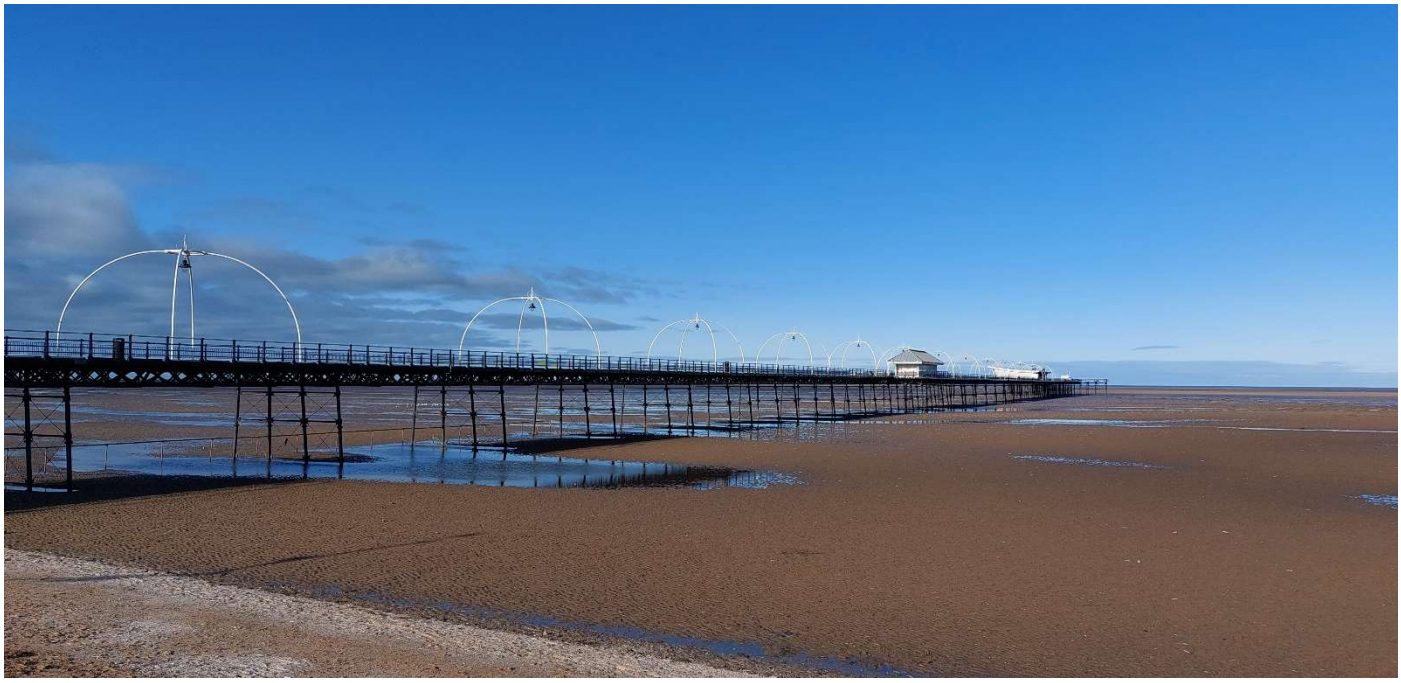
Structural Steelwork Inspection

at

Southport Pier
Promenade
Southport
PR8 1QX



For

Sefton Metropolitan Borough Council
Corporate Legal Services
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Sefton Council
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Contract No: LV1255
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Issue	Description	Date	Originator	Approved
01	First Issue for Comment	27/03/2024	AJJ	IJB
02	Final Issue	26/04/2024	AJJ	IJB

Whilst every effort has been made to fully inspect those parts of the building requested of us, no permanent or secured fixtures and fittings will have been removed. We will not have inspected woodwork or other parts of the structure which were covered, unexposed or inaccessible, and we are therefore unable to report that any such part of the property is free from defect.

Thomason Partnership Limited certify that they have carried out the work contained herein with due care and diligence to their best belief and knowledge based on the time and information available.
This report is made on behalf of Thomason Partnership Limited. By receiving it and acting on it, the client – or any third party relying on it – accepts that no individual is personally liable in contract, tort or breach of statutory duty (including negligence).

THOMASONS

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1.0 INTRODUCTION

1.1 Southport Pier is a Grade II listed structure originally opened in 1860. The pier has undergone significant changes due to damage and fires over the years and was fully refurbished over a four-year period from 1998. The pier originally had a steam train running along the south side edge of the deck. During the refurbishment, the rails were moved to the centre of the deck to allow the running of a new electric tram along the full length of the pier, and the deck widened to one side. The tram has since been decommissioned and a surface running train has been utilised. In December 2022, the structure was closed to the public for health and safety concerns relating to the condition of the timber decking.

1.2 Thomasons have been instructed by AE Yates, to produce a report to ascertain the current structural condition of Southport Piers steelwork, excluding the cast iron columns, and advise on what remedial works are required to achieve a fully accessible pier for a further lifespan of 60 years.

1.3 The survey undertaken consisted of a limited visual inspection of the pier steelwork in four locations along its length, towards the far end of the pier, over the beach, over the land and over the lake. The inspection consisted of the removal where possible of the timber decking and joists to allow access to the steelwork via the installation of a hung scaffold working platform secured to the underside of the steel frame. The inspection involved identifying the most heavily corroded and delaminating steel on an individual section which were then ground to bare, solid metal to allow Thomasons to measure and record the extent of section loss. During the initial opening up works it was discovered that the handrail standards were fixed between two timber joists and therefore could not be removed – similarly two centre oak members supporting the former tram rails could not be removed in most locations.

1.4 Due to the configuration of the scaffolding, access was limited to between the internal faces of the outer South and North longitudinal lattice trusses, access was not sufficient to enable cleaning and measuring of the ‘cantilevered’ extension and the PFC channel forming the edge of the pier that supports the handrail, visual observations are noted and the running alongside the North side of the pier. Due to varying inherent construction tolerance at the interface of the longitudinal trusses cleaning and measuring of the vertical interfaces couldn’t be fully assessed. Similarity access to the bracing between the columns below the scaffolding wasn’t available either.

1.5 The road bridge linking the shore and sea ward side of the pier was also excluded from the survey scope and in further developing the required remedial measures and more importantly the maintenance options consideration of the bridge's impact needs to be considered.

1.6 The purpose of this report is to summarise the condition of the structural frame and advise on the extent of any remediation works required and how these should be undertaken in order to achieve the desired extended lifespan of 60 years. The inspection was carried out by Thomasons starting 11th December 2023 concluding on 4th March 2023.

1.7 The four inspected areas represent approximately 15% of the piers total decked area and were selected to provide a snapshot of the condition of the steelwork. The areas were picked to give an indication of the effect various exposures including weather, over land, inland lake and sea to visually assess the locations effect on the deterioration of the steelwork. It should be noted that during the inspection there were significant differences to the extent degradation in adjacent bays and not just the different areas inspected.

1.8 A separate study of the piers supporting cast iron columns has been undertaken by Sandberg who've reported separately to AE Yates.

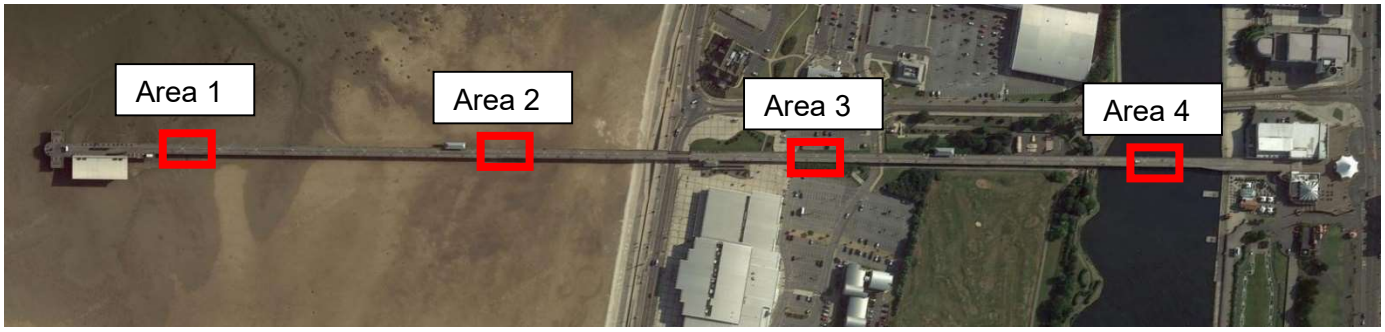
1.9 In preparing this report, comparison and reference will be made to the Feasibility Study for Programme of Major Maintenance Works carried out by Mott MacDonald – their report dated 28 July 2014.

2.0 OBSERVATIONS

Photograph 01 - Aerial image of Southport Pier (Google maps)

2.1 Thomasons inspected the structural steelwork within three or four bays at the locations indicated on photograph 02 below. For clarity these areas are:

- Area 1 – Located towards the seaward end of the pier (4No. Bays)
- Area 2 – Approximately halfway along the seaward section of the pier (3No. Bays)
- Area 3 – A section of the pier over land between car parking for adjacent commercial facilities (3No. Bays)
- Area 4 – Over the Marine Lake (3No. Bays)



Photograph 02 – Plan on pier indicating focused areas of inspection

2.2 This report covers the steel frames within the areas noted above.

2.3 The following Figures 1 to 4 indicate examples of the layouts used for onsite notation to indicate the measurements taken of the members:

- Plan on a typical Frame Bay along the pier,
- Typical section through the deck,
- Typical elevation of the longitudinal truss support frame,
- Elevation on a typical longitudinal truss.

2.4 Truss notation was added by Thomasons to provide clarity for referencing in drawings, photographs and figures in this report, and are included in Appendices A-D of this report.

