1.0 INTRODUCTION:

Tongland Bridge, a distinguished 'Category A' listed structure, stands as a testament to engineering brilliance with its 34m span circular segmented arch and three 2.7m gothic arch approach spans on either end. Crafted from the enduring rough-faced grey sandstone of Arran, this architectural marvel was conceptualized by the renowned Thomas Telford and brought to life between 1805 and 1808.

To address structural challenges, the design incorporated hollow spandrels, a strategic choice to counteract outward pressure from internal fill, alleviate foundation stress, and simplify inspection procedures. Notably, the original constructed bridge featured four longitudinally running cavities, providing ample space for thorough examination.

In the passage of time, the bridge faced the inevitable wear and tear, particularly in 1927 when the 9" thick stone flags, supported by internal spandrels, were discovered broken. Responding to this deterioration, a transformative replacement took place, introducing precast concrete flags and a 6" reinforced slab to distribute the load effectively.

The evolution continued in 1990, as the central spans underwent a substantial upgrade. The original stone flags and slabs were replaced with a robust 225mm thick in-situ reinforced concrete slab, complemented by a 125mm thick precast RC slab serving as permanent formwork.

Figure 1 : Photograph (ca. 1880) Tongland Bridge

Figure 2 Recent photo showing elevation of Tongland bridge

2.0 **CONDITION ASSESSMENT**:

The recent inspection revealed concerning structural issues in the second pier from the south end, with the bottom 2 meters displaying signs of bursting over two-thirds of its length. A similar, though less severe, deterioration was observed in the second pier from the north end, primarily concentrated in the intertidal zone in both piers. Furthermore, the 2017 Geotechnical Investigation (GI) documented open joints and slight separation near the external faces of the spandrels in some of the approach gothic arches.

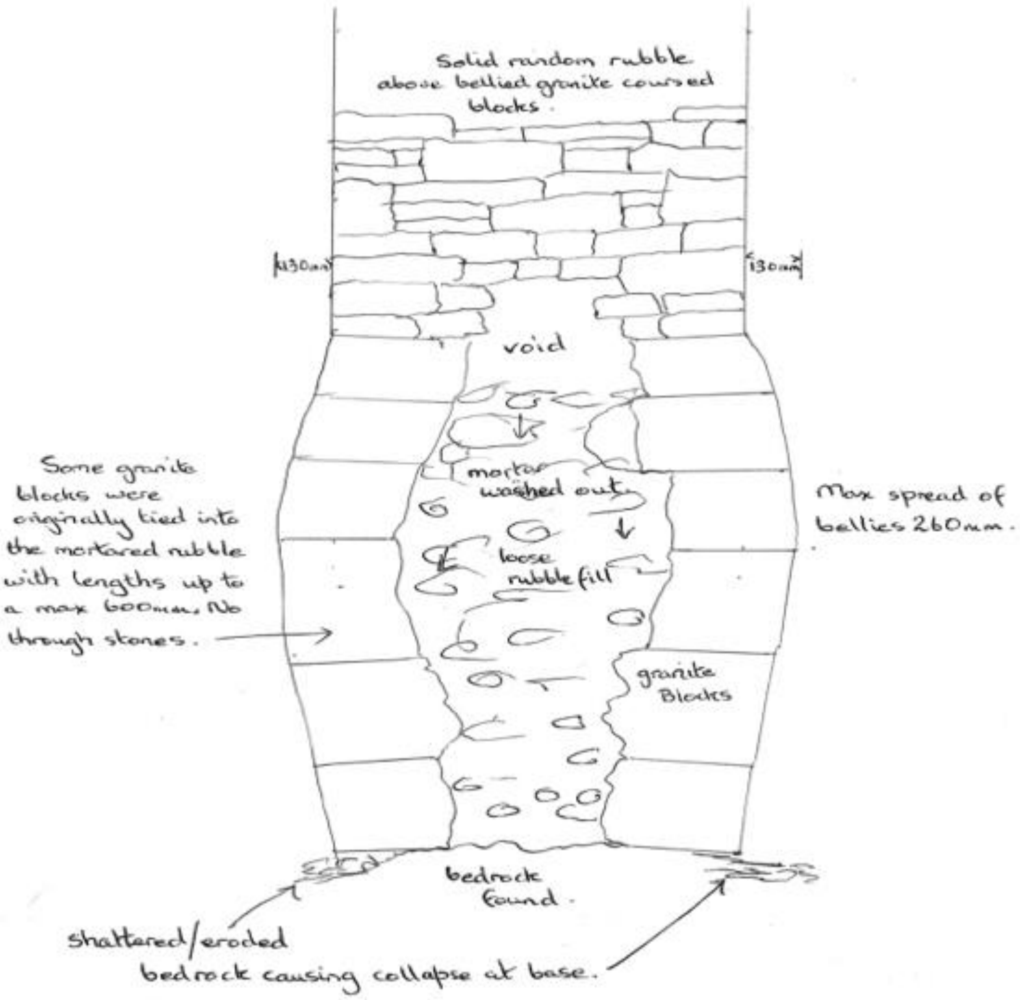
These findings underscore the pressing need for a thorough assessment and timely intervention to address the structural vulnerabilities and ensure the long-term integrity of the infrastructure.

