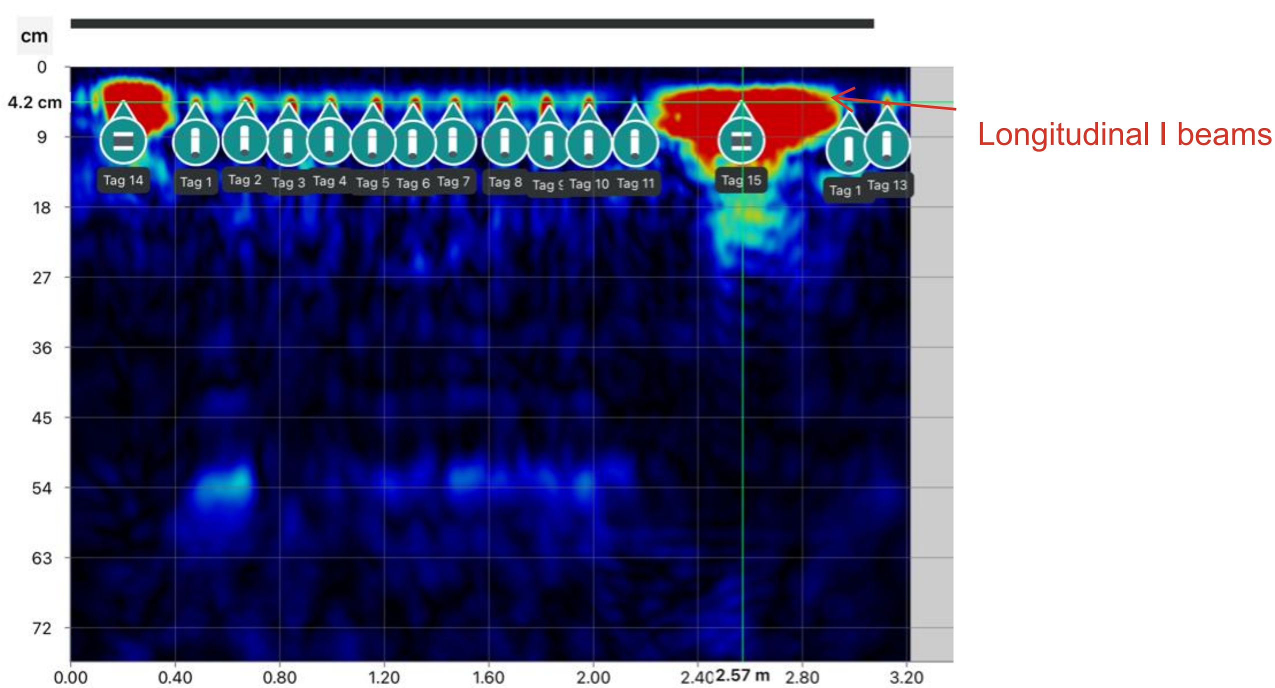
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3 deck face horizontal scan 001	135	n/a	n/a	n/a



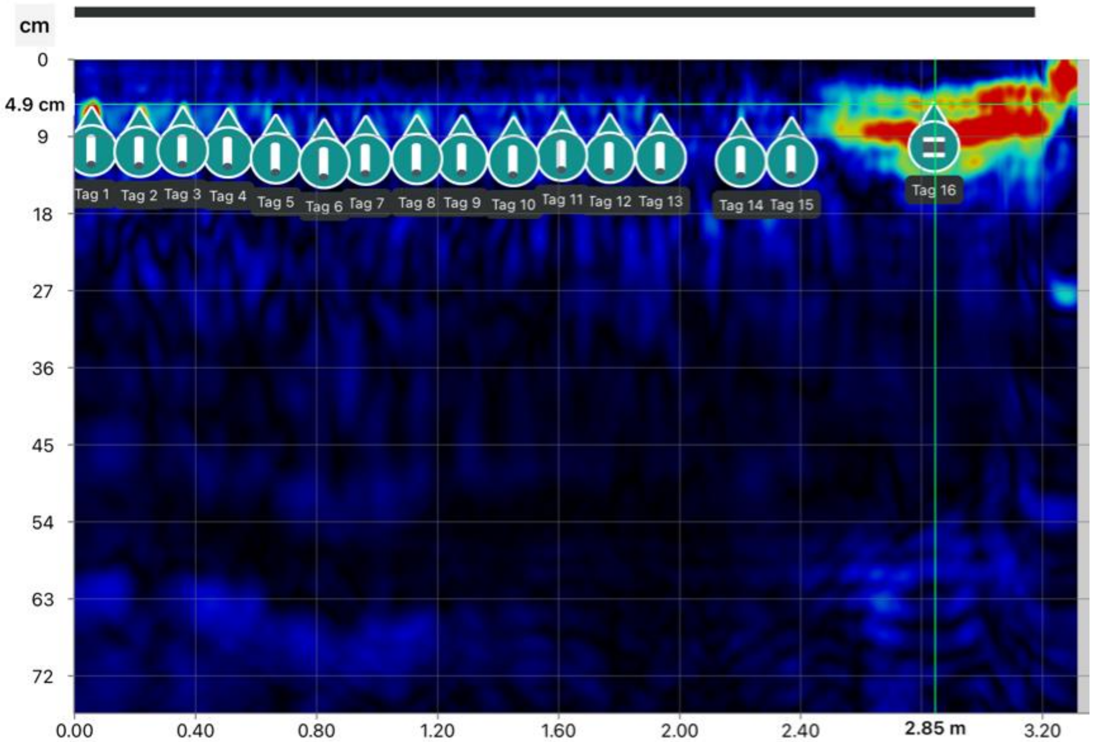
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3.1 soffit longitudinal scan 001	38	28	48	249



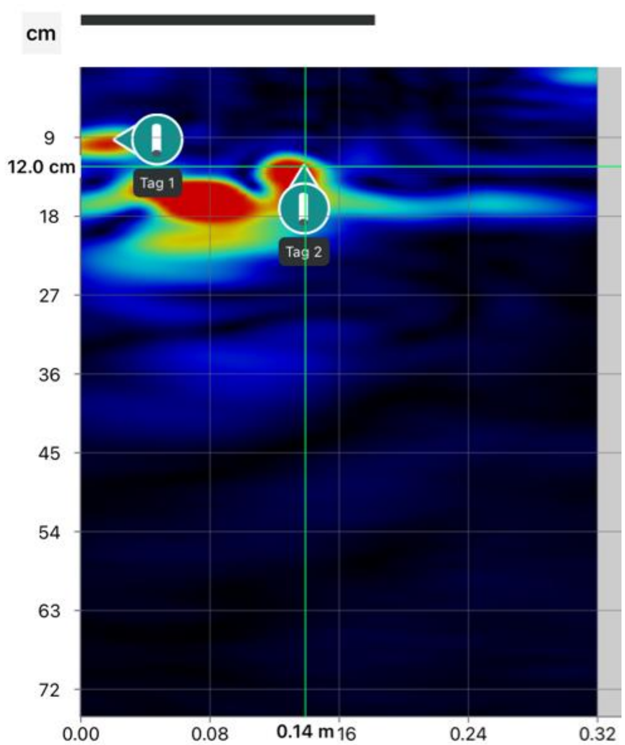
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3.1 soffit longitudinal scan 002	42	37	48	657