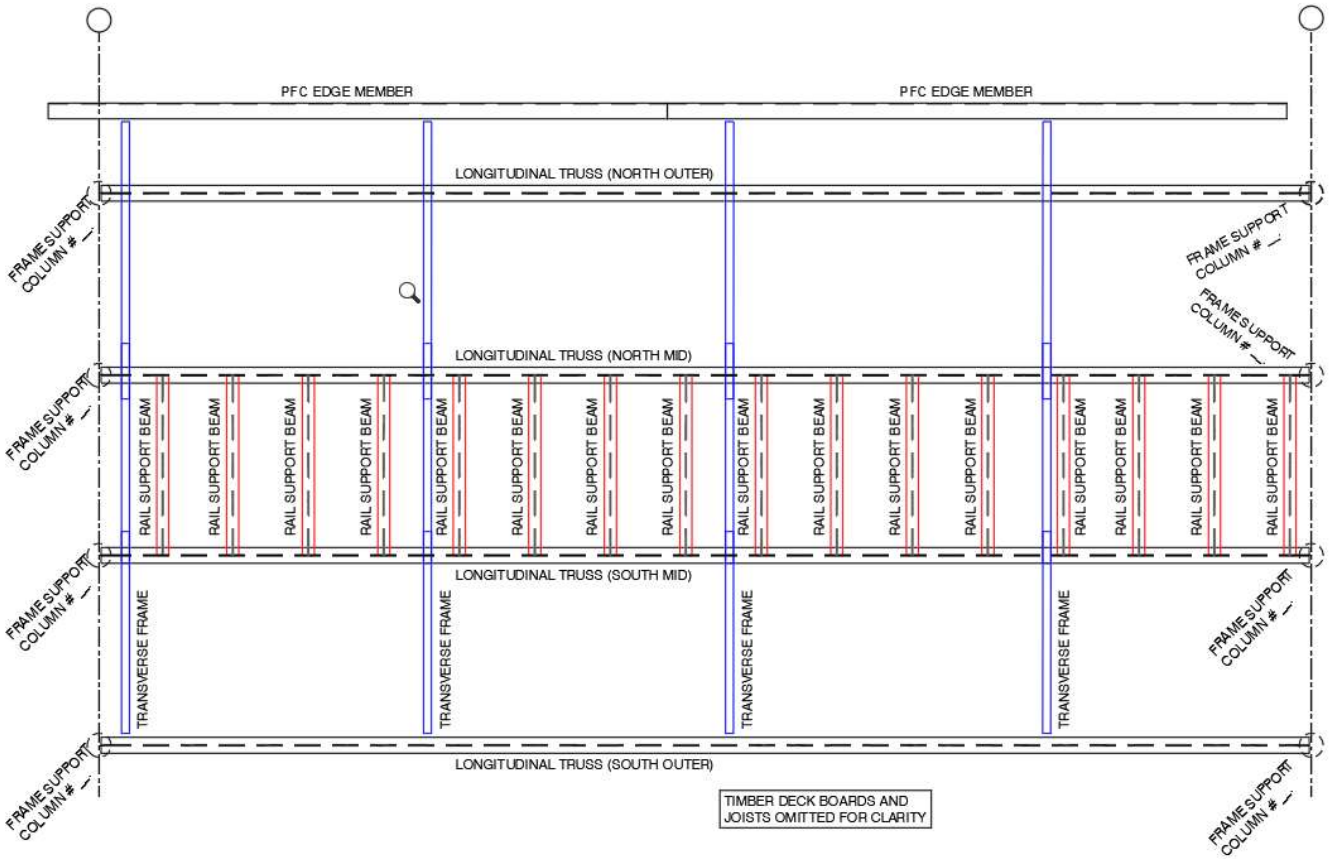


Figure 1 – Plan on Typical Frame Bay to Pier

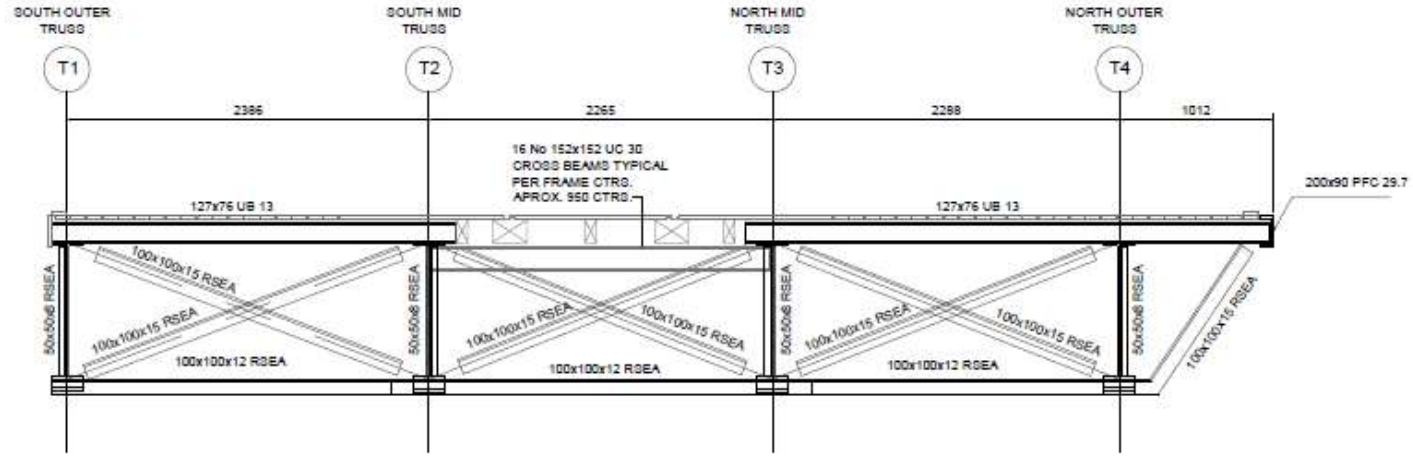


Figure 2 – Typical section through deck

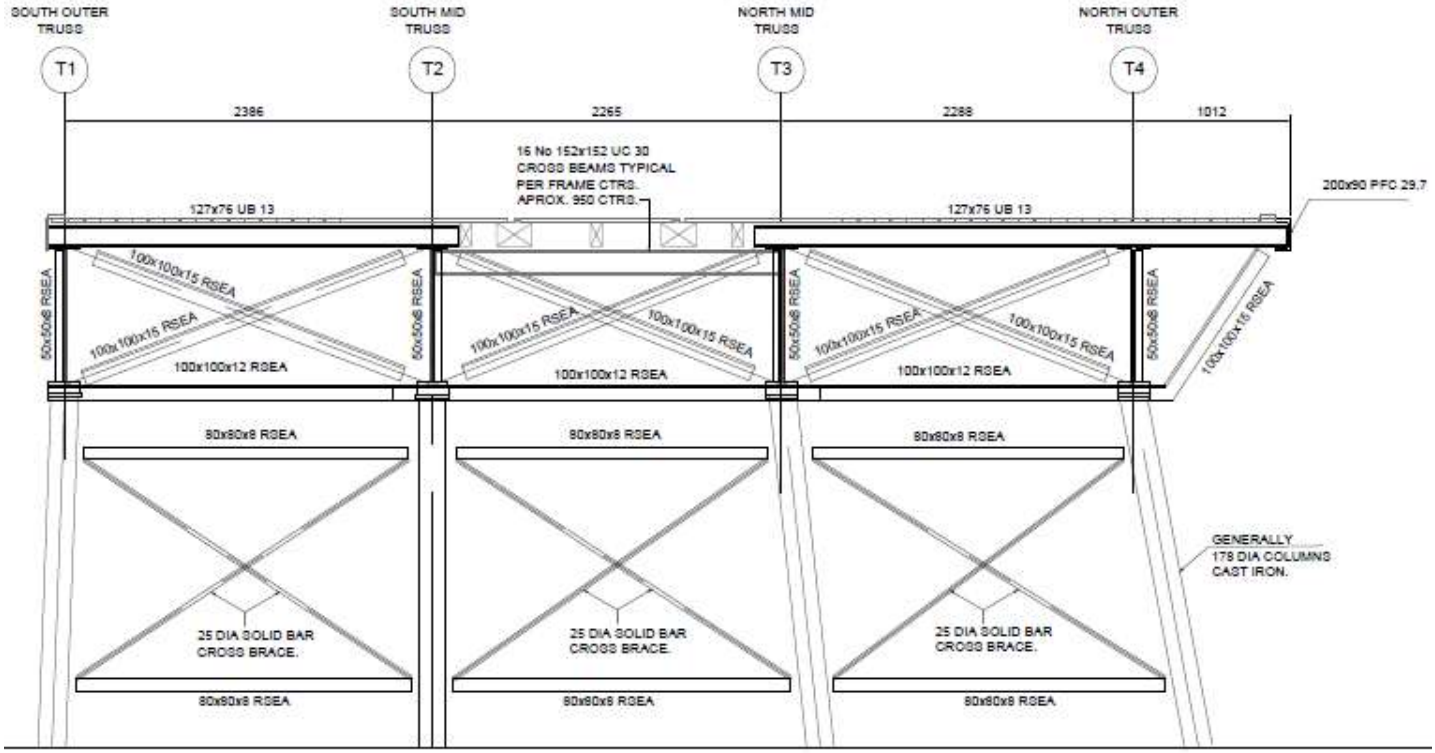


Figure 3 – Typical frame elevation

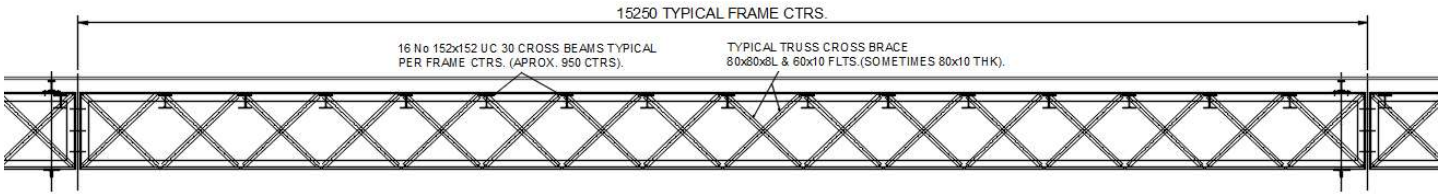


Figure 4 – Typical elevation on longitudinal truss

2.5 No intrusive or destructive testing has been carried out on the steelwork to determine the grade or composition of the materials used. It is understood that Sefton Councils independent consultants, Fairhurst, are undertaking material testing to clarify the steel strength. At the time of writing, these results were not available, and any analytical assessments are based on S275 steel. There has been localised removal of loose paint and corrosion only to allow Thomasons to take measurements of the exposed remaining steel section.

2.7 Due to the unevenness of the surface of the steel members, both in numerous painted thicknesses and the underlying condition of steel, an accurate record of the original size was difficult to obtain. As no historical drawings were available at the time of the survey, Thomasons used digital callipers and NDT Systems – TG110-DL Ultrasonic Thickness Gauge to determine the size and thicknesses of the steelwork to relate to similar sections within the appropriate historical literature, (for ease the sections sizes are noted in metric equivalents) following which as assessment of any loss of section could be evaluated.

2.9 The main issues with the steelwork observed in areas 1-4 inclusive were:

- Loss of protective finishes leading to surface rusting/pitting due to poor quality preparation and/or overpainting of the 2002 finishes previously reported as being of a poor quality.
- Complete loss of protective finishes leading to significant rusting, delamination, and loss of section material due to poor quality preparation and/or overpainting of the 2002 finishes previously reported as being of a poor quality.
- Failure of the protective paint finishes directly below the supported timbers, these being most probably the original coating from early 2002 works having not been repaired/painted in 2017.
- Damaged, deformed and buckled member edges
- Broken and damaged bracing to main frames

2.10 These defects were noted as typical to all areas of the survey. Additional defects are noted accordingly relating to the Areas surveyed.

3.0 Area 1: Located towards the seaward end of the pier (4No. Bays)

3.1 Bay references included within this area are Bays 60-63 inclusive. Views looking over the south and north sides of the bays can be seen in photographs 03 and 04 below – Note - timber left in position due to providing supporting to the handrail standards.

Photograph 03 – View on South side of Area 1

Photograph 04 – View on North side of Area 1

3.2 Generally the decking was supported on, and fixed to, the timber joists although at the ‘cross’ trusses the decking just rested on them with no fixing present.

3.3 This steel member directly under the timber decking had the most significant areas of localised damage including reduction in section size, delamination and rusting, including total loss of web and flange material in place. Photograph 05 shows an example of one of these beams, this is a typical and reoccurring issue with numerous locations observed in all inspected areas along the pier.

3.4 The following table lists out the drawings for this area. Digital (PDF) A1 copies are provided separately, Appendix A contains A3 copies of these drawings which provide a record of the measured steel sizes. These drawings also provide an illustrative reference for members that require replacing or repairing.

