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BEARING INSPECTION REPORT **FORTH ROAD BRIDGE**

Client: Atkins

Prepared by:

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Forth Road Bridge

Executive Summary

A number of pre-identified rocker & roller bearings were inspected on the north & south approach span piers and north tower on the Forth Road Bridge on the 18th & 19th February 2008. The bearings were visually inspected and recorded. In addition to the inspection, the services of an NDT company were employed but due to the surface treatment condition of the bearings no NDT of any form was able to be carried out.

There was generally little or no evidence of movement witnessed on the bearings inspected. There was evidence of concrete cracking and spalling to the pier tops and base grouts at a number of locations. This could be a consequence of the non movement of the bearings causing stresses to be transferred into the structure.

Generally all bearings showed signs of various degrees of corrosion. The surface treatment to the bearing top plates, base plates and rocker or roller elements was generally satisfactory but heavy corrosion was witnessed at the critical rocker/roller and top plate/base plate interfaces. The roller bearings on pier S3 showed signs of previous irregular wear which has resulted in a change the profile of the roller. This has caused the roller to slide (instead of roll) and as a consequence the teeth of the rack assembly have sheared at a number of positions.

In summary, from the sample of bearings inspected, it can be concluded that none of the bearings are in a serviceable condition. It is recommended that the bearings are either replaced or refurbished or a combination of both.

Client: Atkins
Structure: Forth Road Bridge
Location: South Queensferry, West Lothian
Inspector: Paul Latham
Dates: 18 & 19 February 2008

Introduction

Ekspan were contracted to undertake the inspection of a selection of the bridge bearings on The Forth Road Bridge in order to evaluate their condition and serviceability. The inspection took place on the 18th & 19th February 2008, in the presence of David Lancaster of Atkins & Robert McCulloch of the Forth Estuary Transport Authority (FETA), and consisted of a visual inspection to substantiate the condition of the existing bearings. A selection of rocker & roller bearings at various locations were pre-selected by Atkins for inspection. The report provides findings and conclusion with recommendations.

Structure

The Forth Road Bridge spans the Firth of Forth and links North & South Queensferry, to the West of Edinburgh. The suspension bridge was constructed between 1958 & 1964 and comprises a suspension bridge and two approach viaducts. The whole structure is just over 1.5 miles long, with the central span reaching 3300ft in length and the two side spans each at 1340ft in length. At the time of opening the suspension bridge was the longest in Europe. The bridge carries dual carriageways & a cycle pedestrian lane in each direction.

The approach viaducts to the north & south of the main structure comprise concrete piers with steel box section bridge beams and composite concrete deck. The bridge is articulated on the piers by a series of rocker and roller bearings allowing a combination of rotation and longitudinal & transverse movement.