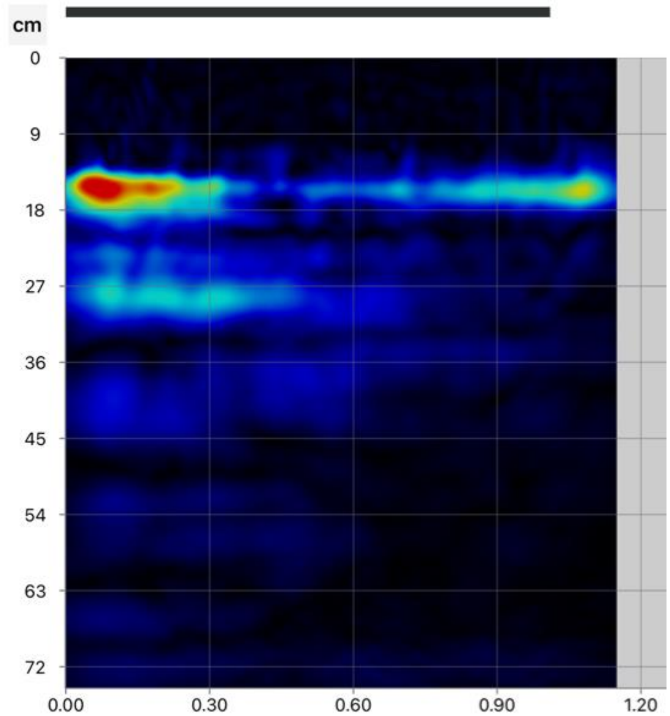
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3.1 soffit transverse scan 001	46	42	55	166



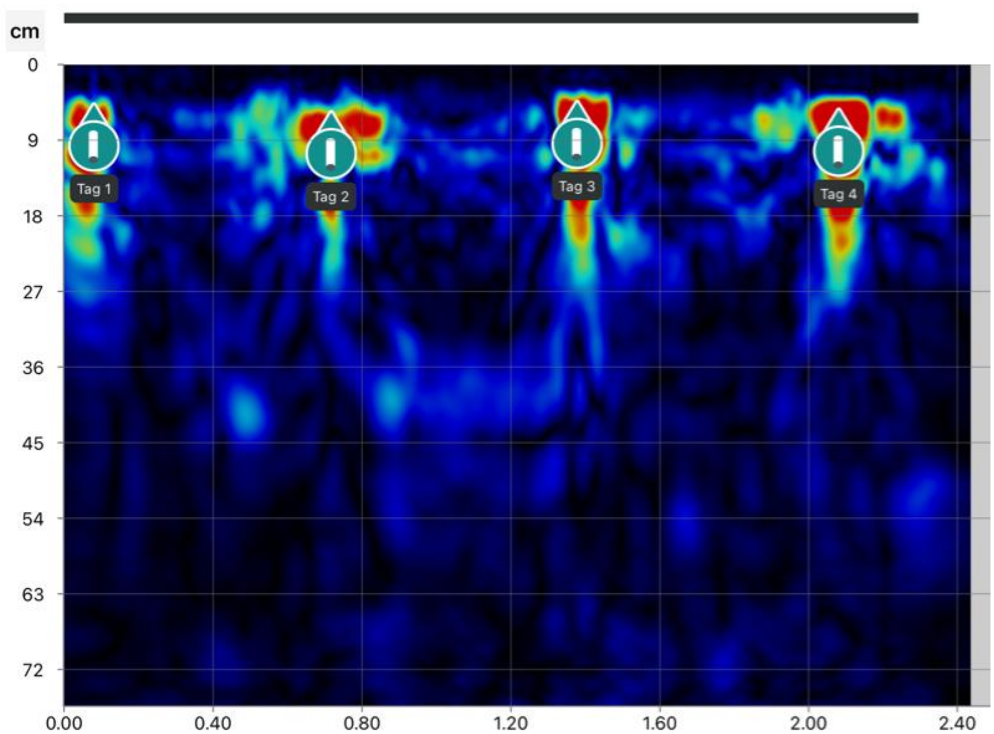
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 3.1 soffit transverse scan 002	62	54	68	165



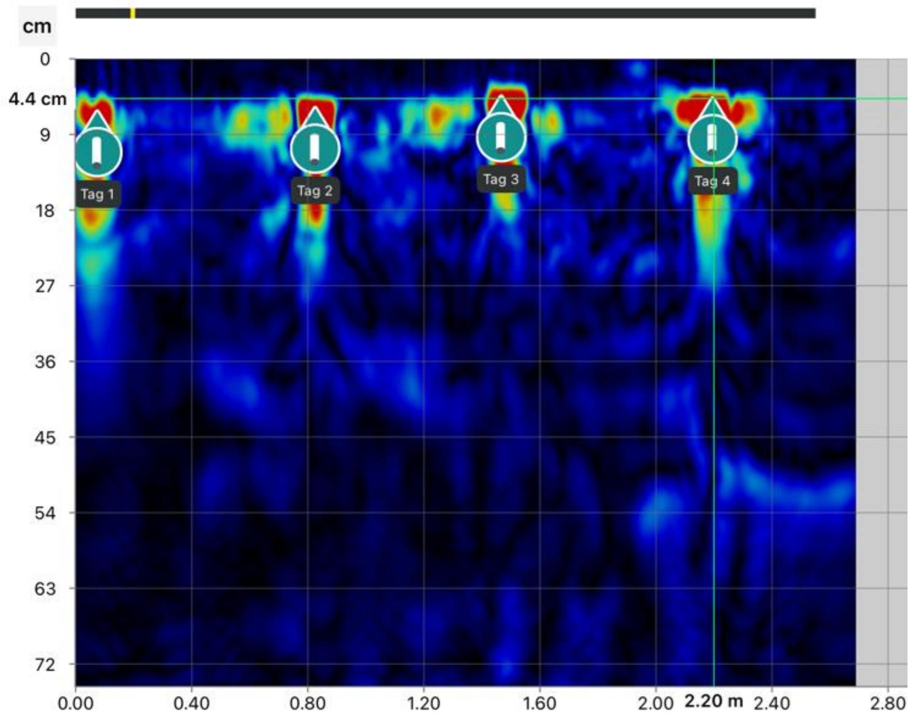
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 4 Deck Face Vertical scan 001	106	92	120	120



Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 4 Deck Face Vertical scan 001	106	92	120	120

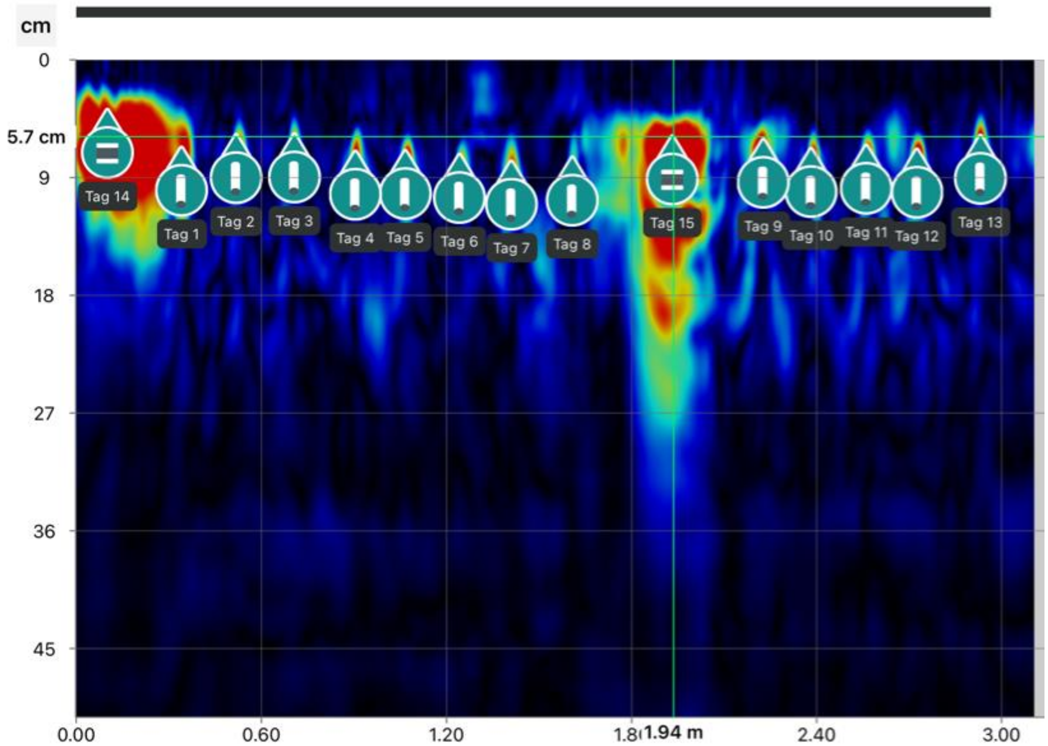


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 4.1 Soffit longitudinal scan 001	48	42	51	666