Drawing Number:	Drawing Title
LV1255-101	PLAN ON FRAMES GRID 59-60
LV1255-102	TRUSS ELEV OUTER SOUTH (59-60)
LV1255-103	TRUSS ELEV MID SOUTH (59-60)
LV1255-104	TRUSS ELEV MID NORTH (59-60)
LV1255-105	TRUSS ELEV OUTER NORTH (59-60)
LV1255-106	TRANSVERSE SUPP'TS 3No (59-60)
LV1255-107	TRANSV'E SUPPORT ADJ COL (59-60)
LV1255-108	PLAN ON FRAMES GRID 60-61
LV1255-109	TRUSS ELEV OUTER SOUTH (60-61)
LV1255-110	TRUSS ELEV MID SOUTH (60-61)
LV1255-111	TRUSS ELEV MID NORTH (60-61)
LV1255-112	TRUSS ELEV OUTER NORTH (60-61)
LV1255-113	TRANSVERSE SUPP'TS 3No (60-61)
LV1255-114	TRANSV'E SUPPORT ADJ COL (60-61)
LV1255-115	PLAN ON FRAMES GRID 61-62
LV1255-116	TRUSS ELEV OUTER SOUTH (61-62)
LV1255-117	TRUSS ELEV MID SOUTH (61-62)
LV1255-118	TRUSS ELEV MID NORTH (61-62)
LV1255-119	TRUSS ELEV OUTER NORTH (61-62)
LV1255-120	TRANSVERSE SUPPORTS 3No (61-62)
LV1255-121	TRANSV'E SUPPORT ADJ COL (61-62)
LV1255-115	PLAN ON FRAMES GRID 62-63
LV1255-123	TRUSS ELEV OUTER SOUTH (62-63)
LV1255-124	TRUSS ELEV MID SOUTH (62-63)
LV1255-125	TRUSS ELEV MID NORTH (62-63)
LV1255-126	TRUSS ELEV OUTER NORTH (62-63)
LV1255-127	TRANSVERSE SUPPORTS 3No (62-63)
LV1255-128	TRANSV'E SUPPORT ADJ COL (62-63)

Table 1 – List of drawings for Area 1

3.5 Central Section

3.6 A visual assessment of the central beams was carried out in this area. Notes and commentary have been added to the drawings for clarity.

3.7 The existing tram rails and supporting oak beams are supported on 152UC steel beams spanning between the two mid (central) trusses. These beams have been bolted to the web of the top chord with a two-bolt fixing, general via an end plate although there is significant packing in places, this can be seen in Photograph 05 below. Some of these beams have had remedial repairs carried out with installation of additional angles or PFC's.

Photograph 05 – Central support Beam Ref 107

3.8 The condition of the central beams varied, with the majority requiring replacing. Beam reference 107 in photograph 05 indicates the typical delamination and section loss noted along the top and bottom flanges. As can be seen, the extent of delamination is such that no solid material of the original steel section remains.

3.9 Photograph 06 below shows a central support beam that has been repaired/strengthened. The 152UC has two 125x65x15PFC's installed back-to-back bolted through the UC web. In addition, full length packing plates, top and bottom, have been installed between the flanges of the UC and PFC's.

Photograph 06 – Central support Beam Ref 120

3.10 Historically where the bottom flange has corroded, leaving a shallow depth of section, a remedial repair has been carried out. The remedial detail consists of two steel angles installed either side of the web, seated on the bottom flange, then dome head bolts through the web. At the beam location shown in photograph 07 below, the top flange has also corroded away to nothing at the location of the oak beam.

Photograph 07 – Central support Beam Ref 150

3.11 Table 2 below provides a summary of the central section beams. It indicates the number of beams that require replacing or repairing as noted on the drawings. The table breaks down each bay within the area to give a percentage per bay, as well as totalling up to summarise the totals for the whole area.

Central Beams	No. Beams Surveyed	No. Beams to Replace	%	No. Beams to Repair	%	Adequate	%
Bay 60	16	16	100%		0%		0%
Bay 61	16	15	94%	1	6%		0%
Bay 62	16	13	81%	1	6%	2	13%
Bay 63	16	6	38%	1	6%	9	56%
Total No.	64	50		3		11	
As %age		78%		5%		17%	

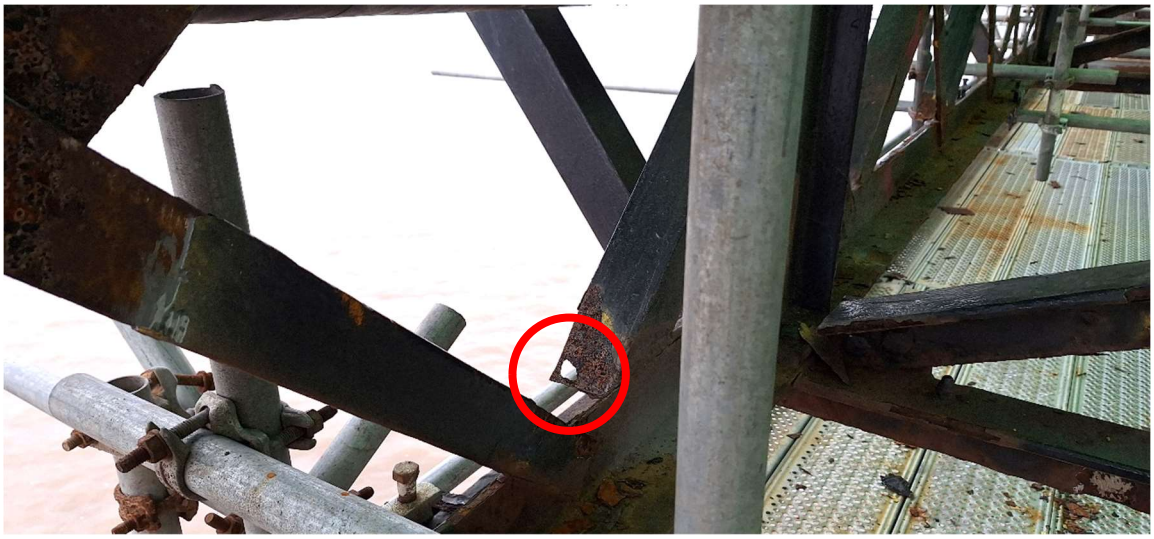
Table 2 – Summary of Central Section Beams for Area 1

3.12 Longitudinal Trusses along the Bays

3.13 The photographs below show examples of the deterioration of various members forming the longitudinal trusses. Bay, and where possible, member references have been added for clarity.

Photograph 08 – Vertical leg of angle brace within Outer North truss in Bay 63

Photograph 09 – Horizontal leg of angle brace within Mid North truss in Bay 62



Photograph 10 – Horizontal leg of angle brace within Outer North truss in Bay 62

Photograph 11 – Bottom chord of Outer North Truss in Bay 62

Photograph 12 – Vertical Leg of angle brace within Outer North Truss in Bay 62

Photograph 13 – View on Outer North truss diagonals in Bay 61

Photograph 14 – Loss of section to horizontal leg of bracing angle within the mid North truss in Bay 60

Photograph 15 – Additional loss of section adjacent to previous repair of vertical leg of bracing angle within Mid North truss of Bay 60

Photograph 16 – Vertical leg of diagonal leg within Outer South truss to Bay 62

Photograph 17 – Pitting and hole in horizontal leg of diagonal brace within Outer South truss in Bay 63

Photograph 18 – Horizontal leg of previously repaired diagonal damaged within Mid South truss in Bay 60

Photograph 19– Buckled flat in Outer South truss in bay 60

Photograph 20– View on Mid-South truss within Bay 60, indicating corrosion to top and bottom chords

Photograph 21 – Severe loss of section to web of bottom Chord of Outer North truss in Bay 62

Photograph 22 – Severe loss of section to top Chord of Outer North truss in Bay 62

Photograph 23 – Outer North Truss support post on Gridline 59, with noticeable movement in bolts.

3.14 Tables 3-6 below provide a summary of the diagonal members for the longitudinal trusses. It indicates the number of members that require replacing or repairing as noted on the drawings. The table summarises each bay, and the totals for the whole area.

Outer South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 60	32	8	25%		0%
Bay 61	32	6	19%	2	6%
Bay 62	32	13	41%		0%
Bay 63	32	4	13%		0%
Total No.	128	31		2	
As %age		24%		2%	

Table 3 – Summary of Outer South Longitudinal truss diagonal members for Area 1

Mid South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 60	32	16	50%	1	3%
Bay 61	32	8	25%	1	3%
Bay 62	32	10	31%		0%
Bay 63	32	10	31%	4	13%
Total No.	128	44		6	
As %age		34%		5%	

Table 4 – Summary of Mid South Longitudinal truss diagonal members for Area 1

Mid North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 60	32	20	63%	3	9%
Bay 61	32	10	31%	1	3%
Bay 62	32	16	50%	1	3%
Bay 63	32	7	22%		0%
Total No.	128	53		5	
As %age		41%		4%	

Table 5 – Summary of Mid North Longitudinal truss diagonal members for Area 1

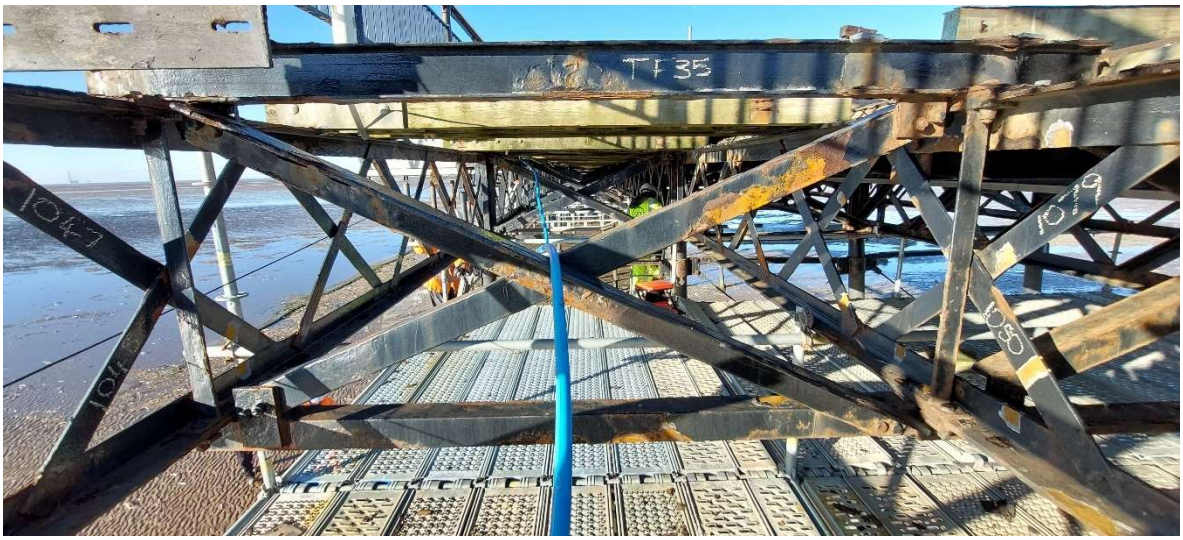
Outer North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 60	32	9	28%		0%
Bay 61	32	13	41%		0%
Bay 62	32	8	25%	2	6%
Bay 63	32	19	59%		0%
Total No.	128	49		2	
As %age		38%		2%	

Table 6 – Summary of Outer North Longitudinal truss diagonal members for Area 1

3.15 Transverse Trusses

3.16 The North and South side trusses were ground back to bare steel and had measurements taken, due to restricted access within the central area, a visual inspection was caried out.