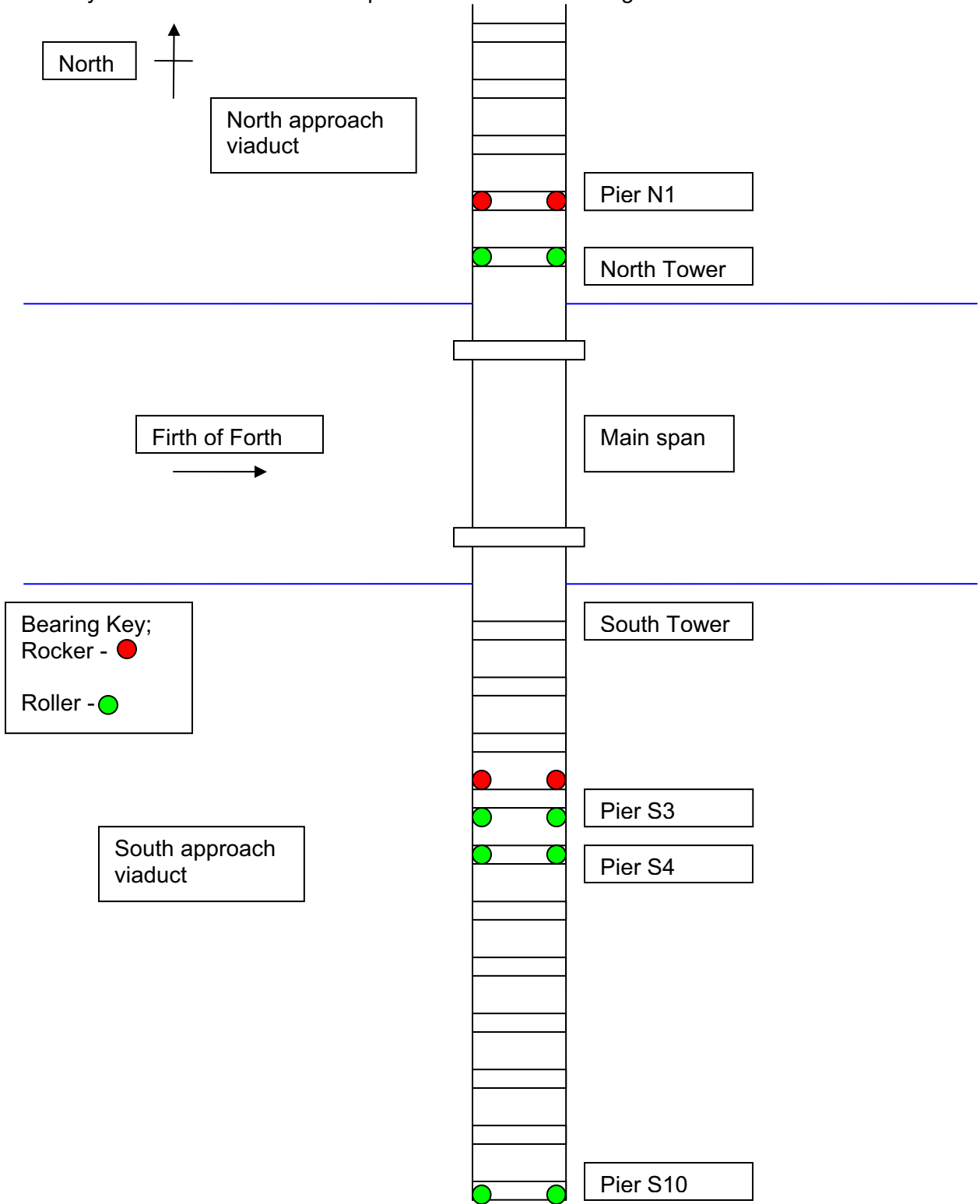


South side viaduct
concrete support
piers

Approach viaduct &
bridge viewed from
south end.

Bearing Identification

The bearings inspected are identified in the bridge plan below. The bearings were inspected individually and the results collated & presented on the following sheets.



Bearing Inspection Report

Structure	Forth Road Bridge
Bearing Type (s)	Roller/Rocker
Serial No;	N/A
Location	Pier S3
Position in structure	S3 West
Photo No (s)	DSC 594/595/596/597 (roller) – DSC 598/600/601/602 (rocker) DSC 611/612 (both)