Figure 3 : Photo showing Elevation of second pier from South end (featuring bulging of Pier and cracks)

3.0 **<u>COMPREHENSIVE INVESTIGATION:</u> Causes for the Deterioration of the Piers**

1) <u>Mortar washing within inside loose rubble of the Pier by tidal water of the river</u> :

The water level of 'River Dee' undergoes bi-daily fluctuations, and over time, the binding mortar of inside rubble mortar fill has eroded, as depicted in the accompanying photo and sketch. This erosion has resulted in the transfer of the load from the superstructure and the self-weight of the pier to concentrate on the outer skin of the ashlar masonry wall. Consequently, the intended support from the entire cross-sectional area of the pier (1.1 m width x 7.4 m length) to superstructure is compromised, and currently, only the outer skin of ashlar stone masonry units, with a width of 0.2m at the periphery in the lower half of the pier, remains effective. This localized support is causing an undue concentration of compressive stress on the outer skin, potentially leading to the development of cracks in the stone blocks and bulging of the pier. Addressing this structural concern is imperative to ensure the pier's stability and prevent further deterioration.



<u>Figure 4</u> : Sketch showing cross-section of the Pier

Figure 5: Photo Showing internal rubble fill when outer skin of Pier was removed during investigation

2) Existing pier built on sloping river embankment of weathered rock :

The structural integrity of the main arch piers is under scrutiny as the approach piers situated at both ends reveal a concerning issue. Built on an inclined rocky river embankment, the levelling rock beneath the pier footing has weathered in several areas, laying bare the foundation, as evident in the accompanying photos. This exposure has given rise to nonlinear stresses within the piers and their foundations. The compromised foundation likely contributes to the exacerbation of the piers' deteriorating condition, leading to the development of additional cracks in the unsupported sections of the structure. Addressing this foundational vulnerability is paramount to mitigating further structural damage and ensuring the long-term stability of the arch.

Figure 6 : Photo of Pier base springing from inclined face of weathered rocky river embankment

3) Filling of openings (above arch shaped piers) causing increased loading :

The original design of the bridge incorporated a strategic approach to minimize self-weight and distribute loads effectively. The section above the main arches featured voids, supported by intermediate spandrel walls and slabs, as illustrated in the artistic impression provided in the extract below. This design not only aimed to reduce the overall weight of the bridge but also facilitated internal access for inspection and maintenance purposes. However, it has come to light that these voids have been filled, and a RC slab has been casted in mid-20's. This deviation from the original design likely led to an increased load on the piers and their foundations. Consequently, the added pressure has manifested in bulging and the formation of cracks in the stone masonry units of the piers. Understanding and rectifying this deviation is crucial to restoring the structural balance and integrity of the bridge.

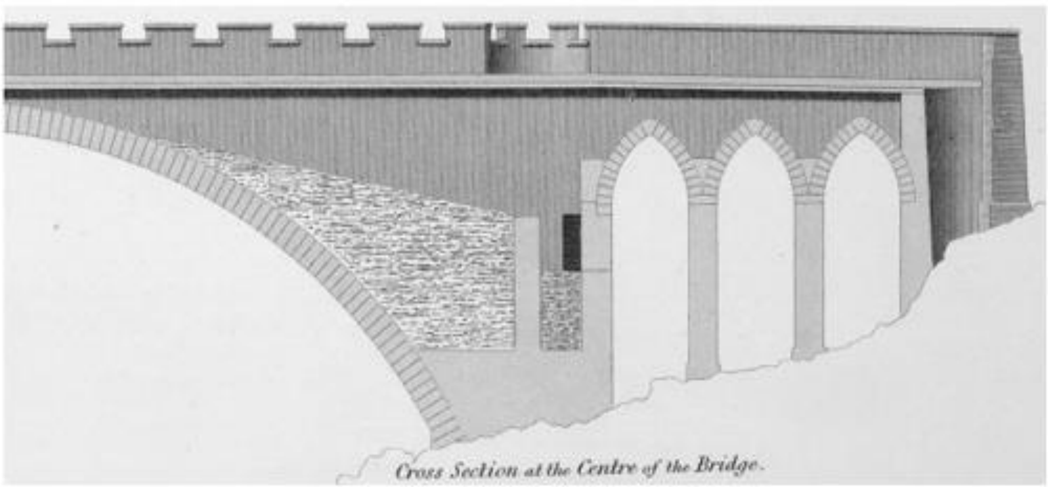


Figure 7 : Sketch showing Part sectional elevation of the bridge from archive drawing

The alteration in mid-20's, particularly the filling of voids and the addition of reinforced concrete slab, is suspected to be introducing an imbalance in horizontal forces. Unequal fill around the 'Intermediate Pier' seems to be generating an additional overturning moment, with the maximum impact observed at the 'Pier base.' This unbalanced force diminishes gradually as it ascends towards the crown level. Understanding and addressing this unequal distribution of forces is essential to rectify the potential structural vulnerabilities and ensure the stability of the bridge in long run.