3.17 Photograph 24 below indicates typical condition of the southern section of the transverse frames. Where the paint has been removed prior to any grinding, the exposed steelwork shows the extent of surface corrosion. The top member of the trusses had evidence of severely delaminating flanges with section loss, and the webs, especially at the ends,



Photograph 24 – View on South section of TF35, Bay 62, looking towards sea

3.18 Photograph 25 highlights the condition to the internal end of the top beam forming the transverse frames. This level of beam damage was noted on both sides of the deck, and at either end of the beams. Along the length of the beam, there was noticeable loss of section, and in some locations had reduced to nothing.

Photograph 25 – View on deteriorated top member of TF34, Bay 63, looking towards land

3.19 Along the central section of the deck, the protective paint finishes to the transverse frames have failed resulting in varying degrees of surface corrosion, this is also evident along the surfaces of the diagonal and horizontal members, this can be seen in photograph 26 below.

Photograph 26– View on Central section of TF36, Bay 62, looking towards land

3.20 Photograph 27 below indicates typical condition of the North side section of the transverse frames. Along the edges of the steel members evidence of corrosion could be seen due to the failed paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members.

Photograph 27 – View on North section of TF34, Bay 62, looking towards land

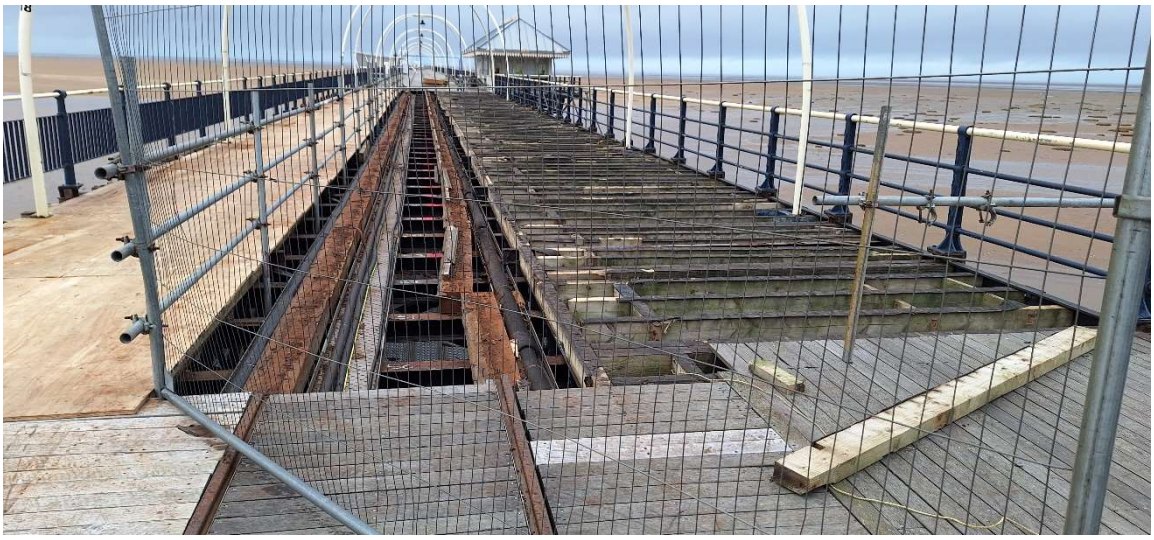
3.21 It was noted that a number of the cantilevering top members had no positive fixing to the PFC to the underside of the handrail along the north edge of the deck, an example can be seen in photograph 28, and further locations are noted on the drawings.

Photograph 28 – No connection between PFC and a transverse member within Area 1

4.0 Area 2: Approximately halfway along the seaward section of the pier (3No. Bays)

4.1 Bay references included within this area are Bays 43-45 inclusive. Views looking over the south and north sides of the bays can be seen in photographs 29 and 30 below – NOTE - timber left in position due to providing supporting to the handrail standards.

Photograph 29 – View on South side of Area 2



Photograph 30 – View on Central and North sections of Area 2

4.2 Table 7 below lists out the drawings for this area, see Appendix B, that provide a record of the measured steel sizes. These drawings also provide an illustrative reference for members that require replacing or repairing.

Drawing Number:	Drawing Title
LV1255-130	PLAN ON FRAMES GRID 43-44
LV1255-131	TRUSS ELEV OUTER SOUTH (43-44)
LV1255-132	TRUSS ELEV MID SOUTH (43-44)
LV1255-133	TRUSS ELEV MID NORTH (43-44)
LV1255-134	TRUSS ELEV OUTER NORTH (43-44)
LV1255-135	TRANSVERSE SUPPORTS 3No (43-44)
LV1255-136	TRANSV'E SUPPORT ADJ COL (43-44)
LV1255-137	PLAN ON FRAMES GRID 44-45
LV1255-138	TRUSS ELEV OUTER SOUTH (44-45)
LV1255-139	TRUSS ELEV MID SOUTH (44-45)
LV1255-140	TRUSS ELEV MID NORTH (44-45)
LV1255-141	TRUSS ELEV OUTER NORTH (44-45)
LV1255-142	TRANSVERSE SUPPORTS 3No (44-45)
LV1255-143	TRANSV'E SUPPORT ADJ COL (44-45)
LV1255-144	PLAN ON FRAMES GRID 45-46
LV1255-145	TRUSS ELEV OUTER SOUTH (45-46)
LV1255-146	TRUSS ELEV MID SOUTH (45-46)
LV1255-147	TRUSS ELEV MID NORTH (45-46)
LV1255-148	TRUSS ELEV OUTER NORTH (45-46)
LV1255-149	TRANSVERSE SUPPORTS 3No (45-46)
LV1255-150	TRANSV'E SUPPORT ADJ COL (45-46)

Table 7 – List of drawings for Area 2

4.3 Central Section

4.4 A visual assessment of the central beams was carried out in this area. Notes and commentary have been added to the drawings for clarity.

4.5 A view along the central section looking back towards the landward end of the pier can be seen in Photograph 31 below. Some of these beams have had remedial repairs carried out with installation of additional angles.

Photograph 31 – View on Area 2 central section looking landward

4.6 Where the bottom flange has corroded leaving a shallow depth of section a remedial repair has been carried out. The remedial detail is two steel angles installed either side of the web, seated on the bottom flange, then bolted through the web, shown in photograph 32 below.

Photograph 32 – Central support Beam Ref 148 indicating remedial repair.

4.7 Table 8 below provides a summary of the central section beams. It indicates the number of beams that require replacing or repairing as noted on the drawings. The table breaks down each bay within

the area to give a percentage per bay, as well as totalling up at the bottom to summarise the totals for the whole area.

Central Beams	No. Beams Surveyed	No. Beams to Replace	%	No. Beams to Repair	%	Adequate	%
Bay 43	16	11	69%	2	13%	3	19%
Bay 44	16	8	50%	6	38%	2	13%
Bay 45	16	2	13%	7	44%	7	44%
Total No.	48	21		15		12	
As %age		44%		31%		25%	

Table 8 – Summary of Central Section Beams for Area 2

4.8 Longitudinal Trusses along the Bays

4.9 The photographs below show a couple of examples of the deterioration of the longitudinal trusses. Issues noted within Area 1 were noted within this Area also.

Photograph 33 – Hole in vertical leg of angle brace within Outer North truss in Bay 45

Photograph 34 – Bubbled paint present to bottom chord of Mid North truss in Bay 45

4.10 Tables 9-12 below provide a summary of the diagonal members for the longitudinal trusses. It indicates the number of members that require replacing or repairing as noted on the drawings. The table summarises each bay, and the totals for the whole area.

Outer South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 43	32	10	31%		0%
Bay 44	32	13	41%		0%
Bay 45	32	12	38%		0%
Total No.	96	35		0	
As %age		36%		0%	

Table 9 – Summary of Outer South Longitudinal truss diagonal members for Area 2

Mid South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 43	32	3	9%		0%
Bay 44	32	4	13%		0%
Bay 45	32	11	34%		0%
Total No.	96	18		0	
As %age		19%		0%	

Table 10 – Summary of Mid South Longitudinal truss diagonal members for Area 2

Mid North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%

Bay 43	32	5	16%		0%
Bay 44	32	2	6%		0%
Bay 45	32	6	19%		0%
Total No.	96	13		0	
As %age		14%		0%	

Table 11 – Summary of Mid North Longitudinal truss diagonal members for Area 2

Outer North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 43	32	11	34%		0%
Bay 44	32	8	25%		0%
Bay 45	32	8	25%		0%
Total No.	96	27		0	
As %age		28%		0%	

Table 12 – Summary of Outer North Longitudinal truss diagonal members for Area 2

4.11 Transverse Trusses

4.12 The North and South side trusses were ground back to bare steel and had measurements taken, due to restricted access within the central area, a visual inspection was caried out.

4.13 Photographs 35 and 36 below indicates typical condition of the southern section of the transverse frames. Where the paint has been removed prior to any grinding, the exposed steelwork shows the extent of surface corrosion. The top member of the trusses had evidence of severely delaminating flanges with section loss, and the webs, especially at the ends,

Photograph 35 – View on South section of TF13, Bay 43, looking seaward.

Photograph 36 – View on deteriorated top member of TF13, Bay 43, looking at top of Mid South truss

4.14 Along the central section of the deck, the transverse frames had evidence of corrosion damaging the paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members.

4.15 Photograph 37 below indicates typical condition of the North side section of the transverse frames. Along the edges of the steel members evidence of corrosion could be seen damaging the paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members.

Photograph 37 – View on North section of TF23, Bay 45, looking seaward

5.0 Area 3: A section of pier over land, with some shelter from the surrounding buildings (3No. Bays)

5.1 Bay references included within this area are Bays 26-28 inclusive. Views looking over the south and north sides of the bays can be seen in photographs 38 and 39 below – NOTE - timber left in position due to providing supporting to the handrail standards.

Photograph 38 – View on South side of Area 3

Photograph 39 – View on Central and North sections of Area 3

5.2 The following table lists out the drawings for this area, see Appendix C, that provide a record of the measured steel sizes. These drawings also provide an illustrative reference for members that require replacing or repairing.

Drawing Number:	Drawing Title
LV1255-155	PLAN ON FRAMES GRID 25-26
LV1255-156	TRUSS ELEV OUTER SOUTH (25-26)
LV1255-157	TRUSS ELEV MID SOUTH (25-26)
LV1255-158	TRUSS ELEV MID NORTH (25-26)
LV1255-159	TRUSS ELEV OUTER NORTH (25-26)
LV1255-160	TRANSVERSE SUPPORTS 3No (25-26)
LV1255-161	TRANSV'E SUPP'T ADJ COL GRID 26
LV1255-162	PLAN ON FRAMES GRID 26-27
LV1255-163	TRUSS ELEV OUTER SOUTH (26-27)
LV1255-164	TRUSS ELEV MID SOUTH (26-27)
LV1255-165	TRUSS ELEV MID NORTH (26-27)
LV1255-166	TRUSS ELEV OUTER NORTH (26-27)
LV1255-167	TRANSVERSE SUPPORTS 3No (26-27)
LV1255-168	TRANSV'E SUPP'T ADJ COL GRID 27
LV1255-169	PLAN ON FRAMES GRID 27-28
LV1255-170	TRUSS ELEV OUTER SOUTH (27-28)
LV1255-171	TRUSS ELEV MID SOUTH (27-28)
LV1255-172	TRUSS ELEV MID NORTH (27-28)
LV1255-173	TRUSS ELEV OUTER NORTH (27-28)
LV1255-174	TRANSVERSE SUPPORTS 3No (27-28)
LV1255-175	TRANSV'E SUPP'T ADJ COL GRID 28

Table 11 – List of drawings for Area 3

5.3 Central Section

5.4 A visual and measured assessment of the central beams was carried out in this area. Notes and commentary have been added to the drawings for clarity.