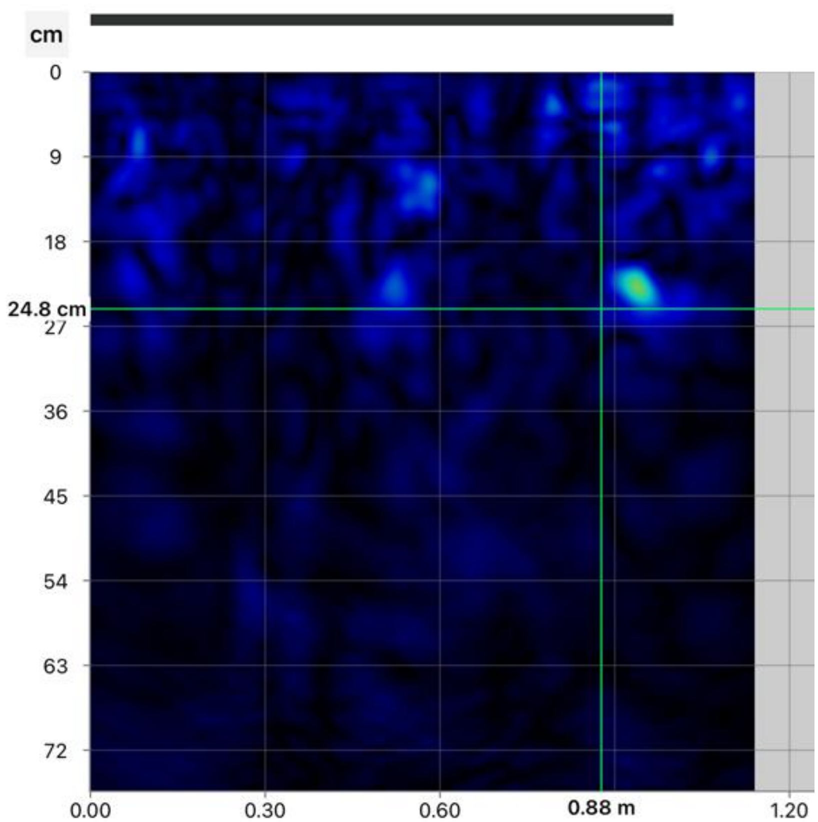


Scan Location	**Mean Cover (mm)**	**Lowest Cover (mm)**	**Highest Cover (mm)**	**Mean Spacing (mm)**
Area 4.1 Soffit longitudinal scan 002	51	42	56	707

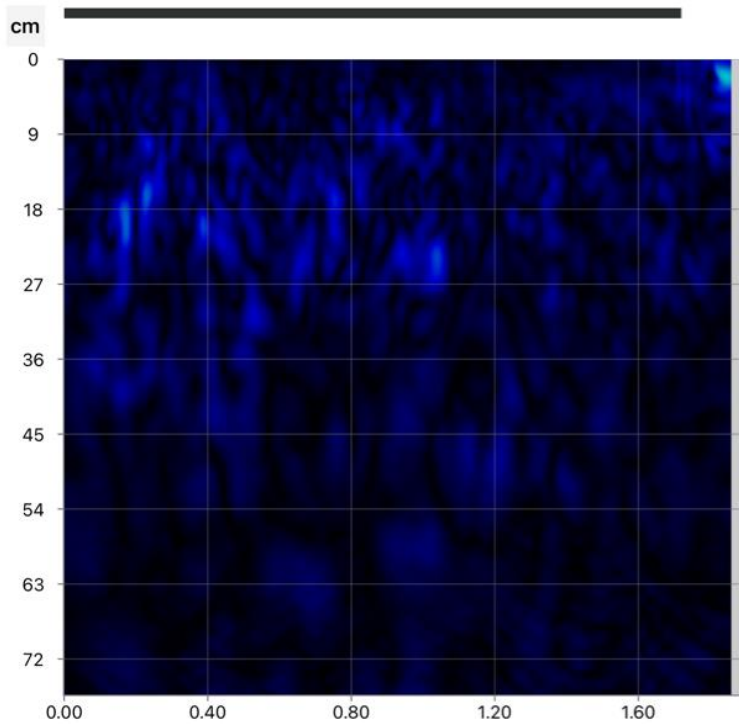
Scan Location	**Mean Cover (mm)**	**Lowest Cover (mm)**	**Highest Cover (mm)**	**Mean Spacing (mm)**
Area 4.1 Soffit transverse scan 001	60	44	69	227



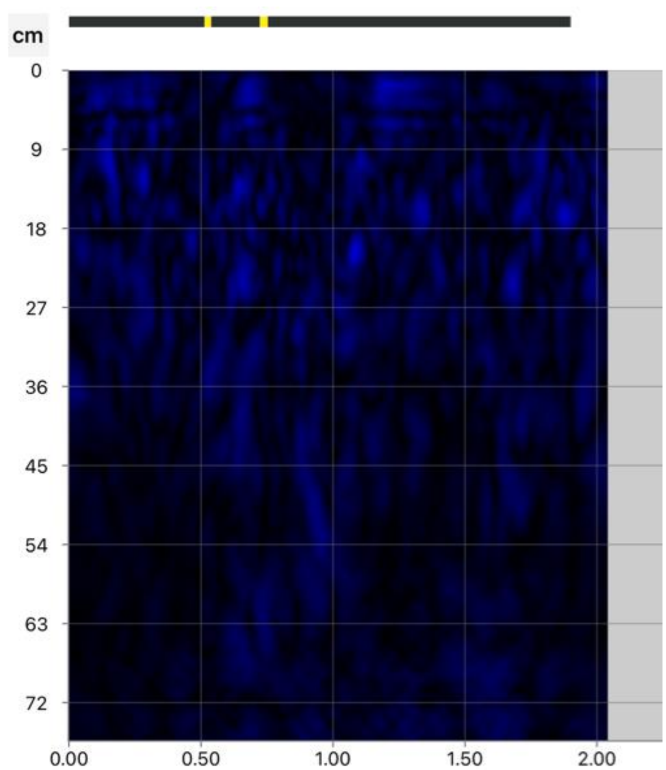
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 4.1 Soffit transverse scan 002	65	55	76	216



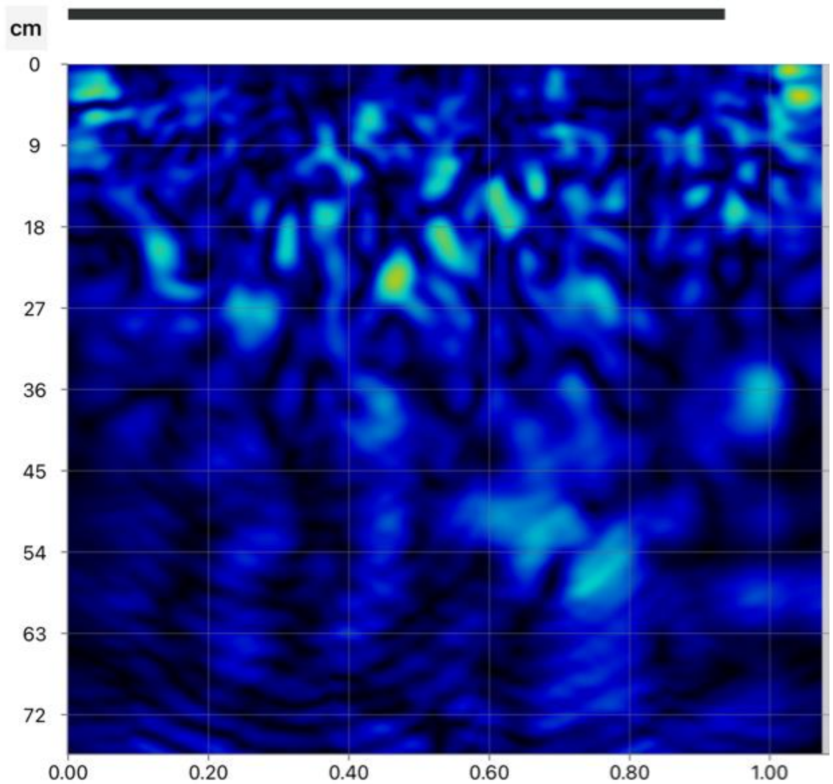
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 5 Abutment vertical scan 001	n/a	n/a	n/a	n/a