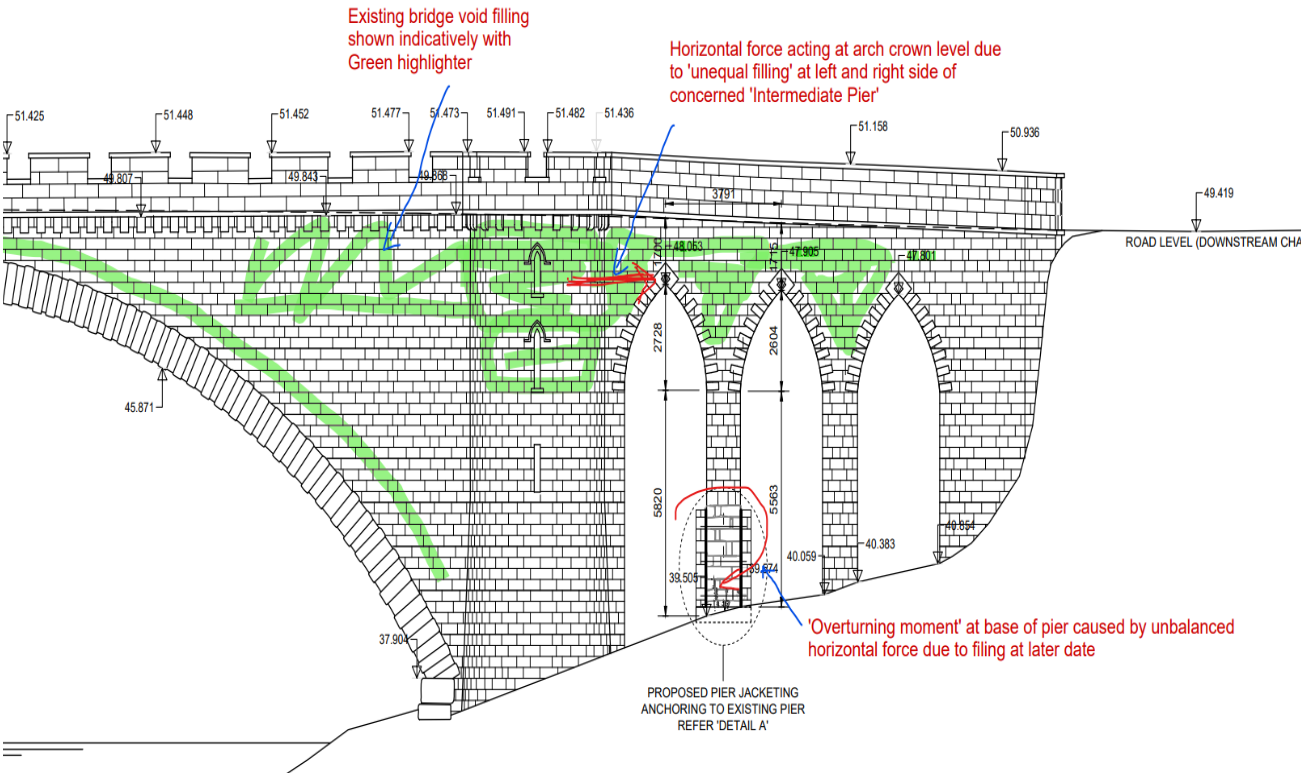


Figure 8 : Sketch showing Part sectional elevation and unbalanced horizontal force due to concrete infill added in mid-20's

4.0 **PROPOSED REPAIR OF INTERMEDIATE PIERS** :

Tie bar + Pier jacketing + Grouting :

Our current proposal involves, grouting voids/ cracks in existing piers, anchoring without a Pattress plate and erecting a pier jacketing wall around the existing pier. This strategy serves as an interim measure to halt any further deterioration of the pier. For a visual reference, please refer to the General Arrangement (GA) drawing (DRG. *: A711_110_KS_10*). This interim solution is intended to provide stability and prevent further damage while more comprehensive measures are being planned and executed.