5.5 The condition of the central beams varies, with a significant number requiring replacing. Beam reference 35 in shown in photographs 40 and 41 indicates minor edge delamination to one end, and at the opposite end, severe loss of section to the top and bottom flanges.

Photograph 40 – Central support Beam Ref 35 looking landward adjacent to Mid North truss

Photograph 41 – Central support Beam Ref 35 looking landward adjacent to Mid South truss

5.6 Photographs 42 and 43 below shows two central support beams that have severe loss of section to the top and bottom flanges on Mid South truss end of the beam.

Photograph 42 – Central support Beam Ref 44 looking seaward

Photograph 43 – Central support Beam Ref 43 looking landward

5.7 Table 12 below provides a summary of the central section beams. It indicates the number of beams that require replacing or repairing as noted on the drawings. The table breaks down each bay within the area to give a percentage per bay, as well as totalling up at the bottom to summarise the totals for the whole area.

Central Beams	No. Beams Surveyed	No. Beams to Replace	%	No. Beams to Repair	%	Adequate	%
Bay 26	15	4	27%		0%		0%
Bay 27	16	3	19%		0%		0%
Bay 28	16	8	50%		0%		0%
Total No.	47	15		0		0	
As %age		32%		0%		0%	

Table 12 – Summary of Central Section Beams for Area 3

5.8 Longitudinal Trusses along the Bays

5.9 The photographs below show examples of the deterioration of various members forming the longitudinal trusses. Bay, and where possible, member references have been added for clarity.

Photograph 44 – View on Outer South truss top chord in Bay 26

Photograph 45 – Loss of section to vertical leg of bracing angle within the mid North truss in Bay 26

Photograph 46 – Loss of section adjacent to truss diagonals within Mid South truss adjacent to TF6 of Bay 27

Photograph 47 – Hole in vertical leg of truss angle (highlighted) and loss of section to truss flat of Mid South truss in Bay 27

5.10 Tables 13-16 below provide a summary of the diagonal members for the longitudinal trusses. It indicates the number of members that require replacing or repairing as noted on the drawings. The table summarises each bay, and the totals for the whole area.

Outer South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 26	32		0%	1	3%
Bay 27	32		0%		0%
Bay 28	32		0%		0%
Total No.	96	0		1	
As %age		0%		1%	

Table 13 – Summary of Outer South Longitudinal truss diagonal members for Area 3

Mid South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 26	32	19	59%		0%
Bay 27	32	14	44%		0%
Bay 28	32		0%		0%
Total No.	96	33		0	
As %age		34%		0%	

Table 14 – Summary of Mid South Longitudinal truss diagonal members for Area 3

Mid North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 26	32	12	38%		0%
Bay 27	32		0%		0%
Bay 28	32		0%		0%
Total No.	96	12		0	
As %age		13%		0%	

Table 15 – Summary of Mid North Longitudinal truss diagonal members for Area 3

Outer North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 26	32	6	19%		0%
Bay 27	32		0%		0%
Bay 28	32		0%		0%
Total No.	96	6		0	
As %age		6%		0%	

Table 16 – Summary of Outer North Longitudinal truss diagonal members for Area 3

5.11 Transverse Trusses

5.12 The North and South side trusses were ground back to bare steel and measurements taken, due to restricted access within the central area, a visual inspection was caried out.

5.13 Photograph 48 below indicates typical condition of the southern section of the transverse frames. Paint had a bubbling effect due to surface corrosion of the steel underneath. The top members of these trusses typically had evidence of reduced section thickness to the flanges, and at the end's delamination around the full section profile, example of this is shown in photograph 49 below.

Photograph 48 – View on South section of TF11, Bay 28, looking landwards

Photograph 49 – Example of delamination of top member of TF8

5.14 Along the central section of the deck, similar issues observed in the other areas were noted. This included surface corrosion damaging the paint finish, and exposed edges of the diagonal and horizontal members due delamination of the steel.

5.15 Photograph 50 below indicates typical condition of the North side section of the transverse frames. Along the edges of the steel members evidence of corrosion could be seen damaging the paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members.

Photograph 50 – View on North section of TF03, Bay 25, looking landwards

6.0 Area 4: Over the Marine Lake (3No. Bays)

6.1 Bay references included within this area are Bays 7-9 inclusive. Views looking over the south and north sides of the bays can be seen in photographs 51 and 52 below – NOTE - timber left in position due to providing supporting to the handrail standards.

Photograph 51 – View on Central and South sections of Area 4

Photograph 52 – Partial view on North side of Area 4

6.2 The following table lists out the drawings for this area, see Appendix C, that provide a record of the measured steel sizes. These drawings also provide an illustrative reference for members that require replacing or repairing.

Drawing Number:	Drawing Title
LV1255-180	PLAN ON FRAMES GRID 6-7
LV1255-181	TRUSS ELEV OUTER SOUTH (6-7)
LV1255-182	TRUSS ELEV MID SOUTH (6-7)
LV1255-183	TRUSS ELEV MID NORTH (6-7)
LV1255-184	TRUSS ELEV OUTER NORTH (6-7)
LV1255-185	TRANSVERSE SUPPORTS 3No (6-7)
LV1255-186	TRANSV'E SUPPORT ADJ COL (6-7)
LV1255-187	PLAN ON FRAMES GRID 7-8
LV1255-188	TRUSS ELEV OUTER SOUTH (7-8)
LV1255-189	TRUSS ELEV MID SOUTH (7-8)
LV1255-190	TRUSS ELEV MID NORTH (7-8)
LV1255-191	TRUSS ELEV OUTER NORTH (7-8)
LV1255-192	TRANSVERSE SUPPORTS 3No (7-8)
LV1255-193	TRANSV'E SUPPORT ADJ COL (7-8)
LV1255-194	PLAN ON FRAMES GRID 8-9
LV1255-195	TRUSS ELEV OUTER SOUTH (8-9)
LV1255-196	TRUSS ELEV MID SOUTH (8-9)
LV1255-197	TRUSS ELEV MID NORTH (8-9)
LV1255-198	TRUSS ELEV OUTER NORTH (8-9)
LV1255-199	TRANSVERSE SUPPORTS 3No (8-9)
LV1255-200	TRANSV'E SUPPORT ADJ COL (8-9)

Table 17 – List of drawings for Area 4

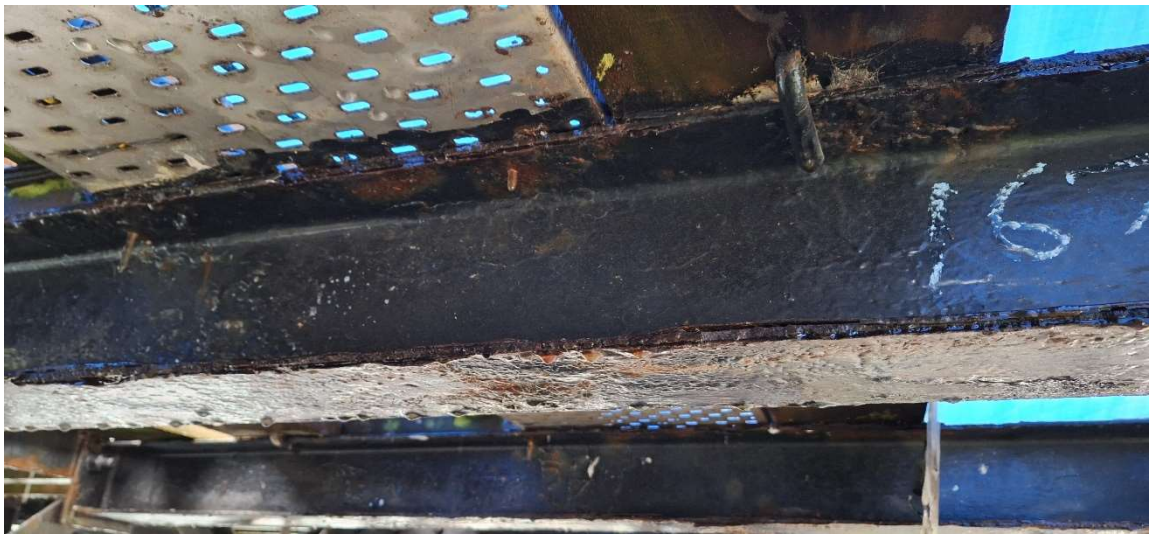
6.3 Central Section

6.4 A visual assessment of the central beams was carried out in this area. Notes and commentary have been added to the drawings for clarity.

6.5 These beams have been bolted to the web of the top chord with a two-bolt fixing. This can be seen in Photograph 53 below. Some of these beams have had remedial repairs carried out with installation of additional angles or PFC’s.

Photograph 53 – Central support Beam Ref 172

6.6 The condition of the central beams varied, with the majority requiring replacing. Beam reference 167 in photograph 54indicates the typical delamination and section loss noted along the top and bottom flanges, in some cases it is difficult to determine what, if any, original steel section remains.



Photograph 54 – Central support Beam Ref 167 indicating delamination and loss of section

6.7 Where the bottom flange has corroded leaving a shallow depth of section a remedial repair has been carried out. The remedial detail is two steel angles installed either side of the web, seated on the bottom flange, then bolted through the web, shown in photograph 55 below.

Photograph 56 – Central support Beam Ref 165

6.8 Table 18 below provides a summary of the central section beams. It indicates the number of beams that require replacing or repairing as noted on the drawings. The table breaks down each bay within the area to give a percentage per bay, as well as totalling up at the bottom to summarise the totals for the whole area.

Central Beams	No. Beams Surveyed	No. Beams to Replace	%	No. Beams to Repair	%	Adequate	%
Bay 7	16	16	100%		0%		0%
Bay 8	16	14	88%	2	13%		0%
Bay 9	16	12	75%	3	19%	1	6%
Total No.	48	42		5		1	
As %age		88%		10%		2%	

Table 18 – Summary of Central Section Beams for Area 4

6.9 Longitudinal Trusses along the Bays

6.10 The photographs below show examples of the deterioration of various members forming the longitudinal trusses. Bay, and where possible, member references have been added for clarity. Issues noted within Area 1 were noted within this Area also.

Photograph 57– View on Mid-South truss within Bay 7, indicating corrosion to bottom chord and previous repairs to diagonals

Photograph 58 – Example of previous repair detail to diagonal member in Outer North truss in Bay 7

Photograph 59 – Severe loss of section to diagonal member of Outer North truss in Bay 8

Photograph 60 – Outer North Truss support post on Gridline 7, with noticeable movement in trusses.

6.11 Tables 19-22 below provide a summary of the diagonal members for the longitudinal trusses. It indicates the number of members that require replacing or repairing as noted on the drawings. The table summarises each bay, and the totals for the whole area.