Plinth condition	Poor with evidence of concrete spawling. Point loading on steel packs beneath rocker causing fracture cracks to pier.
Base grout condition	Poor. Grout showing signs of failure particularly around roller base.
Bearing fully supported	Yes
Top plate condition	Heavy corrosion at roller /top plate interface and rocker/top plate interface.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above, rocker top plate welded to steel beam above.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No evidence of movement on rocker bearing. Movement of between 80 – 100mm witnessed on roller bearing.
Base plate condition	Evidence of heavy corrosion at roller/base plate interface. Roller gear cogs out of synchronization and broken.
Base plate fixings condition	Rocker bearing good condition. Roller bearing fixings showing some signs of corrosion to bolt heads.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally unsatisfactory with evidence of heavy corrosion to rocker/top plate interface & roller/top plate/base plate interfaces.
Structural concrete condition	Spawling witnessed on north face of pier with evidence of previous repair work been carried out at an earlier date.
Water penetration evidence	Evidence of water penetration around roller base grout bed.
Inspector's Comments	<p>Roller Bearing</p> <p>Excessive corrosion to both the top & bottom bearing faces & to the corresponding roller surface causing irregular wear and changes to the profile of the roller. This has caused the roller to slide and break the teeth off the rack assembly.</p> <p>The base grout is of poor quality & has insufficient cover around the perimeter of the bearing. There is evidence of sections of the base grout separating from the base plate which has probably been caused by the sliding effect of the roller.</p> <p>The paint system is generally in poor condition. The bearing is in an unserviceable state.</p>

	<p>Rocker Bearing Extensive wear to rocker top plate with evidence of severe corrosion. The painted areas on the rocker ends show no signs of any movement which seems to suggest that the bearing is not functioning as it was designed for.</p> <p>There is evidence of the base grout separating from the rocker base. This has exposed the steel shim packs beneath suggesting that possible point loading is occurring. This is further justified by the concrete spawling witnessed on the pier top, directly below the steel shims.</p>
<p>Recommendation</p>	<p>Both the rocker & roller bearing should be replaced as neither are functioning correctly.</p>

Pier S3 – Position: S3 West - Roller Bearings



No. DSC 594



No. DSC 595



No. DSC 596



No. DSC 597

Pier S3 – Position: S3 West - Rocker Bearings



No. DSC 598



No. DSC 601



No. DSC 600



No. DSC 602

Pier S3 – Position: S3 West - Roller and Rocker Bearings



No. DSC 611



No. DSC 612

Structure	Forth Road Bridge
Bearing Type (s)	Roller/Rocker
Serial No;	N/A
Location	Pier S3
Position in structure	S3 East
Photo No (s)	DSC 603/604/605/606 (roller) – DSC 607/608/609/610 (rocker) DSC 629 (both)

Plinth condition	Poor with evidence of concrete spawling. Point loading on steel packs beneath rocker causing fracture cracks to pier.
Base grout condition	Poor. Grout showing signs of failure particularly around roller base.
Bearing fully supported	Yes
Top plate condition	Heavy corrosion at roller /top plate interface and rocker/top plate interface.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above, rocker top plate welded to steel beam above.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No evidence of movement on rocker bearing. Movement of between 80 – 100mm witnessed on roller bearing.
Base plate condition	Evidence of heavy corrosion at roller/base plate interface. Roller gear cogs out of synchronization and broken.
Base plate fixings condition	Rocker bearing good condition. Roller bearing fixings showing some signs of corrosion to bolt heads.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally unsatisfactory with evidence of heavy corrosion to rocker/top plate interface & roller/top plate/base plate interfaces.
Structural concrete condition	Spawling witnessed on north face of pier with evidence of previous repair work been carried out at an earlier date.
Water penetration evidence	Evidence of water penetration around roller base grout bed.
Inspector's Comments	<p>Roller Bearing</p> <p>Excessive corrosion to both the top & bottom bearing faces & to the corresponding roller surface causing irregular wear and changes to the profile of the roller. This has caused the roller to slide and break the teeth off the rack assembly.</p> <p>The base grout is of poor quality & has insufficient cover around the perimeter of the bearing. There is evidence of sections of the base grout separating from the base plate which has probably been caused by the sliding effect of the roller.</p> <p>The paint system is generally in poor condition. The bearing is in an unserviceable state.</p> <p>Rocker Bearing</p> <p>Extensive wear to rocker top plate with evidence of severe corrosion.</p>

	<p>The painted areas on the rocker ends show no signs of any movement which seems to suggest that the bearing is not functioning as it was designed for.</p> <p>The base grout is of poor quality & shows signs of insufficient cover around the base.</p>
Recommendation	Both the rocker & roller bearing should be replaced as neither are functioning correctly.