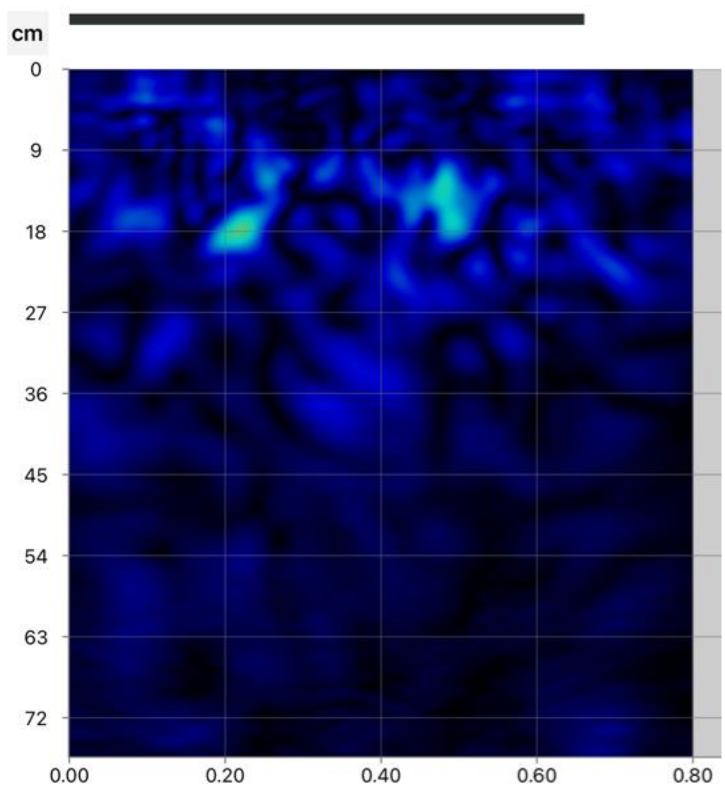
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 5 Abutment horizontal scan 001	n/a	n/a	n/a	n/a



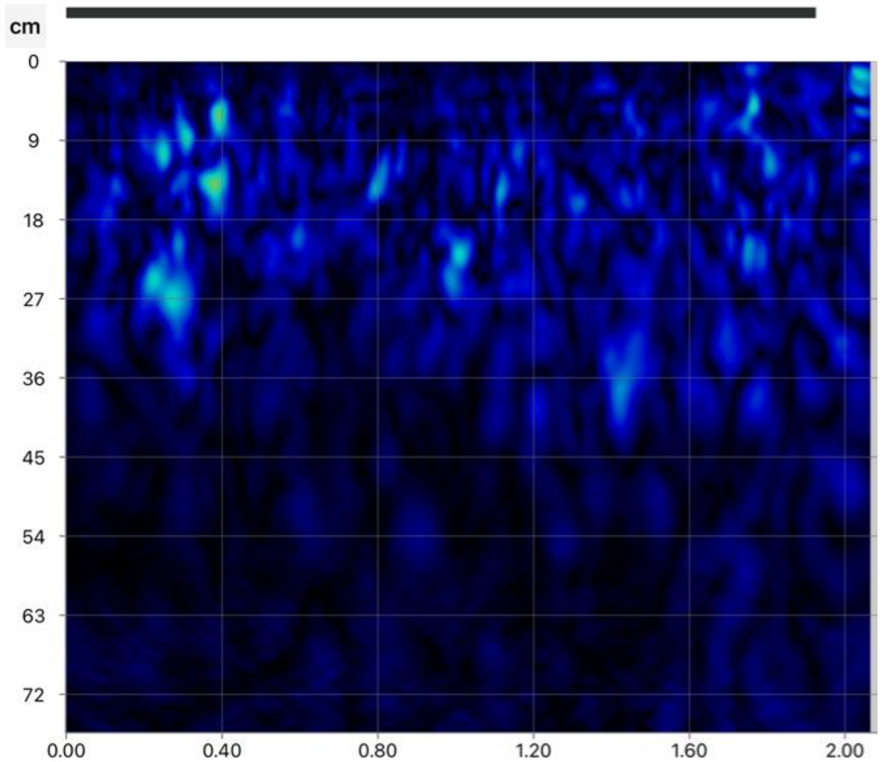
Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 6 Abutment horizontal scan 001	n/a	n/a	n/a	n/a



Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 6 Abutment vertical scan 001	n/a	n/a	n/a	n/a



Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 7 Abutment vertical scan 001	n/a	n/a	n/a	n/a

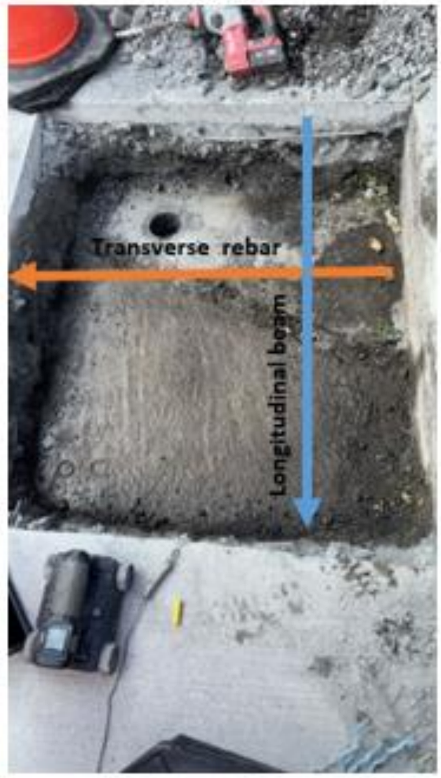


Scan Location	Mean Cover (mm)	Lowest Cover (mm)	Highest Cover (mm)	Mean Spacing (mm)
Area 7 Abutment horizontal scan 001	n/a	n/a	n/a	n/a

Photographs of breakout

Area 1

Area 2



Area 3 breakout

Area 3 – web 129mm cover

Area 3 - Bottom flange 32mm	Area 3 - Bottom of side flange 68mm
	
Area 3 - Top side flange 105mm cover side	**Area 3 - 300mm**
	

Area 3 - Bottom flange 10.89mm

Area 3 - Bottom flange 124mm width

Area 3 - 117mm

Area 4

Area 3.1 uncovered area

Area 3.1 Soffit breakout

Cover bottom flange 34mm

Cover transverse square rebar 59mm

Transverse rebar 28.9mm

Transverse rebar 15.38mm

Spacing transverse 160mm centre

Area 4 Face deck breakout

Area 4 –top side flange cover 104mm

Area 4 - 132mm cover web

Area 4 - Cover 80mm side bottom flange

Area 4 – 37mm bottom flange

Area 4 – bottom flange 8.86

Area 4 - top flange 31.39mm

Area 4.1 soffit breakout

Area 4.1 uncovered area

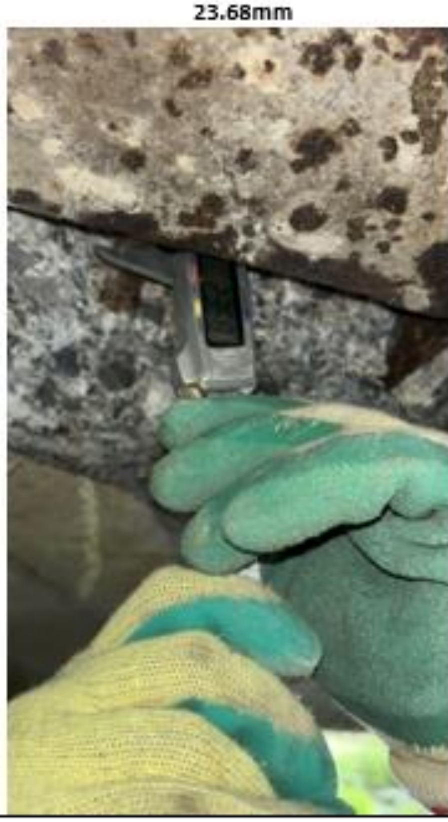
Area 1 Top of deck Breakout

Cover 109mm Transverse square rebar

Transverse square rebar cover 51mm

13,5mm

23.68mm



Area 4.1 bottom flange 47mm cover

Authorised by:

Date Issued: 26th August 2024

James Purcell
Structural Testing Manager
For and on behalf of BHP Laboratories Ltd.