Outer South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 7	32	1	3%		0%
Bay 8	32	12	38%		0%
Bay 9	32	7	22%		0%
Total No.	96	20		0	
As %age		21%		0%	

Table 19 – Summary of Outer South Longitudinal truss diagonal members for Area 4

Mid South Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 7	32	16	50%		0%
Bay 8	32	14	44%		0%
Bay 9	32	7	22%		0%
Total No.	96	37		0	
As %age		39%		0%	

Table 20– Summary of Mid South Longitudinal truss diagonal members for Area 4

Mid North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 7	32	8	25%		0%
Bay 8	32	9	28%		0%
Bay 9	32	12	38%		0%
Total No.	96	29		0	
As %age		30%		0%	

Table 21– Summary of Mid North Longitudinal truss diagonal members for Area 4

Outer North Truss	Diagonals Surveyed	No. to Replace	%	No. to Repair	%
Bay 7	32	14	44%		0%
Bay 8	32	13	41%		0%
Bay 9	32	14	44%		0%
Total No.	96	41		0	
As %age		43%		0%	

Table 22– Summary of Outer North Longitudinal truss diagonal members for Area 4

6.12 Transverse Trusses

6.13 The North and South side trusses were ground back to bare steel and had measurements taken, due to restricted access within the central area, a visual inspection was caried out.

6.14 Photograph 61 below indicates typical condition of the southern section of the transverse frames. Where the paint has been removed prior to any grinding, the exposed steelwork shows the extent of surface corrosion. The top member of the trusses had evidence of severely delaminating flanges with section loss, and the webs, especially at the ends,

Photograph 61 – View on South section of TF44, Bay 7, looking landwards

6.15 Photograph 62 highlights the typical condition to the top beam forming the transverse frames. This level of beam damage was noted on both sides of the deck. Along the length of the beams, there was noticeable loss of section, and in some locations had reduced to nothing.

Photograph 63 – View on deteriorated top member of TF47, Bay 8, looking towards outer south truss

6.16 Along the central section of the deck, the transverse frames had evidence of corrosion damaging the paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members, this can be seen in photograph 64 below.

Photograph 64– View on Central section of TF51, Bay 9, looking landwards

6.17 Photograph 65 below indicates typical condition of the North side section of the transverse frames. Along the edges of the steel members evidence of corrosion could be seen damaging the paint finish, and surface corrosion was present along the surfaces of the diagonal and horizontal members.

Photograph 65 – View on North section of TF44, Bay 7, looking landwards

6.18 It was noted that a number of the cantilevering top members had no positive fixing to the PFC to the underside of the handrail along the north edge of the deck, an example can be seen in photograph 66, and locations are noted on the drawings.

Photograph 66 – No connection between PFC and a transverse member within Area 4

7.0 Handrails

7.1 As part of the inspections, Thomasons were asked to review the handrails to provide some commentary regarding the suitability of the fixings to the steelwork.

7.2 It was noted that along the pier within the areas inspected, four different style handrails were noted:

Type 1 (photograph 67) was located on the south side of the deck along area 1 and area 3.

Type 2 (photograph 68) was noted in all four areas along the north side of the pier deck.

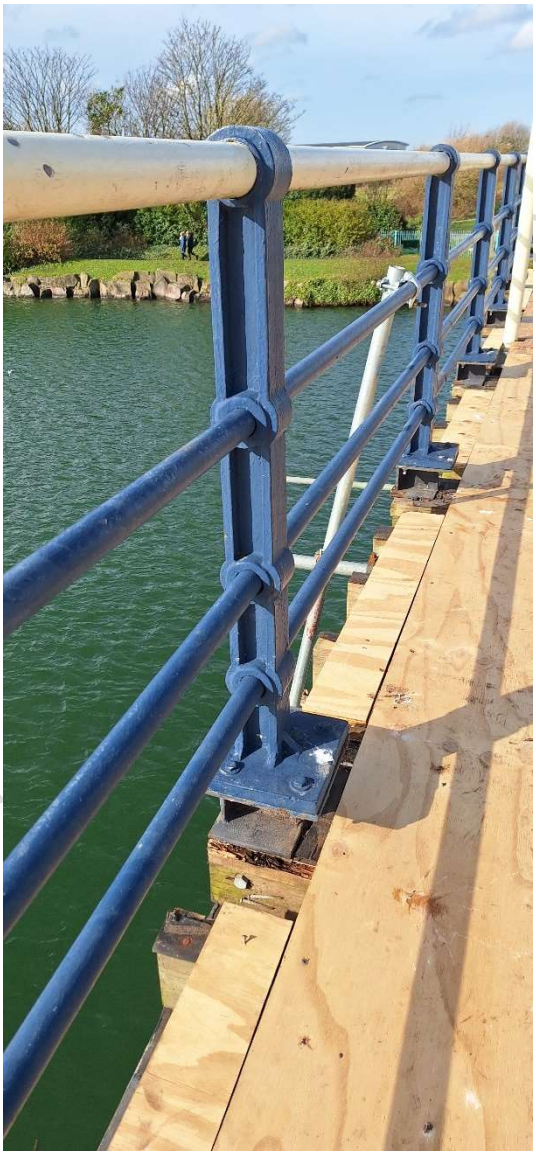
Type 3 (photograph 69) was located on the south side of the deck along area 2.

Type 4 (photograph 70) was located on the south side of the deck along area 4.

Photograph 67 – Handrail Type 1 to South side of Area 1

Photograph 68 – Handrail Type 2 to North side of Area 1

Photograph 69 – Handrail Type 3 to South side of Area 2



Photograph 70 – Handrail Type 4 to South side of Area 4

7.3 Photographs (71-73) indicate the fixing detail along the south side of the pier. Each handrail upright has a four-bolt fixing to a fabricated bracket. The bracket has been formed from 12mm plates, to form an 'I' section with strengthening plates to the front and rear, as seen in photograph 72. At the top of the brackets, there are web stiffeners located under the upright. These brackets are welded to a vertical flat plate that is bolted between two timber joists forming the deck, see photograph 73.

Photograph 71 – Handrail base details to South side of deck in Area 1

Photograph 72 – Handrail base detail to South side of deck in Area 3,

Photograph 73 – Typical handrail base detail along South side of pier

7.4 Photograph 73 above, indicates the vertical plate that fixes directly to the timber and has no positive fixing to the top chord of the outer south truss. It appears the design philosophy adopted during the major refurbishment circa 2000, utilizes the timber joists and decking boards dead load to provide sufficient counteraction for any load applied to, and from, the handrails.

7.5 The North side of the pier deck has a 200x90 PFC member providing support for the handrail fixings. The bracket to the base of the handrail uprights is an integrated ‘L-shaped’ baseplate as shown in photograph ‘1’ below. The vertical leg of the bracket overhangs the rear of the PFC, the horizontal leg has a two-bolt fixing to a fabricated bracket to the top and front of the PFC edge member. Similar to the south side, there is a vertical plate bolted between the timber deck joists. This plate extends up past the top flange and a horizontal plate is welded across forming a ‘tee’ that allows the fixing of the handrail above.

Photograph 74 – 2-Bolt Handrail base connection on North side of Area 1

7.6 In area 3, a variation of the base detail was noted, see photograph ‘2’ below. Due to the proximity of the transverse frame, the joists have been installed adjacent to the base connection. At this location the support bracket has been installed with a full depth stiffener within the PFC. The plate bolted between the joists has also been welded within the profile of edge PFC.

Photograph 75 – Handrail base connection on North side of Area 3

8.0 Corrosion of elements:

8.1 Observations to the steelwork, previously noted, note significant corrosion to the members, and around the connections. An explanation for this would be that the steelwork was not completely cleaned of all contaminants during the previous refurbishment and corrosion has re-appeared in these areas. Any voids or cracks in the paintwork will allow ingress of salt via the sea water at high tide or moisture in the sea air. This leads to a cyclic issue of damage due to increase in size of void, increases the exposure to the elements and allows greater ingress of contaminants.

8.2 Due to the marine environment, the risk of corrosion would be classed as C4 High or C5 Very High taken from the table in figure 5 below. Clarification of the salinity in the area around the pier would allow confirmation of the corrosive category for the next phase of the remedial works.

Atmospheric corrosivity categories and examples of typical environments (BS EN ISO 12944-2[1])

Corrosivity category	Low-carbon steel Thickness loss (µm)[a]	Examples of typical environments (informative only)	
		Exterior	Interior
C1 very low	≤ 1.3	-	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 low	> 1.3 to 25	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e.g. depots, sports halls
C3 medium	> 25 to 50	Urban and industrial atmospheres, moderate sulphur dioxide pollution; coastal area with low salinity	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies
C4 high	> 50 to 80	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	> 80 to 200	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and high pollution
CX extreme	> 200 to 700	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and sub-tropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere

Notes:

- 1µm (1 micron) = 0.001mm
- [a] The thickness loss values are after the first year of exposure. Losses may reduce over subsequent years.
- The loss values used for the corrosivity categories are identical to those given in BS EN ISO 9223[2].

Figure 5 – Classification of atmospheric corrosivity taken from BS EN ISO 12944-2

8.3 Based on the C4 and C5 categories, and a current lifespan of approximately 20 years, this would mean a loss of section for C4 category of between 1-1.6mm during this time frame, and for C5 category a loss of 1.6-4mm. From the measurements taken during the survey, reduction in section thickness in the transverse frame bracing angles (100x100x15RSA's) varies between 23-41% loss,

which equates to 3-5mm. In some of the longitudinal frames, the 15mm thick flange has reduced down to approximately 6mm in locations, meaning a loss in section of 56%. The values for reduction in section thickness are higher than the anticipated typical thickness loss values given in Figure 6.

8.4 Subject to the specification of the coating applied during the refurbishment, Figure 6 gives an indication of the coating life for C4 and C5 risk categories. This gives a typical coating life of between 15-20 years. This means that the coating is approaching/past the expected lifespan and needs re-applying as soon as possible. From historical photographs online and streetview on Google Maps, the corrosion can be seen to start appearing on the steelwork either side of Marine Drive in approximately 2014. This likely due to inadequate cleaning/painting of the steelwork during the refurbishment in early 2000's.

8.5 It should be noted that to achieve the anticipated coating lifespan, the metals needed to be cleaned to SA $2_{1/2}$ prior to the application of the paint system. Given the difficulty in achieving this level of preparation insitu, and the correct application and control of the original and remedial paint system, especially the remedial paint system where the timber decking and joists remained insitu, together with the added difficulty in accessing tight and in places, inaccessible locations, due to the construction and fixing positions the higher level of failure of the finishes and subsequent areas of corrosion recorded are as expected.

Standard systems for C4 – High risk environment category

System number	E-C4-A	E-C4-B	E-C4-C
Coating life	15-20	20	20+
Nearest equivalent BS EN ISO 12944-5[3]	C4.11	-	-
Surface preparation to BS EN ISO 8501-1[4]	Blast clean to Sa 2½	Blast clean to Sa 2½	Blast clean to Sa 2½
Factory applied coatings	i) Zinc rich epoxy primer 40µm (note 6) ii) High build epoxy MIO 100µm	i) Zinc phosphate epoxy primer 80µm ii) High build glass flake epoxy 300µm	i) Zinc phosphate epoxy primer 25µm (note 7) ii) Elastomeric urethane 1000µm (note 8)
Site applied coatings	High build epoxy MIO 100µm (notes 4 & 5)	Recoatable polyurethane finish 60µm	Recoatable polyurethane finish 60µm

Standard systems for C5 – Very high risk environment category

System number	E-C5-A	E-C5-B	E-C5-C
Coating life	15	20	15
Nearest equivalent BS EN ISO 12944-5[3]	TSM5.01	C5.08	G5.04
Surface preparation to BS EN ISO 8501-1[4]	Blast clean to Sa 3	Blast clean to Sa 2½	-
Factory applied coatings	i) Sprayed aluminium to BS EN ISO 2063[8][9] 150µm (note 9) ii) Zinc phosphate epoxy sealer coat 50µm iii) High build epoxy MIO 100µm (note 4)	i) Zinc rich epoxy primer 40µm (note 6) ii) High build epoxy MIO 200µm total (one or two coats) (note 4)	i) Hot-dip galvanize to BS EN ISO 1461[5] (note 1) ii) Mordant wash iii) Etch primer 40µm iv) High build epoxy MIO 100µm (note 4)
Site applied coatings	Recoatable polyurethane finish 60µm	High solid aliphatic polyurethane finish 60µm	Recoatable polyurethane finish 60µm

Figure 6 – Standard protection systems for C4 & C5 categories from BS EN ISO 14713

9.0 ASSESSMENTS

9.1 There are two different configurations of lateral trusses each with different member types for their top and bottom chords and internal members. Due to their positions the two central trusses support the same loads whereas the outer two trusses support different loadings. The trusses were labelled on site and for assessment as Outer South, Mid South and North, and Outer North.