Pier S3 – Position: S3 East - Roller Bearings



No. DSC 603



No. DSC 604



No. DSC 605



No. DSC 606

Pier S3 – Position: S3 East - Rocker Bearings



No. DSC 607



No. DSC 608



No. DSC 609



No. DSC 610

Pier S3 – Position: S3 East - Roller and Rocker Bearing



No. DSC 629

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	Pier S4
Position in structure	S4 West
Photo No (s)	DSC 613/614/615/616

Plinth condition	Satisfactory
Base grout condition	No evidence of structural failure, excessive paint applied to base grout.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory although evidence of corrosion at roller /top plate interface witnessed.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above. Connection appears structurally sound.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	Minimal evidence of movement witnessed.
Base plate condition	Generally satisfactory. Evidence of corrosion at base plate/roller interface.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory except at roller/top plate/base plate interfaces.
Structural concrete condition	Spawling witnessed on west face of pier.
Water penetration evidence	None witnessed.
Inspector's Comments	Heavy corrosion to both top & bottom bearing faces & to the corresponding roller surface causing an irregular bearing surface. A consequence of this may cause an increase in stresses being transferred to the sub-structure. Large areas of stress cracking to the west pier sub-structure were witnessed. Evidence of any movement is very minimal. The paint system is generally in poor condition.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced.

Pier S4 – Position: S4 West



No. DSC 613



No. DSC 614



No. DSC 615



No. DSC 616

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	Pier S4
Position in structure	S4 East
Photo No (s)	DSC 630/631/632/633

Plinth condition	Generally satisfactory
Base grout condition	Poor quality and porous in appearance.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory although evidence of corrosion at roller /top plate interface witnessed.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No visible evidence of movement witnessed.
Base plate condition	Generally satisfactory. Evidence of corrosion at base plate/roller interface.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory except at roller/top plate/base plate interfaces.
Structural concrete condition	Evidence of cracking witnessed on north face of pier. Spawling witnessed on east face of pier.
Water penetration evidence	None
Inspector's Comments	Heavy corrosion to both top & bottom bearing faces & to the corresponding roller surface causing an irregular bearing surface. A consequence of this may cause an increase in stresses being transferred to the sub-structure. Areas of stress cracking to the north pier sub-structure were witnessed & concrete spawling witnessed on east face of pier. No evidence of any movement was witnessed. The paint system is generally in poor condition.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced.

Pier S4 – Position: S4 East



No. DSC 630



No. DSC 631



No. DSC 632



No. DSC 633

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	Pier S10
Position in structure	S10 West
Photo No (s)	DSC 617/618/619/620

Plinth condition	Satisfactory
Base grout condition	No evidence of structural failure, excessive paint applied to base grout.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above. Connection appears structurally sound.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	Evidence of minimal movement witnessed.
Base plate condition	Generally satisfactory.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory. Evidence of corrosion at north west corner base.
Structural concrete condition	Spawling witnessed on west face of pier.
Water penetration evidence	None witnessed.
Inspector's Comments	The bearing is coated in excessive paint and any movement would normally be clearly visible between mating moving components. The bearing shows little or no movement at all. There is evidence of concrete spawling to the west face of the pier.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

Pier S10 – Position: S10 West



No. DSC 617



No. DSC 618



No. DSC 619



No. DSC 620

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	Pier S10
Position in structure	S10 East
Photo No (s)	DSC 634/635/636/637

Plinth condition	N/A
Base grout condition	Generally poor quality, showing signs of laminating and porous in appearance.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above. Connection appears structurally sound.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No evidence of movement witnessed.
Base plate condition	Generally satisfactory.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory.
Structural concrete condition	Spawling witnessed on east face of pier. Re-bar exposed in two separate locations.
Water penetration evidence	None witnessed.
Inspector's Comments	The bearing is coated in excessive paint and any movement would normally be clearly visible between mating moving components. The bearing shows no movement at all. There is evidence of concrete spawling to the east face of the pier with re-bar exposed at two positions.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