Test results relate only to this item. This test report shall not be duplicated except in full and with the permission of the test laboratory

Appendix E

CHLORIDE CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F063 V1 08/07/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-1-6
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	20/08/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: See below
Test Standard: BS 1881 Part 124

Location Reference	Sample Reference	Depth (mm)	Chloride Content *% by mass of* Sample	
			Sample	Cement
Area 1 - Car 1	24/07/072-1	5-30	0.01	0.08
		30-55	0.01	0.08
		55-80	0.02	0.15
		80-105	0.01	0.08
Area 2 - Car 2	24/07/072-2	5-30	0.04	0.20
		30-55	0.03	0.15
		55-80	0.03	0.15
		80-105	0.01	0.05
Area 3 - Car 3	24/07/072-3	5-30	0.02	0.13
		30-55	0.02	0.13
		55-80	0.02	0.13
		80-105	0.02	0.13
Area 3.1 - Car 4	24/07/072-4	5-30	0.03	0.20
		30-55	0.02	0.13
		55-80	0.03	0.20
		80-105	0.03	0.20
Area 4 - Car 5	24/07/072-5	5-30	0.04	0.19
		30-55	0.02	0.10
		55-80	0.02	0.10
		80-105	0.02	0.10
Area 4.1 - Car 6	24/07/072-6	5-30	0.04	0.33
		30-55	0.03	0.25
		55-80	0.03	0.25
		80-105	0.04	0.33

REMARKS:
The Chloride Content is a Acid Soluble Chloride value.
The Chloride Content as a % by mass of cements as stated in EN 206 is a maxium allowable of 0.4% (containing embedded steel).

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories — Issue Date: 27/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CHLORIDE CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F063 V1 08/07/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-7-12
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	20/08/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: See below
Test Standard: BS 1881 Part 124

Location Reference	Sample Reference	Depth (mm)	Chloride Content *% by mass of*	
			Sample	Cement
Area 5 - Car 7	24/07/072-7	5-30	0.02	0.20
		30-55	0.01	0.10
		55-80	0.01	0.10
		80-105	0.01	0.10
Area 5 - Car 8	24/07/072-8	5-30	0.02	0.25
		30-55	0.01	0.13
		55-80	0.01	0.13
		80-105	0.01	0.13
Area 6 - Car 9	24/07/072-9	5-30	0.01	0.07
		30-55	0.01	0.07
		55-80	0.01	0.07
		80-105	0.01	0.07
Area 6 - Car 10	24/07/072-10	5-30	0.03	0.21
		30-55	0.03	0.21
		55-80	0.03	0.21
		80-105	0.03	0.21
Area 7 - Car 11	24/07/072-11	5-30	0.01	0.08
		30-55	0.01	0.08
		55-80	0.01	0.08
		80-105	0.01	0.08
Area 7 - Car 12	24/07/072-12	5-30	0.03	0.17
		30-55	0.03	0.17
		55-80	0.02	0.11
		80-105	0.02	0.11

REMARKS:
The Chloride Content is a Acid Soluble Chloride value.
The Chloride Content as a % by mass of cements as stated in EN 206 is a maxium allowable of 0.4% (containing embedded steel).

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 27/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

Appendix F

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-1
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 1 - Car 1
Test Standard: BS 1881 Part 124

Sample Weight (g)	**5**
Determined Values	
Insoluble residue (%)	**32.4**
Soluble silica (%)	**2.9**
Calcium oxide (%)	**49**
Calculated Values	
Cement Content (%)	
ex silica	**13.5**
ex lime	**76**
preferred / mean value %	**13.5**
Reported to nearest whole figure (%)	**13**
Aggregate Content (%)	
ex silica	**83.4**
ex lime	**6.6**
preferred / mean value	**83.4**
Aggregate / Cement Ratio	
ex silica	**6.2**
ex lime	**0.1**
preferred / mean value	**6.2**

REMARKS:
The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories   Issue Date: 21/08/2024

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-2
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 2 - Car 2
Test Standard: BS 1881 Part 124

Sample Weight (g)	**9**
Determined Values	
Insoluble residue (%)	**15.2**
Soluble silica (%)	**4.2**
Calcium oxide (%)	**43.4**
Calculated Values	
Cement Content (%)	
ex silica	**19.9**
ex lime	**67.3**
preferred / mean value %	**19.9**
Reported to nearest whole figure (%)	**20**
Aggregate Content (%)	
ex silica	**75.5**
ex lime	**17.3**
preferred / mean value	**75.5**
Aggregate / Cement Ratio	
ex silica	**3.8**
ex lime	**0.3**
preferred / mean value	**3.8**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client: TRIUR Construction Ltd
13 Society Street
Ballinasloe
Galway
FAO: Lurcan Donnellan

BHP Ref. No.: 24/07/072-4
Order No: Not Supplied
Date Tested: 20/08/2024
Test Specification: Customer Spec.
Test Element: Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 3.1 - Car 4
Test Standard: BS 1881 Part 124

Sample Weight (g)	**12**
Determined Values	
Insoluble residue (%)	**20.7**
Soluble silica (%)	**3.3**
Calcium oxide (%)	**40.6**
Calculated Values	
Cement Content (%)	
ex silica	**15.4**
ex lime	**63**
preferred / mean value %	**15.4**
Reported to nearest whole figure (%)	**15**
Aggregate Content (%)	
ex silica	**81**
ex lime	**22.6**
preferred / mean value	**81**
Aggregate / Cement Ratio	
ex silica	**5.2**
ex lime	**0.4**
preferred / mean value	**5.2**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:
Silica content of cement (CEM I) 20.2%
Soluble silica content of aggregate 0.5%
Calcium oxide content of cement (CEM I) 64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-5
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 4 - Car 5
Test Standard: BS 1881 Part 124

Sample Weight (g)	**17**
Determined Values	
Insoluble residue (%)	**10.3**
Soluble silica (%)	**4.4**
Calcium oxide (%)	**46.2**
Calculated Values	
Cement Content (%)	
ex silica	**21**
ex lime	**71.6**
preferred / mean value %	**21**
Reported to nearest whole figure (%)	**21**
Aggregate Content (%)	
ex silica	**74.1**
ex lime	**12**
preferred / mean value	**74.1**
Aggregate / Cement Ratio	
ex silica	**3.5**
ex lime	**0.2**
preferred / mean value	**3.5**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-6
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 4.1 - Car 6
Test Standard: BS 1881 Part 124

Sample Weight (g)	**10**
Determined Values	
Insoluble residue (%)	**9.4**
Soluble silica (%)	**2.7**
Calcium oxide (%)	**46.7**
Calculated Values	
Cement Content (%)	
ex silica	**12.4**
ex lime	**72.4**
preferred / mean value %	**12.4**
Reported to nearest whole figure (%)	**12**
Aggregate Content (%)	
ex silica	**84.7**
ex lime	**11**
preferred / mean value	**84.7**
Aggregate / Cement Ratio	
ex silica	**6.8**
ex lime	**0.2**
preferred / mean value	**6.8**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories — Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-7
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 5 - Car 7
Test Standard: BS 1881 Part 124

Sample Weight (g)	**12**
Determined Values	
Insoluble residue (%)	**18.4**
Soluble silica (%)	**2.1**
Calcium oxide (%)	**43.1**
Calculated Values	
Cement Content (%)	
ex silica	**9.6**
ex lime	**66.9**
preferred / mean value %	**9.6**
Reported to nearest whole figure (%)	**10**
Aggregate Content (%)	
ex silica	**88.2**
ex lime	**17.7**
preferred / mean value	**88.2**
Aggregate / Cement Ratio	
ex silica	**9.2**
ex lime	**0.3**
preferred / mean value	**9.2**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories — Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-8
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 5 - Car 8
Test Standard: BS 1881 Part 124