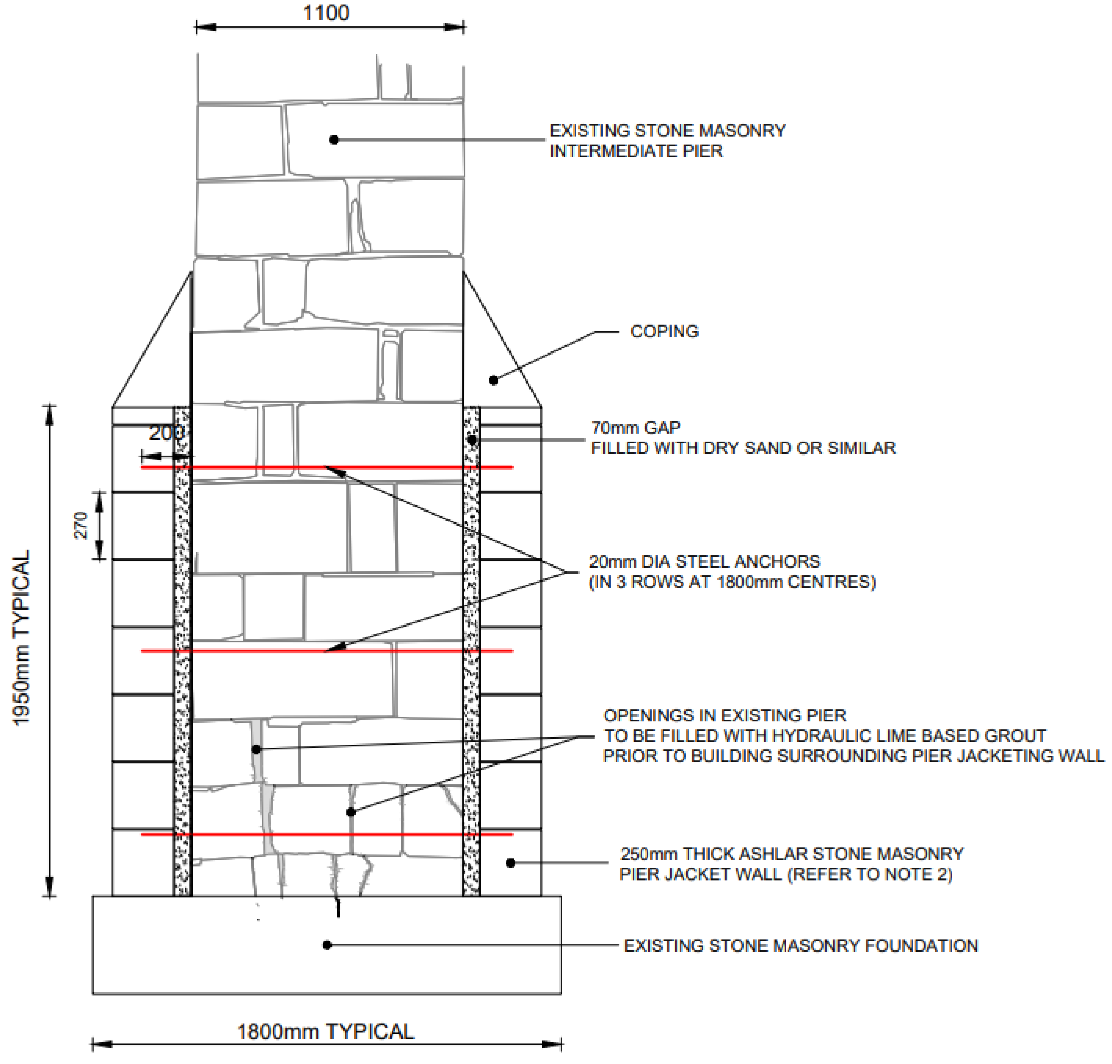


Figure 9 : Sketch showing existing Pier cross-section and Pier jacketing wall with ties

This scheme has following advantages:

The proposed measures encompass a comprehensive approach to address the current structural challenges of the pier:

1. Anchoring is designed to bind the bulging pier, while grouting will play a crucial role in filling voids within the pier. The investigation revealed that tidal river water has eroded the original binding mortar within the loose rubble stone fill, emphasizing the need for internal restoration.
2. The installation of a pier jacketing wall serves as a protective barrier against direct exposure to tidal water, mitigating further deterioration.
3. Post-anchoring, the grouting process becomes instrumental in transforming the pier into a cohesive unit, restoring its original design by addressing gaps and voids.

A proactive step involves sending stone samples from the existing pier for 'Petrographic testing' in the laboratory. This ensures an exact match for the stone of the existing piers when constructing the pier jacketing wall, preserving the bridge's aesthetics.

5.0 **FURTHER DISCUSSION**

a) **Specification of Lime based mortar**:

For the proposed 'Stone masonry Pier Jacketing wall,' a hydraulic lime-based mortar will be employed. Additionally, any openings and voids in the current pier jacketing wall will be meticulously filled with lime-based grout to preserve the original flexibility of the initially constructed pier.

b) **Texture, bonding pattern and dressing of stone masonry units of 'Pier Jacketing wall'** :

The historical documentation reveals that the outer skin of the bridge is crafted from 'rough-faced grey sandstone from Arran.' In an effort to maintain authenticity, a stone sample has been dispatched to the 'Scottish Lime Centre' for a 'Petrographic test' to identify an exact match from nearby quarries. The report received from the laboratory is attached.
According to the 'Petrographic test' results, the 'Birchover stone' sourced from a nearby quarry in Derbyshire seems to be the closest match to the existing stonework of the bridge.

The current observation indicates variations in the existing coursework and texture of the ashlar masonry, particularly along the longer direction of the 'Intermediate Piers' with differences in the length, height, and texture of individual stone units. This could be attributed to this section of the bridge being obscured from direct view. For visual reference, please refer Figures 10 and 11.

<u>Figure 10</u>: Photo showing layout of existing ashlar Stone masonry Intermediate (South) Pier