9.2 Assessment was carried out using Tekla Structural Designer and TEDD's software and supplemented with Excel spreadsheets. These assessments are included in Appendix E.

9.3 Loadings applied to the steelwork are included within the appendices.

9.4 A typical bay of the pier deck was modelled in Structural Designer to determine the axial forces in the truss chords due to the differing loads applied to each truss. The axial forces were used within the spreadsheets to determine the utilisation of the members for compression or tension forces. Figures 7 and 8 indicated the output from Tekla Structural Designer.

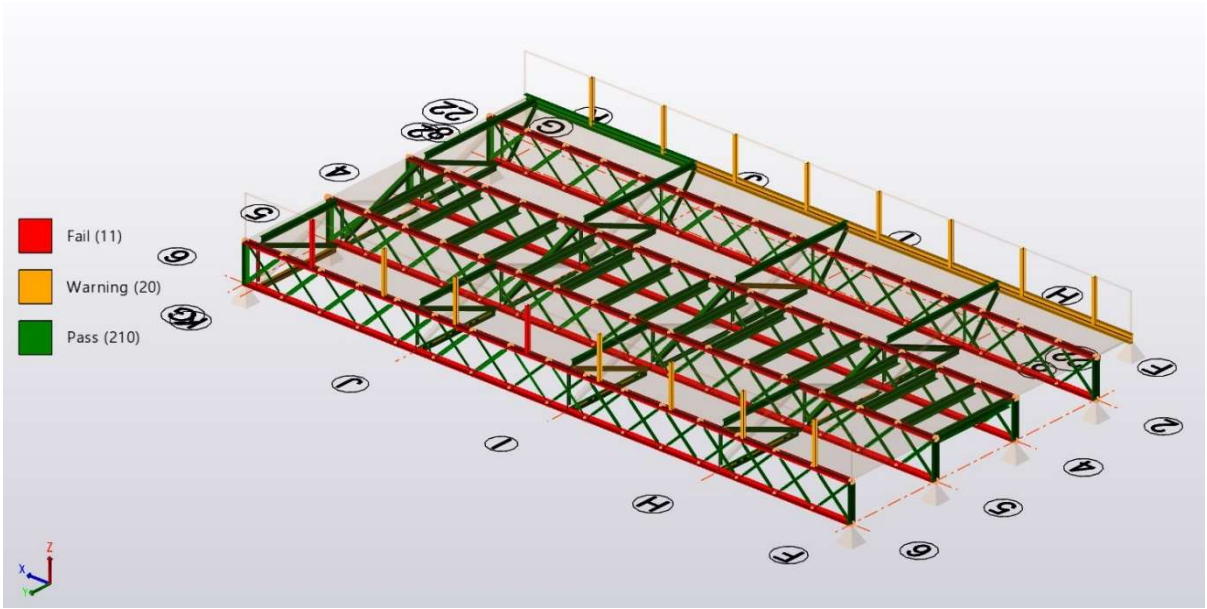


Figure 7 – Output from Tekla Structural Designer Indicating failing members.

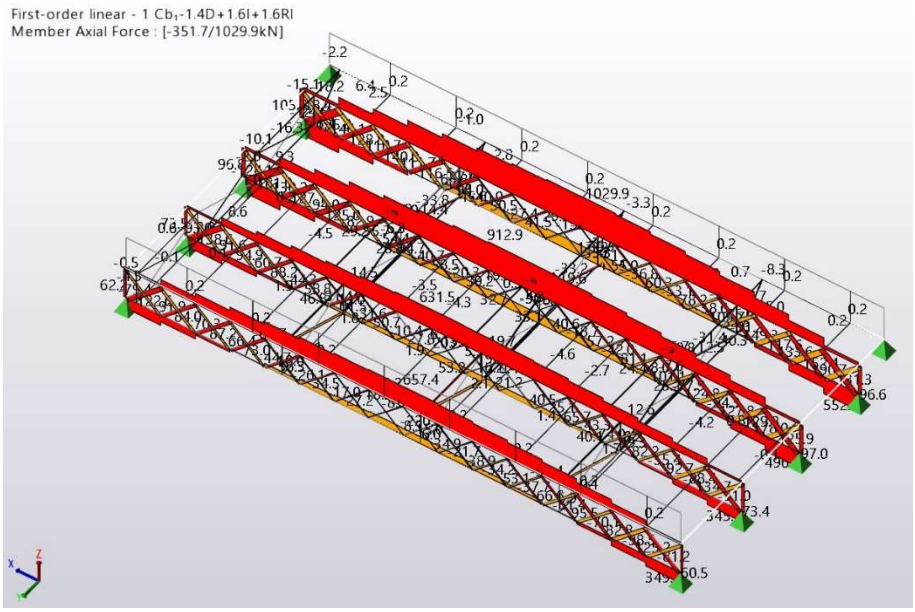


Figure 8 – Output from Tekla Structural Designer Indicating Axial Forces.

9.5 TEDD's 2D frame analysis software was used to determine the member forces for each of the three types of member/load configurations.

9.6 The output from Tekla's 2D truss analysis is shown in figure 9 below highlighting the forces within a truss based on a fully loaded bay, and no loss of section. The tabulated values for the members were exported into Excel to assess the diagonal members.

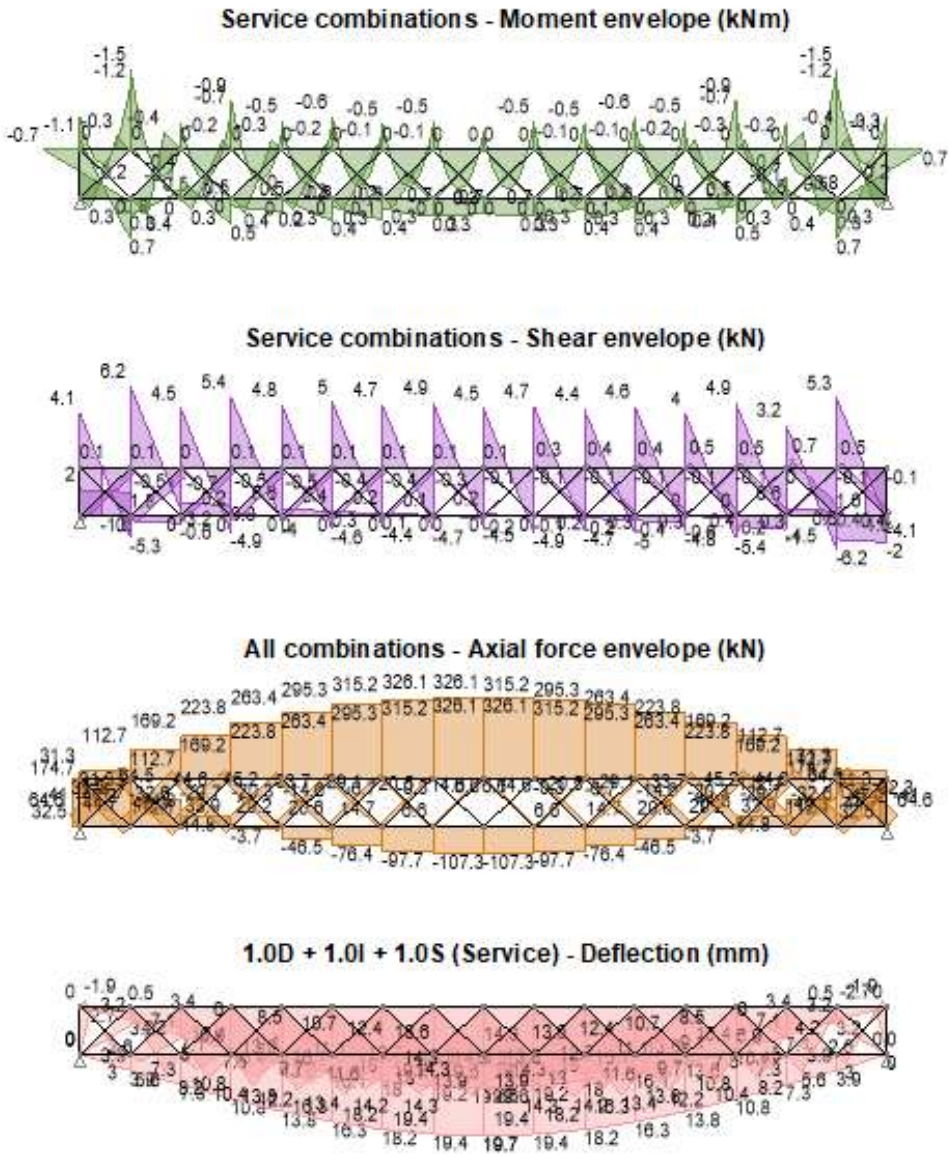


Figure 9 – Output from Tekla TEDD's diagrammatically indicating forces to Outer South Truss.

9.7 A spreadsheet was used to determine the utilisation of each member under full load with the original section properties, the outer trusses have been assessed with top chord lateral restraint at 3.8m and the inner trusses with restraints at 0.95m centres. The assessment of the outer trusses revealed the top chord to fail in compression and bending, reiterative assessments were undertaken to determine the distance between restraints to achieve a utilisation ratio less than 1.0, this was determined to be @ 1.80m coinciding with the distance between handrail standards. Due to the general poor condition of the former tram rail support members between the inner trusses Thomasons are recommending these are removed, therefore these trusses have been reassessed with the top chord restraints @ 1.8m to reflect those required to the outer trusses.

Overall, 52 lattice trusses, within the four areas, have been surveyed at varying points along the top and bottom chords, 1580.8m, together with 1,560No internal members and the 'worst' visually identified sections have been cleaned and measured to ascertain the residual sections.

These residual sections have then been analysed to determine the effects on the section loss observed within the internal members to determine their reduced section utilisation ratios. The results of which have been used to populate the drawings in Appendix A – D advising on repair and replace locations.

9.8 All tabulated results are included within the calculations in Appendix E, despite these results the overriding assessment and conclusion have been based on the instructed scope of assessing the structure to achieve a further 60yr lifespan in that the steelwork needs to be removed from site to be cleaned to SA 2½ prior to repairing any section to have a minimum of 70% of its original section size and painting off-site before re-erection.