Sample Weight (g)	**4**
Determined Values	
Insoluble residue (%)	**25.4**
Soluble silica (%)	**1.8**
Calcium oxide (%)	**37.9**
Calculated Values	
Cement Content (%)	
ex silica	**8**
ex lime	**58.8**
preferred / mean value %	**8**
Reported to nearest whole figure (%)	**8**
Aggregate Content (%)	
ex silica	**90.2**
ex lime	**27.7**
preferred / mean value	**90.2**
Aggregate / Cement Ratio	
ex silica	**11.3**
ex lime	**0.5**
preferred / mean value	**11.3**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-9
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 6 - Car 9
Test Standard: BS 1881 Part 124

Sample Weight (g)	**10**
Determined Values	
Insoluble residue (%)	**35.2**
Soluble silica (%)	**2.9**
Calcium oxide (%)	**33**
Calculated Values	
Cement Content (%)	
ex silica	**13.6**
ex lime	**51.2**
preferred / mean value %	**13.6**
Reported to nearest whole figure (%)	**14**
Aggregate Content (%)	
ex silica	**83.3**
ex lime	**37**
preferred / mean value	**83.3**
Aggregate / Cement Ratio	
ex silica	**6.1**
ex lime	**0.7**
preferred / mean value	**6.1**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	Lukasz Zalewski

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-10
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 6 - Car 10
Test Standard: BS 1881 Part 124

Sample Weight (g)	**10**
Determined Values	
Insoluble residue (%)	**15.7**
Soluble silica (%)	**3**
Calcium oxide (%)	**42.1**
Calculated Values	
Cement Content (%)	
ex silica	**14**
ex lime	**65.3**
preferred / mean value %	**14**
Reported to nearest whole figure (%)	**14**
Aggregate Content (%)	
ex silica	**82.7**
ex lime	**19.7**
preferred / mean value	**82.7**
Aggregate / Cement Ratio	
ex silica	**5.9**
ex lime	**0.3**
preferred / mean value	**5.9**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:

Silica content of cement (CEM I)	20.2%
Soluble silica content of aggregate	0.5%
Calcium oxide content of cement (CEM I)	64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-11
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 7 - Car 11
Test Standard: BS 1881 Part 124

Sample Weight (g)	**9**
Determined Values	
Insoluble residue (%)	**19**
Soluble silica (%)	**2.5**
Calcium oxide (%)	**41.9**
Calculated Values	
Cement Content (%)	
ex silica	**11.7**
ex lime	**64.9**
preferred / mean value %	**11.7**
Reported to nearest whole figure (%)	**12**
Aggregate Content (%)	
ex silica	**85.6**
ex lime	**20.2**
preferred / mean value	**85.6**
Aggregate / Cement Ratio	
ex silica	**7.3**
ex lime	**0.3**
preferred / mean value	**7.3**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:
Silica content of cement (CEM I) 20.2%
Soluble silica content of aggregate 0.5%
Calcium oxide content of cement (CEM I) 64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	[signature]

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CEMENT CONTENT OF CONCRETE
TEST REPORT

BHP/MTIField/F056 V1 20/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-12
		Order No:	Not Supplied
		Date Tested:	20/08/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Dust

Project: Mayo Bridges Investigation - Strade River Bridge
Location Reference: Area 7 - Car 12
Test Standard: BS 1881 Part 124

Sample Weight (g)	**9**
Determined Values	
Insoluble residue (%)	**20.6**
Soluble silica (%)	**3.9**
Calcium oxide (%)	**39.4**
Calculated Values	
Cement Content (%)	
ex silica	**18.4**
ex lime	**61**
preferred / mean value %	**18.4**
Reported to nearest whole figure (%)	**18**
Aggregate Content (%)	
ex silica	**77.4**
ex lime	**25**
preferred / mean value	**77.4**
Aggregate / Cement Ratio	
ex silica	**4.2**
ex lime	**0.4**
preferred / mean value	**4.2**

REMARKS:

The cement contents were determined in accordance with B.S. 1881:Part 124:2015+A1:2021. The silica content was determined using inductively coupled plasma optical emission spectroscopy.
Assumptions used for the cement and aggregate content calculations:
Silica content of cement (CEM I) 20.2%
Soluble silica content of aggregate 0.5%
Calcium oxide content of cement (CEM I) 64.5%

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories

Issue Date: 21/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

Appendix G

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING
TEST REPORT

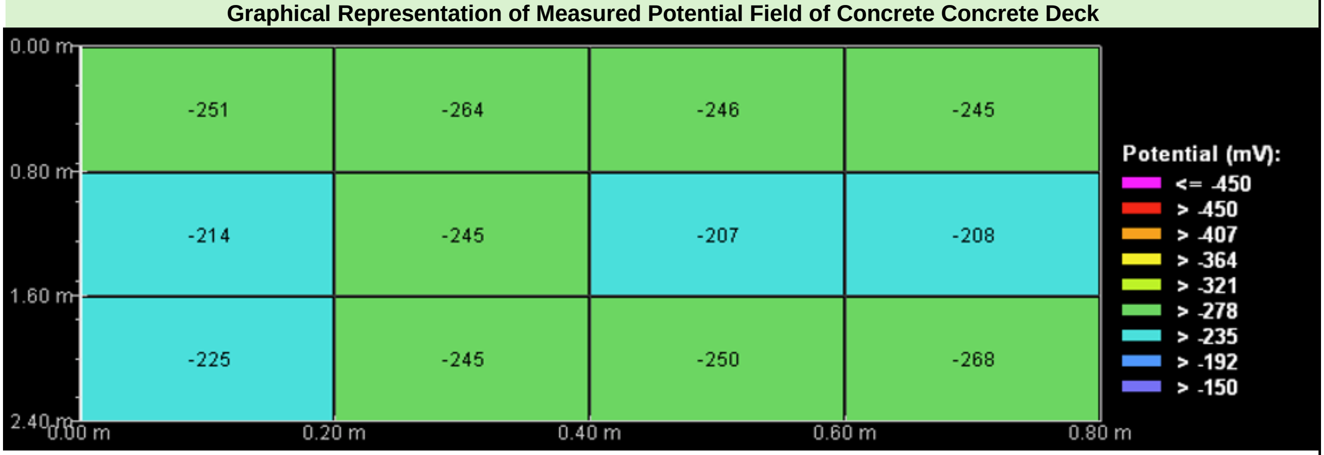
BHP/MTIField/F057 V1 21/05/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-1
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	12/07/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Deck

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 1 C1 Deck
Test Standard: ASTM C876

Test No.	1
No. of Readings	12
Median (mV)	-245
Mean (mV)	-239
Standard Deviation	19.8
Lowest (mV)	-268
Highest (mV)	-207
Reinforcement Condition	Intermediate Risk of Corrosion

Graphical Representation of Measured Potential Field of Concrete Concrete Deck



REMARKS:
This test was performed using a Copper-Copper Sulphate Electrode.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories   Issue Date: 14/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING
TEST REPORT