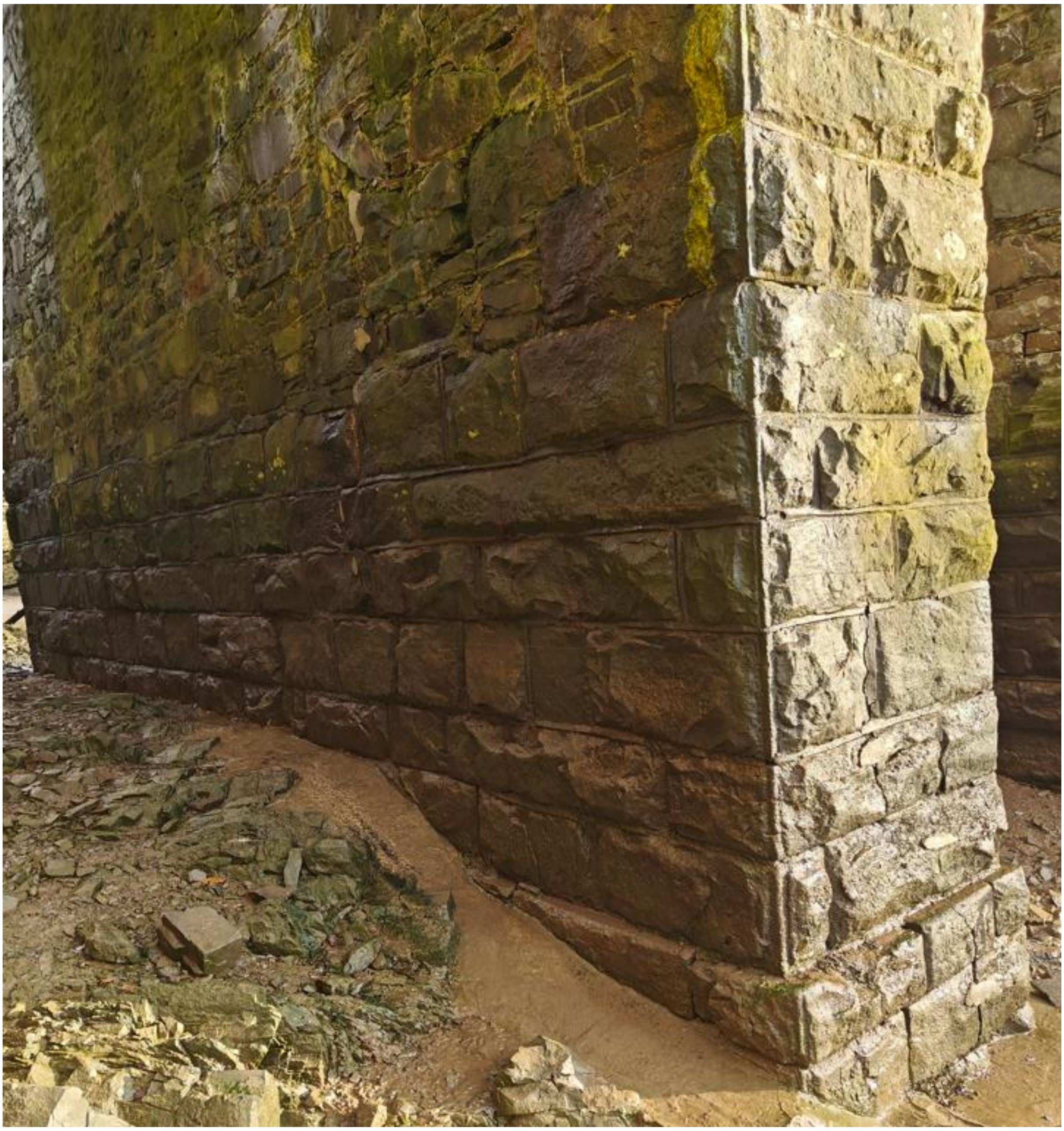


Figure 11: Photo showing layout of existing ashlar Stone masonry Intermediate (North) Pier

Given the varying nature of the coursework, our proposal suggests employing a coursework pattern resembling 'Flemish bond' showcased in 'Figure 12' along the longer surface of the 'Pier Jacketing wall' for South and North Intermediate Piers.

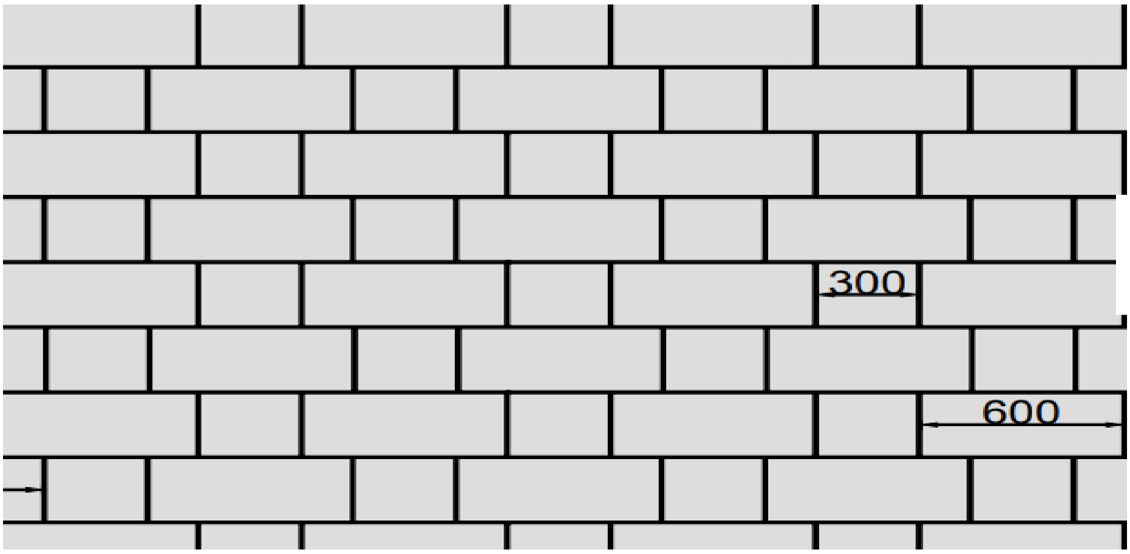


Figure 12: Sketch showing 'Flemish bond' pattern along longer surface of new Pier Jacketing Wall

The proposed typical facework along the longer direction of the new 'Pier Jacketing' wall features an alternating arrangement of 600mm and 300mm length stonework as can be seen in 'Figure 12'.

The typical sizes for rectangular shaped stone masonry units are as follows:

a) 600mm in length x 250mm in width x 270mm in height

b) 300mm in length x 250mm in width x 270mm in height

Typical triangular shaped stone masonry 'Coping' units will be provided in the following sizes:

a) 600mm in length x 250mm in width x 555mm in height

b) 300mm in length x 250mm in width x 555mm in height

Conversely, in shorter direction of existing Pier has different arrangement of 'Stone pattern'. See Figure 13 for reference. This pattern is closer to 'Running bond' pattern and similar arrangement is proposed for the new 'Pier Jacketing wall' Refer to 'Figure 14' for the detail .