Pier S10 – Position: S10 East



No. DSC 634



No. DSC 635



No. DSC 636



No. DSC 637

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	North Side Tower West
Position in structure	West
Photo No (s)	DSC 625/626/627/628

Plinth condition	Evidence of cracking on north face.
Base grout condition	Generally poor quality and porous in appearance.
Bearing fully supported	Yes
Top plate condition	Heavy corrosion evident between top bearing surface and roller.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above. Connection appears structurally sound.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	Evidence of minimal movement witnessed. Roller is offset from original centre.
Base plate condition	Heavy corrosion all round. Roller gear cogs out of synchronization and broken.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings. Bolt heads showing signs of corrosion.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally unsatisfactory with evidence of heavy corrosion between roller/top plate/base plate interfaces.
Structural concrete condition	Generally satisfactory.
Water penetration evidence	None witnessed.
Inspector's Comments	<p>Excessive corrosion to both the top & bottom bearing faces & to the corresponding roller surface causing irregular wear and changes to the profile of the roller. This has caused the roller to slide and break the teeth off the rack assembly. The roller has slid approximately 50mm from its original centre position.</p> <p>The base grout is of poor quality & has insufficient cover around the perimeter of the bearing. There is evidence of sections of the base grout separating from the base plate which has probably been caused by the sliding effect of the roller.</p> <p>The paint system is generally in poor condition. The bearing is in an unserviceable state.</p>
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

North Side Tower West – Position: West



No. DSC 625



No. DSC 626



No. DSC 627



No. DSC 628

Structure	Forth Road Bridge
Bearing Type (s)	Roller
Serial No;	N/A
Location	North Side Tower East
Position in structure	East
Photo No (s)	DSC 621/622/623/624

Plinth condition	Generally satisfactory.
Base grout condition	Generally poor quality with evidence of surface lamination and porous in appearance.
Bearing fully supported	Yes
Top plate condition	Heavy corrosion evident between top bearing surface and roller.
Top plate fixings condition	N/A. Roller top plate welded to steel beam above. Connection appears structurally sound.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	Evidence of minimal movement witnessed. Roller is offset from original centre.
Base plate condition	Heavy corrosion witnessed to north side in particular. Heavy corrosion evident at roller/base plate interface. Roller gear cogs out of synchronization and broken.
Base plate fixings condition	Counter-bored fixing holes. Unable to ascertain condition of fixings. Bolt heads showing signs of corrosion.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally unsatisfactory with evidence of heavy corrosion between roller/top plate/base plate interfaces.
Structural concrete condition	Generally satisfactory.
Water penetration evidence	None witnessed.
Inspector's Comments	<p>Excessive corrosion to both the top & bottom bearing faces & to the corresponding roller surface causing irregular wear and changes to the profile of the roller. This has caused the roller to slide and break the teeth off the rack assembly. The roller has slid approximately 30mm from its original centre position.</p> <p>The base grout is of poor quality & has insufficient cover around the perimeter of the bearing. There is evidence of sections of the base grout separating from the base plate which has probably been caused by the sliding effect of the roller.</p> <p>The paint system is generally in poor condition. The bearing is in an unserviceable state.</p>
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

North Side Tower East – Position: East



No. DSC 621



No. DSC 622



No. DSC 623



No. DSC 624

Structure	Forth Road Bridge
Bearing Type (s)	Rocker
Serial No;	N/A
Location	Pier N1
Position in structure	N1 West
Photo No (s)	DSC 648/649/650/651/652