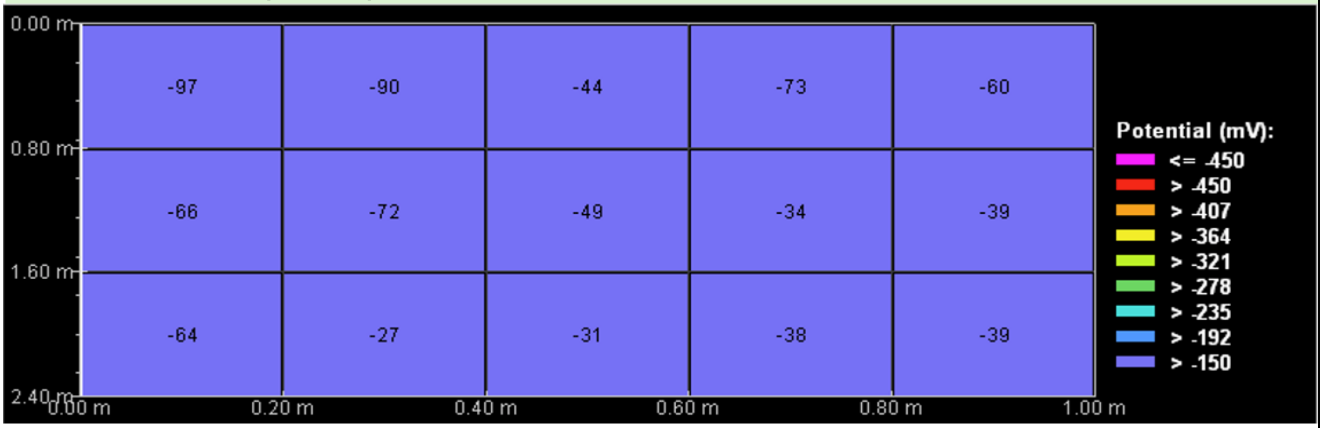
BHP/MTIField/F057 V1 21/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-2
		Order No:	Not Supplied
		Date Tested:	12/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Deck

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 3 Face Deck
Test Standard: ASTM C876

Test No.	2
No. of Readings	15
Median (mV)	-49
Mean (mV)	-54.9
Standard Deviation	21
Lowest (mV)	-97
Highest (mV)	-27
Reinforcement Condition	Low risk of Corrosion

Graphical Representation of Measured Potential Field of Concrete Concrete Deck



REMARKS:
This test was performed using a Copper-Copper Sulphate Electrode.

Approved By:	Signature:
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 14/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING
TEST REPORT

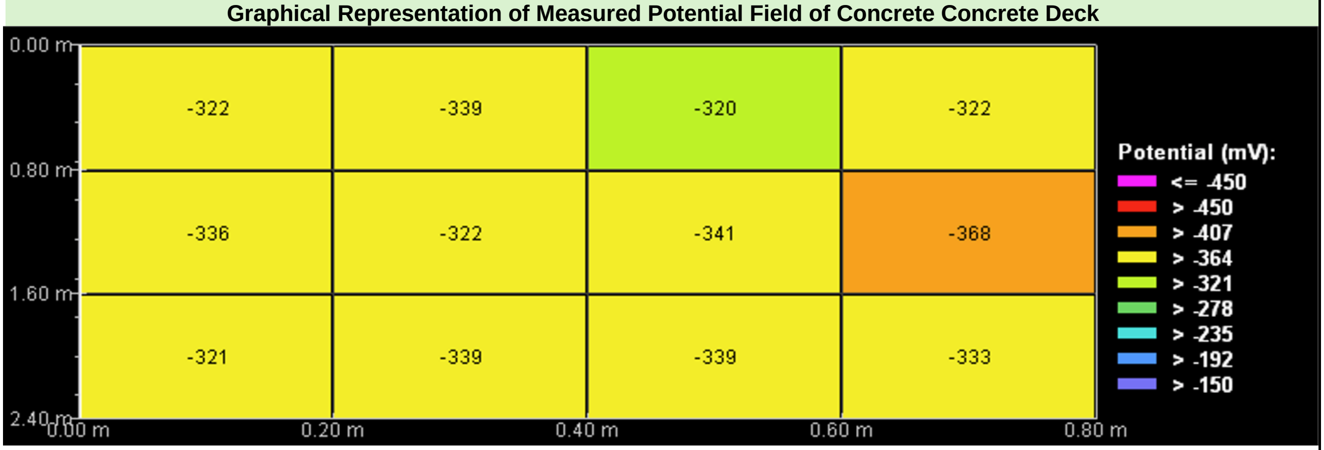
BHP/MTIField/F057 V1 21/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-3
		Order No:	Not Supplied
		Date Tested:	12/07/2024
		Test Specification:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Deck

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 3.1 Soffit
Test Standard: ASTM C876

Test No.	3
No. of Readings	12
Median (mV)	-335
Mean (mV)	-333.5
Standard Deviation	13.2
Lowest (mV)	-368
Highest (mV)	-320
Reinforcement Condition	Intermediate Risk of Corrosion

Graphical Representation of Measured Potential Field of Concrete Concrete Deck



REMARKS:
This test was performed using a Copper-Copper Sulphate Electrode.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 14/08/2024

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CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING
TEST REPORT

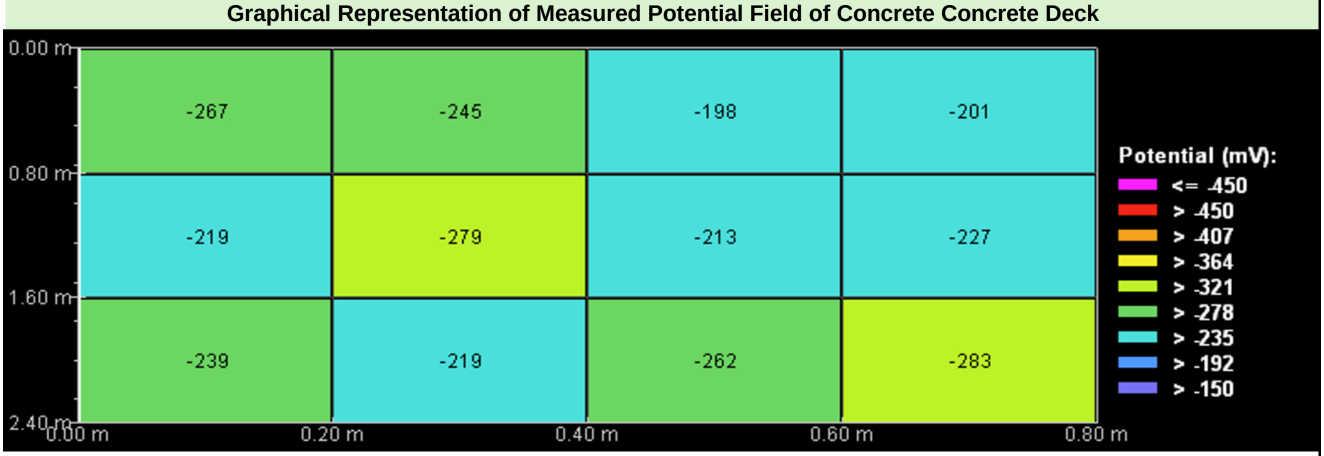
BHP/MTIField/F057 V1 21/05/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**: **Order No**: **Date Tested**: **Test Specification**:	24/07/072-4 Not Supplied 12/07/2024 Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Deck

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 4 Face Deck
Test Standard: ASTM C876

Test No.	4
No. of Readings	12
Median (mV)	-233
Mean (mV)	-237.7
Standard Deviation	28.3
Lowest (mV)	-283
Highest (mV)	-198
Reinforcement Condition	Intermediate Risk of Corrosion

Graphical Representation of Measured Potential Field of Concrete Concrete Deck



REMARKS:
This test was performed using a Copper-Copper Sulphate Electrode.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 14/08/2024

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CORROSION POTENTIAL ASSESSMENT OF STEEL REINFORCEMENT BY HALF CELL TESTING
TEST REPORT