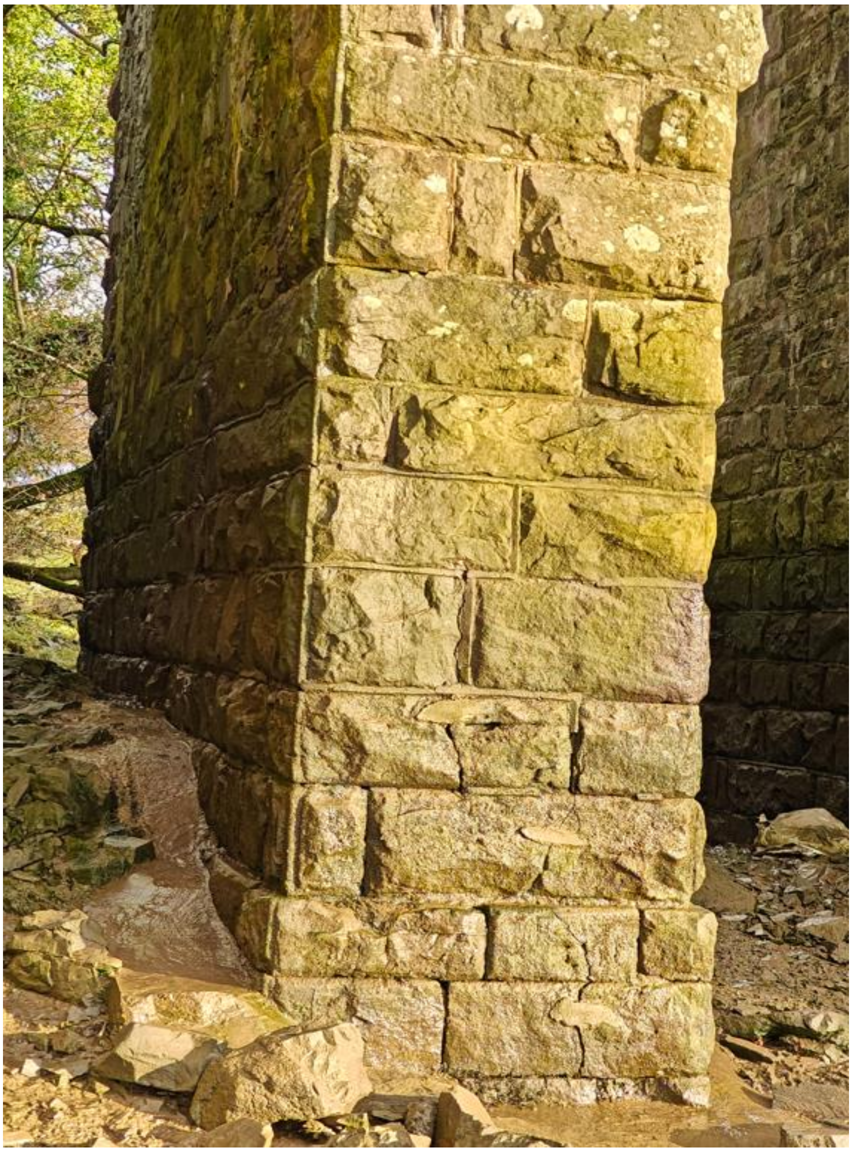


Figure 13: Elevation showing coursework of existing (North) Intermediate pier at shorter face