Plinth condition	N/A
Base grout condition	Generally poor quality with evidence of surface lamination from pier water penetration around base.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory but with evidence of heavy corrosion between rocker & top plate interface.
Top plate fixings condition	N/A. Rocker top plate welded to steel beam above.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No evidence of movement on bearing.
Base plate condition	Generally satisfactory but some areas of minor corrosion evident between base and grout bed.
Base plate fixings condition	Generally satisfactory condition but some areas of corrosion present on bolt heads.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory with evidence of heavy corrosion to rocker/top plate interface.
Structural concrete condition	Cracks witnessed on west face of pier. Crack propagation from central load point of bearing.
Water penetration evidence	Evidence of water penetration around rocker base grout bed.
Inspector's Comments	The bearing shows signs of heavy wear on the top plate mating surface, although there is no evidence to suggest that there has been any movement recently. Extensive wear to rocker top plate with evidence of severe corrosion. The crack on the west face of the pier is propagating from the bolt line on the north side and is approximately 600mm in length. This is a possible sign of over-loading.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

Pier N1 – Position: N1 West



No. DSC 648



No. DSC 649



No. DSC 651



No. DSC 652



No. DSC 650

Structure	Forth Road Bridge
Bearing Type (s)	Rocker
Serial No;	N/A
Location	Pier N1
Position in structure	N1 East
Photo No (s)	DSC 653/654/655/656/657/658

Plinth condition	N/A
Base grout condition	Generally poor quality and porous in appearance. Steel packs are exposed at a couple of locations within the grout bed.
Bearing fully supported	Yes
Top plate condition	Generally satisfactory but with evidence of heavy corrosion between rocker & top plate interface.
Top plate fixings condition	N/A. Rocker top plate welded to steel beam above.
Stainless steel bearing surface condition	N/A
Witness & extent of movement	No evidence of movement on bearing.
Base plate condition	Generally satisfactory but some areas of minor corrosion evident between base and grout bed.
Base plate fixings condition	Generally satisfactory condition but some areas of corrosion present on bolt heads.
PTFE condition & thickness	N/A
Elastomeric pad condition	N/A
Bearing Rotation	N/A
Bearing surface treatment condition	Generally satisfactory with evidence of heavy corrosion to rocker/top plate interface.
Structural concrete condition	Some evidence of light cracking to east face of the east bearing.
Water penetration evidence	Evidence of water penetration around rocker base grout bed.
Inspector's Comments	The bearing shows signs of heavy wear on the top plate mating surface, although there is no evidence to suggest that there has been any movement recently. Extensive wear to rocker top plate with evidence of severe corrosion.
Recommendation	It is unlikely that this bearing is functioning correctly & ideally the bearing should be replaced or fully refurbished.

Pier N1 – Position: N1 East



No. DSC 653



No. DSC 654



No. DSC 656



No. DSC 658



No. DSC 657

Conclusion

There was generally little or no evidence of movement witnessed on the bearings inspected. There was evidence of concrete cracking and spalling to the pier tops and base grouts at a number of locations. This could be a consequence of the non movement of the bearings causing stresses to be transferred into the structure.

All bearings showed signs of various degrees of corrosion. The surface treatment to the bearing top plates, base plates and rocker or roller elements was generally satisfactory but heavy corrosion was witnessed at the critical rocker/roller and top plate/base plate interfaces. The roller bearings on pier S3 showed signs of previous irregular wear which has resulted in a change the profile of the roller. This has caused the roller to slide (instead of roll) and as a consequence the teeth of the rack assembly have sheared at a number of positions.

A specialist NDT sub-contractor was employed to carry out ultra-sonic or magnetic particle inspection (MPI) of the bearings. However, due to the poor surface condition of the bearings no NDT could be carried out as readings could not be correctly identified. Therefore the structural integrity of the rocker or roller elements cannot be quantified at this stage.

Recommendations

From the inspection results collated and the conclusion above it can be concluded that none of the bearings are in a serviceable condition. It is recommended that a full bearing replacement or refurbishment scheme is investigated and developed to restore the articulation of the structures to their original state.