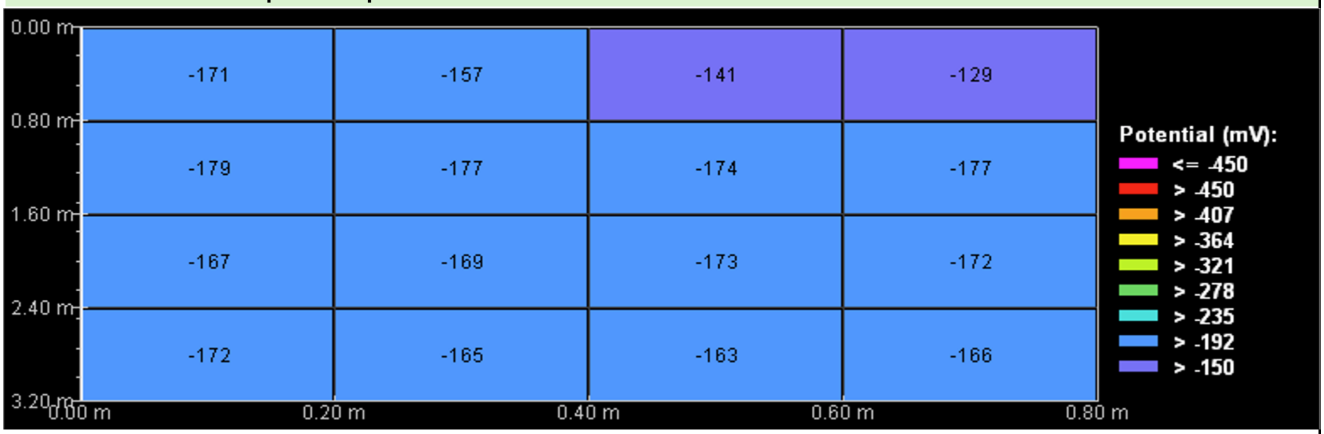
BHP/MTIField/F057 V1 21/05/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-5
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	12/07/2024
	Galway	**Test Specification**:	Customer Spec.
FAO:	Lurcan Donnellan	**Test Element:**	Concrete Deck

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 4.1 Soffit
Test Standard: ASTM C876

Test No.	5
No. of Readings	16
Median (mV)	-170
Mean (mV)	-165.8
Standard Deviation	13
Lowest (mV)	-179
Highest (mV)	-129
Reinforcement Condition	Low risk of Corrosion

Graphical Representation of Measured Potential Field of Concrete Concrete Deck



REMARKS:
This test was performed using a Copper-Copper Sulphate Electrode.

Approved By:	**Signature:**
Lukasz Zalewski *Field Service Manager*	

For and On Behalf of BHP Laboratories — Issue Date: 14/08/2024

DETERMINATION OF RESISTIVITY OF CONCRETE

BHP/MTIField/F048 V1 30/04/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-1
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	09/07/2024
	Galway	**Test Specification**:	Client Spec.
FAO:	Lurcan Donnellan	**Material**	Concrete Element

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 1 Top Deck
Test Standard: EN 12390-19 2021

RESULTS	
Structural Element	Deck
Measurement Mode	Surface
Contact Spacing	50mm
Specimen Shape	Flat
Dimensions of Test Area (mm)	400x400
Minimum Measurement (kΩcm)	106
Maximum Measurement (kΩcm)	190
Mean Value (kΩcm)	153
Interpreatation of Result	Negligible risk of corrosion

Resistivity Measurements (kΩcm)

106	**112**	**172**	**185**	**190**
0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**

REMARKS:
Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.
A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Equipment used was a Proceq Resipod

Approved By:	**Signature:**
Lukasz Zalewski Field Service Manager	Lukasz Zalewski

For and On Behalf of BHP Laboratories — Issue Date: 28/08/2024

Tested by BHP Laboratories, New Road, Thomondgate, Limerick. Phone: (061) 455399 Email: jamespurcell@bhp.ie

DETERMINATION OF RESISTIVITY OF CONCRETE

BHP/MTIField/F048 V1 30/04/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-3
		Order No:	Not Supplied
		Date Tested:	09/07/2024
		Test Specification:	Client Spec.
FAO:	Lurcan Donnellan	**Material**	Concrete Element

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 3 Face dek
Test Standard: EN 12390-19 2021

RESULTS	
Structural Element	Soffit
Measurement Mode	Surface
Contact Spacing	50mm
Specimen Shape	Flat
Dimensions of Test Area (mm)	200x200
Minimum Measurement (kΩcm)	55
Maximum Measurement (kΩcm)	72
Mean Value (kΩcm)	65
Interpreatation of Result	Negligible risk of corrosion

Resistivity Measurements (kΩcm)

69	**55**	**72**	**0**	**0**
0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**

REMARKS:
Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.
A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Equipment used was a Proceq Resipod

Approved By:	Signature:
Lukasz Zalewski Field Service Manager	Lukasz Zalewski

For and On Behalf of BHP Laboratories Issue Date: 28/08/2024

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DETERMINATION OF RESISTIVITY OF CONCRETE

BHP/MTIField/F048 V1 30/04/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-4
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	09/07/2024
	Galway	**Test Specification**:	Client Spec.
FAO:	Lurcan Donnellan	**Material**	Concrete Element

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 3.1 Soffit
Test Standard: EN 12390-19 2021

RESULTS				
Structural Element	Soffit			
Measurement Mode	Surface			
Contact Spacing	50mm			
Specimen Shape	Flat			
Dimensions of Test Area (mm)	400x400			
Minimum Measurement (kΩcm)	256			
Maximum Measurement (kΩcm)	303			
Mean Value (kΩcm)	279			
Interpreatation of Result	Negligible risk of corrosion			
Resistivity Measurements (kΩcm)				
285	**278**	**303**	**256**	**272**
0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**

REMARKS:
Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.
A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Equipment used was a Proceq Resipod

Approved By:	**Signature:**
Lukasz Zalewski Field Service Manager	Lukasz Zalewski

For and On Behalf of BHP Laboratories — Issue Date: 28/08/2024

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DETERMINATION OF RESISTIVITY OF CONCRETE

BHP/MTIField/F048 V1 30/04/24

Client:	TRIUR Construction Ltd 13 Society Street Ballinasloe Galway	**BHP Ref. No.**:	24/07/072-5
		Order No:	Not Supplied
		Date Tested:	09/07/2024
		Test Specification:	Client Spec.
FAO:	Lurcan Donnellan	**Material**	Concrete Element

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 4
Test Standard: EN 12390-19 2021

RESULTS	
Structural Element	Face Deck
Measurement Mode	Surface
Contact Spacing	50mm
Specimen Shape	Flat
Dimensions of Test Area (mm)	200x200
Minimum Measurement (kΩcm)	156
Maximum Measurement (kΩcm)	194
Mean Value (kΩcm)	179
Interpreatation of Result	Negligible risk of corrosion

Resistivity Measurements (kΩcm)

186	**156**	**194**	**0**	**0**
0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**

REMARKS:
Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.
A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Equipment used was a Proceq Resipod

Approved By:	**Signature:**
Lukasz Zalewski Field Service Manager	

For and On Behalf of BHP Laboratories — Issue Date: 28/08/2024

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DETERMINATION OF RESISTIVITY OF CONCRETE

BHP/MTIField/F048 V1 30/04/24

Client:	TRIUR Construction Ltd	**BHP Ref. No.**:	24/07/072-6
	13 Society Street	**Order No**:	Not Supplied
	Ballinasloe	**Date Tested**:	09/07/2024
	Galway	**Test Specification**:	Client Spec.
FAO:	Lurcan Donnellan	**Material**	Concrete Element

Project: Mayo Bridges - Strade River Bridge
Location Reference: Area 4.1
Test Standard: EN 12390-19 2021

RESULTS	
Structural Element	Face Deck
Measurement Mode	Surface
Contact Spacing	50mm
Specimen Shape	Flat
Dimensions of Test Area (mm)	400x400
Minimum Measurement (kΩcm)	196
Maximum Measurement (kΩcm)	272
Mean Value (kΩcm)	228
Interpreatation of Result	Negligible risk of corrosion

Resistivity Measurements (kΩcm)

196	**206**	**209**	**255**	**272**
0	**0**	**0**	**0**	**0**
0	**0**	**0**	**0**	**0**

REMARKS:

Resistivity measurements can be used to estimate the likelihood of corrosion. When the electrical resistivity of the concrete is low, the likelihood of corrosion increases. When the electrical resistivity is high, the likelihood of corrosion decreases.

A guide to interpretation of resistivity results is:

When ≥ 100 kΩcm	Negligible risk of corrosion
When 50 to 100 kΩcm	Low risk of corrosion
When 10 to 50 kΩcm	Moderate risk of corrosion
When ≤ 10 kΩcm	High risk of corrosion

Equipment used was a Proceq Resipod

Approved By:	**Signature:**
Lukasz Zalewski Field Service Manager	Lukasz Zalewski

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