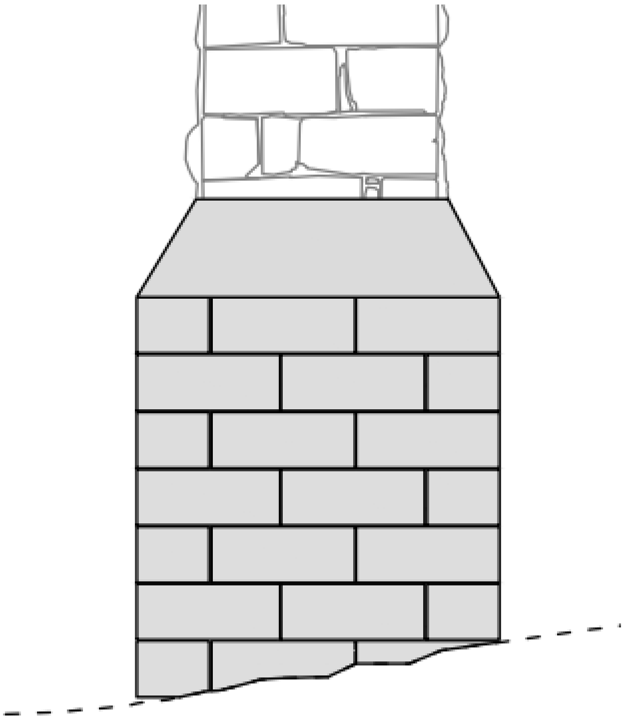
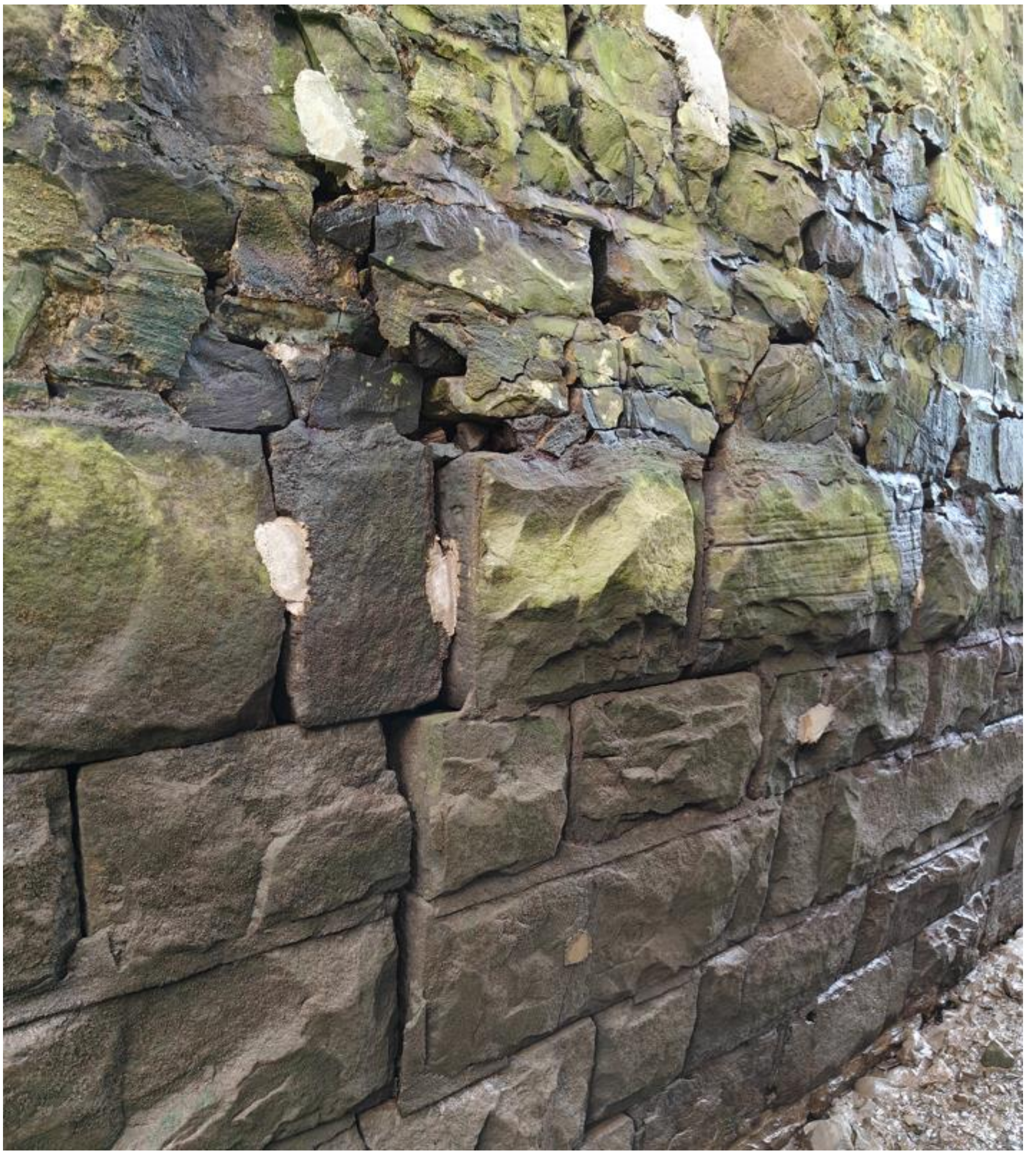


Figure 14: Elevation showing 'Running bond' pattern proposed for 'Pier Jacketing wall' at shorter face

It has come to our attention that in certain areas, the length of the current ashlar stone masonry units surpasses 1.4 meters. Additionally, these existing stone masonry units can range from 100kg to 400kg in weight. However, to restrict the weight of individual stone units to approximately 100kg, the length of new masonry units is generally capped at 600mm (maximum), except in a few isolated locations.

Furthermore, there have been observations of localized isolated bulging exceeding 100mm in certain isolated spots of both the North and South Intermediate Piers. Refer to Figure 15 for detail. This substantiates the proposal to maintain a 70mm gap between pier jacketing wall and the existing intermediate pier. This space will be filled with dry sand or a similar material to prevent a tight bond between stonework of the outer skin of new wall and the existing pier, as recommended by the HES and Planning department during the 'Pre-application' discussions. Refer 'Figure 9' for cross-section showing current proposal.



<u>Figure 15</u>: Photo showing localised bulging and opening of the joints in isolated locations of existing 'Intermediate Pier'

6. Existing Environment and SEPA guidelines :

The bridge spans the River Dee within a tidal zone downstream of the Tongland DRAX Power Station and Dam. While this area is not considered environmentally sensitive, it is imperative for the contractor to adhere to the standard guidelines set forth by Marine Scotland, SEPA, and the Fishery Board.

The recommendations outlined in the contract documents regarding special requirements pertaining to the Scottish Environment Protection Agency's "Prevention of Pollution from Civil Engineering Contracts," Version 2, must be strictly followed.

Additionally, the contractor must adhere to all relevant guidelines for working in proximity to water environments as stipulated in "The Water Environment (Controlled Activities) (Scotland) Regulations 2005.