Truss Ref:	Chord Ref:	Centre of Truss % section loss Chord Fails	End of Truss % section loss Chord Fails
South Outer Truss	Top	0	0
	Bottom	70	90
South Mid Truss	Top	60	80
	Bottom	80	90
North Mid Truss	Top	30	70
	Bottom	70	90
South Outer Truss	Top	0	0
	Bottom	50	80

Table 23 – Summary of Iterative Assessment of Top and Bottom Chords

9.9 From the results obtained from assessing a fully loaded bay, the following notes summarise the findings for the Outer South and North trusses:

a. The outer truss top chords exceed the compression capacity (utilisation 106%) for the applied axial forces within an unrestrained length of 3.8m.

b. Limiting the length of restraint to 1.8m, the top chords can withstand the compressive forces applied.
c. Bottom chords of the outer trusses were within the design limits for the members but it was determined that if the section loss is 70% of the original section size, the tensile capacity is exceeded.
d. Compression check: Assessment of the frame determined, with no section loss of the members, all diagonal angles passed. Further assessment determined that the first five angle members from the left-hand side of figure 10 below achieved a utilisation of >90% when the loss of section reached between 80-90% of its original area. Two of the flat members at the centre of the truss in compression are exceeding their capacity and will require replacing with suitable angle members.
e. Tensile check: Assessment of the frame determined, with no section loss of the members, all diagonals passed. Further assessment determined that the first six flat members from the left-hand side of figure 10 below achieved a utilisation of >90% when the loss of section reached between 60% at the left-hand member, and 90% on the members closer to the middle of the frame.

9.10 From the results obtained from assessing a fully loaded bay, the following notes summarise the findings for the Mid South and North trusses:

a. The inner truss top chords have sufficient capacity for the stresses applied along an unrestrained length of 0.95m
b. Assessing the trusses based on the removal of the central beams by adding a restraint length of 1.8m proved that there is sufficient capacity in the member to withstand the increased compressive forces.
c. Bottom chords of the outer trusses were within the limits and could withstand a section loss of 70-80% before exceeding the tensile capacity.
d. Compression check: Assessment of the frame determined similar results to the outer trusses. In addition to these members, the equivalent flat forming the cross bracing to the right of the figure above, had a compressive capacity utilisation of 100%.
e. Tensile check: Assessment of the frame determined similar results to the south outer truss, but with the first six flat members varying between 40% and 90% section loss to achieve a utilisation of >90%.

9.11 Figure 10 below indicates indicatively, with flats in blue, and angle in red, the configuration of the internal diagonal members,

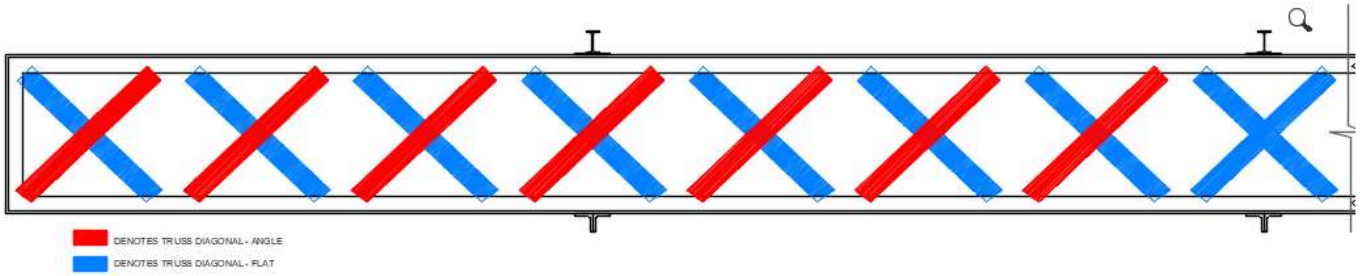


Figure 10 – Part elevation on frame indicating the internal elements (Frame mirrors about centerline of truss).

10.0 CONCLUSION

10.1 Thomasons conclude that based on the survey and analysis undertaken and contained within this report that we are of the opinion that the pier should remain closed until all repair, replacement and strengthening works recommended works are implemented to the area of the survey within this report but also such investigations and assessments are carried out to the whole of the piers structure, including the bridge across the Marine Drive before the pier reopens to the public.

10.2 Based on the analytical assessment of the original trusses, it would appear the existing outer North and South trusses are not suitable in their current configuration to support the suggested – BS6399 Pt 1, Table 1, Designated C5 - Areas susceptible to overcrowding – imposed design load of 5.0kN/m^2 and the use of S275 grade steel in their original configuration. The failure mechanism is due to a lack of restraint to the top chord of the outer North and South trusses, and in order for the trusses to support the implied loads lateral restraints are required at 1800crs.

10.3 The assessment of the inner two trusses also reported the truss chords were sufficient to withstand the applied loading. The results indicate that some of the diagonal flat members at the centre of the truss fail due to compression under the full loadings. These members would be better suited to be replaced with an angle section as per the other compression members within the truss. As noted in the results in Appendix E, the top chord will accept a change in the design by providing positive restraints at a maximum of 1.8m centres, to replace the current restraints at 0.95m.

10.4 Following the survey, it is apparent the steelwork has incurred section loss greater, in locations total loss, than would be expected following the 2002 construction works and subsequent 2017 remedials works, albeit these generally occur in positions where moisture has been retained, i.e. under timber bearing/support locations, tight gaps between cross members in lattice trusses and timber decking sitting on steel members.

10.5 As there are no 2002 as-built construction works it is assumed that all works carried out under that contract were on the basis of providing a further 50 – 60-year structural life span which would have included replacing the decking and timber support members together with any remedial works to the structure between years 20 to 25 thus allowing for a similar cyclic maintenance programme between years 40 – 45. Due to the issues with the works carried out in 2002 the opportunity to implement a cyclic maintenance programme has been lost and a new regime is required alongside the appropriate remedial works to the current structure.

10.6 Thomasons conclude, that due to the current condition of the Pier in the areas surveyed that any insitu repair/replace remedial works undertaken would not be suitable or capable of extending the life of the piers metal structure to 60 yrs. Nor due to the limited locations of the member assessments can a reasonable assumption be made of the remaining lifespan in its current condition due to the varied degradation recorded, without the complete removal of the existing coatings. This would ideally need to include the removal of the embedded salts and undertaken within a controlled environment to fully assess extent and magnitude of the section losses. It should be noted that similar members exhibit little or no section loss whereas other members in close proximity have areas of total section loss, this can only be attributed to the varying quality, application and preparation of the former protective coatings not being appropriate or poorly applied.

10.7 Thomasons further conclude that it is their opinion that carrying out insitu repairs and replacement of the individual members to prolong the current lifespan of the Pier wouldn't achieve a cost-effective approach due to the inherent construction and protection faults nor, if carried out, would they be expected to last long enough to achieve a similar lifespan to match the currently proposed replacement of the timber elements.

10.6 It is therefore Thomasons opinion that in order to achieve a prolongation of the Piers lifespan extending to a further 60yrs into the future that following the removal of the existing timber decking and supported joists that the steelwork is systematically dismantled and taken off site to allow the steelwork to be cleaned via a wet grit blasting process to remove all the existing surface coating, and in the process the embedded salts, prior to repairing the steel by welding in new plates, angles to reinstate the full section capacity together with the additional works noted in Section 11 – Recommendations. This solution also negates issues with the weather and potential issues with the local and over wintering bird life albeit some form of sheeting would need to be provided to discourage roosting affecting any sequence of work.

10.7 Inspection of the handrails revealed that the South side handrail balusters had no positive fixing to the trusses and relied on being bolted between two timbers joists and the mass of the decking above to provide its stability, it should be noted there are no positive fixings between the timber joists and the piers supporting steel structure. Similar reliance was made of the joists and decking on the North side although there was a positive connection of the baluster support bracket to the perimeter channel torsional resistance and stability still relied on the connection to two timber joists and the weight of the timber decking. Thomasons conclude these are not appropriate and positive fixing is

required to support the balusters both vertically and also in torsion. There is opportunity to integrate this detail with the lateral restraint required to the top chord of the trusses as noted in paragraph 11.2 of the recommendations.

11.0 RECOMMENDATIONS

11.1 Due to the amount of corrosion, delamination, loss of section and condition of the existing paint protection system observed to the steelwork, Thomasons recommend that in order to provide a Pier that is both structurally adequate and has a future life expectancy of 60yrs then the structural steel has to be removed off-site to enable the existing finishes to be completely removed, including the embedded salts using a wet grit blasting in a controlled environment. This also allows the 'hidden' inaccessible areas to be similarly cleaned, assessed, and remediated as appropriate prior to re-painting as noted in Section 8.0.

11.2 As noted in Section 9.0 the current configuration of the piers main lattice beam trusses needs to be enhanced for the full design load to be adequately supported, including the loadings applied by the use of the passenger train along the pier. The requirement for this restraint provides opportunity to provide the required top chord restraint of the trusses whilst providing a revised and appropriate support for the handrail standards rather than the current approach that relies on the dead weight of the decking and in places no mechanical anchorage to the main structure.

11.3 Thomasons recommend that consideration is given to using a resin/plastic-based material below the timber joists bearing and the decking laid to permit its systematic replacement over a period of years to allow future maintenance to be adequately budgeted and undertaken. Such a system would initially involve the acceptance that parts of the piers decking would be replaced earlier than initially planned but the follow-on programme would maximise the weakest materials lifespan. This isn't a simple equation and thought needs to be given to maximising the piers accessibility during the works whilst not compromising the work being undertaken. For example, following completion of the necessary work required to make the pier accessible for the public (Year 1), detailing the decking to allow for sectional removal of the decking and supporting joists including any repairs and painting would be undertaken at year 15 and involve removing 8 bays of decking to one half of the piers width, year 16 would involve the opposite half with this cycle continuing over a period of 8 years until the pier has been completely re-joisted, re-decked and the steelwork cleaned/repaired and painted as required. The owners would then have a 15-year respite (to recover and accumulate the required expenditure to continue the same works. This approach is simplistic but involves commitment to replacing and repainting the remediated pier with the aim of establishing a manageable cyclic maintenance regime for the future although in establishing this cycle the initial works undertaken at year 15/16 would include replacement of timbers that still have a remaining 8 years of life expectancy, this can be reduced but would require larger areas of work to be carried out each year.

There are different options to when and how this cyclic maintenance regime is implemented and each option will have differing financial and operation implications, all of which would require exploring, the above is based on future maintenance to half of the pier at any one time whilst the below is based on a third of the pier to try and achieve a maintenance strategy for Sefton MBC moving forward which has a disproportionate cost at years 8 & 16 but resulting in a more cost manageable solution for the piers future maintenance and longevity.

Year 0 – Pier is fully refurbished/re-built with a project lifespan of 60 years.

Year 8 – First 33% of the timber deck and joists are replaced – any steel remedial works are carried out.

Year 16 – Second 33% of the timber deck and joists are replaced – any steel remedial works are carried out.

Year 24 – Third 33% of the timber deck and joists are replaced – any steel remedial works are carried out.

This initially will not be seen as cost effective for Years 8 & 16 but after year 24 the 33% cycle starts again – this doesn't have to be 33% it can be 25% every 6 years – the cycle will depend on Sefton's budgets.

The viability of this approached will be heavily influenced on what works are required to the un-surveyed length of pier and any changes to the structural configuration and proposed protective systems implemented.

11.4 Due to the required top chord restraint and the proposed use of a steel member to provide the restraint whilst also providing a positive connection detail for the handrail standards Thomasons have proposed that there are 6No joists (@ 300crs) between the standards and that these are 63x150 C24 timber joists, currently there are 5No 75x150 Joists between each standard – this revised detail increases the timber volume by 0.008% whilst also suitable to carry the proposed public tram service along the pier.

APPENDIX A

Area 1 Drawings

APPENDIX B

Area 2 Drawings

APPENDIX C

Area 3 Drawings

APPENDIX D

Area 4 Drawings

APPENDIX E

Assessment Calculations

APPENDIX F

Remedial Option Drawings