7. Recommendations: Construction activity and material :

It is imperative to implement measures aimed at preventing the pollution of river water and mitigating any adverse effects on fish and marine animals resulting from the use of construction materials during the repair work. All construction materials, including lime-based mortar, lime-based grout, stonework, and anchors, must be suitable for use in water bodies and marine environments.

Regarding waste management, recyclable materials such as steel will be promptly removed from the site for recycling or transported to an appropriately licensed facility or treatment plant. Waste generated from grouting, anchoring, and building the pier jacketing wall must be disposed of properly at licensed sites or treatment plants.

While the majority of construction activities involve manual labour with minimal machinery use, precautions must be taken to prevent any spillage of oil or other pollutants at the construction site during work.

Any discharge resulting from the proposed grouting or anchoring operations into the main water body, potentially contaminating the river water, must be prevented. This involves collecting any contaminated discharge and debris and disposing of them in suitable containers located within the site compound.

The contractor is responsible for ensuring that all oil storage is situated well away from drains or water bodies, typically at a distance of not less than 10 meters, within the site compound in an open field. Oil storage tanks must be placed on impermeable bases and surrounded by impervious bunds with no surface water outlets. These bunds must be capable of retaining at least 110% of the volume of the tanks. All relevant guidelines provided by SEPA, as outlined in the "Prevention of Pollution from Civil Engineering Contracts Version 2 June 2006," must be strictly adhered to in this regard.

8.0 **Restrictions in relation to working practices**:

The contractor is required to adhere to the following recommendations:
i) Ensure that skips and waste in bags are covered to prevent the dispersion of dust and litter, as well as to safeguard against the ingress of rainwater.

ii) Store liquid wastes securely to mitigate the risk of escape, utilizing bunding where appropriate.

iii) Clearly label waste containers and store them in designated areas isolated from surface water drains, ensuring they are located well away from surface waters.

iv) Manage dust, emissions, and odours during works through the best practical means to minimize potential adverse impacts on sensitive receptors. Utilize water as a dust suppressant whenever feasible to prevent the emission of dust and the introduction of silt into drainage systems or watercourses.

v) Manage all substances in accordance with the relevant COSHH Assessments. Remove all containers at the end of each shift/operation and dispose of them according to the manufacturer's instructions for all substances used. Upon completion of works, remove all construction debris; refrain from using air pressure or water streams to clean up debris as it may redistribute or dilute waste materials.

Furthermore, ensure that all workforce and site staff are provided with suitable protective clothing while working. Take measures to prevent or control sparks from vehicles and machinery as far as practicable.

The Contractor is required to ensure that non-road mobile machinery utilizes Ultra Low Sulphur Diesel (ULSD) whenever feasible.

Additionally, the contractor must adhere to a 'Safe System of Work', ensuring that all operations on-site are meticulously planned, taking into account the tidal river timetable.

9. NOISE POLLUTION:

It is anticipated that none of the construction activities will exceed the permissible noise limits outlined in Appendix 1/9 of the Contract Document. However, the following recommendations and restrictions regarding working hours must be observed:

The ambient noise level, originating from all sources and measured 2.0 meters above the ground at designated noise control stations located 1 meter outside the nearest building window of the nearest occupied room closest to the noise source, should either not surpass the specified level provided in the Schedule or exceed the existing ambient noise level by more than 3dB(A) at the control station over the same period, whichever is greater. Furthermore, the maximum sound level at any noise control station should not exceed the level stipulated in the Schedule.

In exceptional cases, the Contractor may be granted permission to conduct works that exceed the prescribed noise levels in the Schedule. However, this is subject to the Contractor providing 14 days' notice to the D & G Council regarding the date and timing of these works. The Contractor must also demonstrate their commitment to implementing all reasonable measures to mitigate noise nuisance.

Subsequently, after consultations with the Local Authority and other relevant bodies, a decision will be made within 7 days of receiving the notice.

Schedule	Total Noise levels at Control Stations			
Period	Hours	Ambient Noise Level, Leq measured at Control Station dB(A)	Period of Hours over which Leq is applicable	Maximum Sound Level (see note (iv) below) Measured at Control Station dB(A)
Mondays to Fridays	24.00	75dB(A) 55dB(A)	07.00 - 19.00 19.00 - 07.00	90 dB
Saturdays	24.00	75dB(A) 55dB(A)	07.00 - 13.00 13.00 - 07.00	90 dB
All Unattended plant outside normal working hours	24.00	55dB(A)	All day if permitted	75 dB

The Contractor shall comply with the contents and recommendations of BS 5228: “Code of Practice for Noise Control on Construction and Open Sites”.

10. <u>CONSTRUCTION PERIOD and WORKING HOURS</u> :

We anticipate commencing the proposed repair work on June 3rd, 2024, with an estimated duration of approximately four months. The construction activities, including repointing, grouting of existing piers, anchoring, and the construction of the 'Pier jacketing' wall, will be scheduled to take place during the dry periods between two high tide levels. The contractor is expected to plan these activities in accordance with the tidal timetable at Kirkcudbright Bay.

Under normal circumstances, the working hours within the site shall be from Monday to Friday, between 07:00 hours and 19:00 hours, and on Saturdays between 08:00 hours and 13:00 hours, with no work scheduled on Sundays or public holidays. However, consent for work outside of these hours may be granted by Environmental Standards, Dumfries and Galloway Council. The Contractor must provide a minimum of 7 days' notice when seeking such consent, subject to the other requirements of the Contract.