Forth Road Bridge

Main Expansion Joints- Condition Inspection Report

Forth Estuary Transport Authority

May 2015

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Table of contents

Executive summary

Investigation and inspection of the Forth Road Bridge roller shutter joints have been ongoing since before 2007. Previous investigations indicated that the joint had reached the end of it's service life and required replacement. A scheme to replace the joint was initially prepared but delayed after the announcement of the construction of the new Queensferry Crossing.

Failsafe measures were designed and installed in 2010 to allow the safe operation of the joint until the commissioning of the new crossing in 2016 reduces traffic demand on the Forth Road Bridge and permits better access to replace the joints.

The failsafe measures installed are passive components which do not replace the functioning of the joint components or safeguard the uninterrupted operational integrity but they do ensure public safety by preventing major failure of the joint.

As part of the management of the joint, regular condition inspections and joint openings are undertaken to confirm that the condition and rate of deterioration is not increasing at an unexpected rate.

The joint opening inspection and gap measurements undertaken in October 2014 and May 2014 respectively indicated that the joint has worn and parts of the failsafe measures are now taking load. The wear necessary to engage the failsafe measures is small and not outside the wear rate expected from previous measurements, however regular inspection and gap measurements should be undertaken to ensure that the rate of deterioration does not accelerate.

The decision to delay the replacement of the joint until the new Queensferry crossing is in place balances a number of risk factors such as increased journey time, maintenance costs and available diversion routes during a joint replacement set against the possibility and consequences of a joint failure. A new Crossing will affect this balance. The joints are currently subject to a management regime to ensure safe operation is maintained, however this is designed to swiftly detect defects to limit any risk to the public and not prevent defects from occurring. The replacement of the joints should remain a high priority once the new Queensferry Crossing is in operation.

GLOSSARY OF TERMS

Term	***Meaning / Definition***
FETA	Forth Estuary Transport Authority
FMEA	Failure Mode and Effect Analysis
ALARP	As Low As Reasonably Practicable

1. Introduction

Atkins has been requested by the Forth Estuary Transport Authority (FETA) to undertake a condition inspection of the main roller shutter joints in the Forth Road Bridge. This forms part of the ongoing management of the joint and accords with the inspection regime agreed as part of the Failure Mode and Effect Analysis ('Extending the Life of the Main expansion Joints' Atkins reference 5057541/011) undertaken as part of design and verification of the joint failsafe scheme installed in 2010.
The purpose of the FMEA undertaken and installation of failsafe measures is to allow the safe management of the main expansion joints until the replacement of the joints can be undertaken with minimum disruption to the travelling public. In 2016 the new Queensferry Crossing is planned to be operational allowing traffic to be diverted onto the new crossing reducing the potential for traffic disruption, and therefore reducing the risk of consequent adverse economic effects in the region.

It should be noted that the existing joints are extensively worn, and are at the end of their service life, and there is the risk that part of a joint could fail before 2016. Although the risk of failure is low, a failure could result in an incident and closure of a carriageway on the bridge. The failsafe measures are design to reduce the likely consequence of a failure. However, should a failure occur, closure of a carriageway on the bridge (with associated traffic disruption) will be required until repairs are completed.

2. Scope of Report

The roller shutter joints are the main carriageway deck movement joints located at both main towers and on both carriageways of the suspended section of the bridge. This inspection report will cover the opening up and inspection of a single joint train (North Tower, main span, northbound carriageway, joint train 3). The opportunity was taken during the work to visually inspect the adjacent joint trains. This report discusses the observed condition of the roller shutter joint and makes comparisons with the previous joint openings undertaken. Inspection of the failsafe measures was also undertaken. The results of this inspection and other condition monitoring measurements is discussed with recommendations on future actions to take.

3. Background

3.1. Overall Description of Structure

In 2007 Atkins was commissioned by FETA to investigate options for either the repair or replacement of all the bridge deck movement joints in the Forth Road Bridge. This was in response to increasing maintenance work on the joints and the findings of inspections which revealed areas of heavy wear. A final report (ref 5032119.125.002 Rev B 'Options Report for Bridge Deck Joints') was presented in November 2007. The report concluded that the joints have reached the end of their useful service life and all should be replaced to ensure satisfactory long term performance. In addition an improvement to general access for inspection and maintenance of the main roller shutter joints under the bridge deck was recommended.

As a consequence Atkins prepared tender documentation for the work to the joints and subsequently for the improved access. Installation of the new joints would have required long term access to the joints from the carriageway under carriageway and full bridge closures. Such closures would have severe detrimental effects on traffic flows over the bridge and, as a consequence, significant economic effects in the region.

After the return of the tenders, but before award of a contract, the Scottish Government announced on 10th December 2008 that a new Forth Replacement Crossing would be in place by 2016. In response FETA requested that Atkins investigate the consequences of retaining the joints until the new crossing is in place.

The results of this investigation were the implementation of failsafe measures determined from a FMEA undertaken for the joint. This analysis agreed a number of management measures to be applied to ensure the risks were maintained at ALARP levels. These included regular visual inspections undertaken from the improved access platforms, carriageway measurements of joint train gaps and, lifting of sample joint trains at intervals to undertake a more detailed condition inspection.

This roller shutter joint opening and inspection form part of the agreed management measures for the joint.

4. Joint Opening and Inspection

4.1. Description of the Roller Shutter Joints

Each separate roller shutter joint in the bridge comprises a series of six individual units. Each unit has effectively two movement joints, one for each (side and main) span. Each individual movement joint comprises a shuttle (also known as a bridge or anchor) plate, which is articulated on the deck side and effectively spans over the physical movement gap of the deck itself. On the opposite side to the deck, the shuttle plate is connected to a series of link plates by hinges to form a train. The shuttle and link plates slide, via discrete feet, over the curved top flanges of track beams as the deck moves. The other side of the joint supports a tongue plate. This tongue plate is also supported on top of the link plate train to form a level running surface for traffic. An as-built drawing showing the typical layout of the joint is included in Appendix A.

As part of the joint opening, a single tongue plate and joint train (shuttle and link plates) are lifted from their working position and laid upside down on the carriageway. This allows access to the train to inspect the wear to the joint feet, hinge pins and bushing.

The slide track, remaining in position, is also accessible for inspection. The condition of the feet and slide track of adjacent joints can also be partially assessed

4.2. Previous Inspection and Maintenance

A number of previous joint opening inspections have been undertaken throughout the life of the Forth Road Bridge. The main carriageway joint at the North Tower, main span, joint train 3 on the northbound carriageway, was previously opened and inspected in January 2009. This inspection was undertaken by FETA and witnessed by Atkins as designer and Flint and Neil as peer reviewer. The joint was chosen as observations had indicated it to be most heavily worn. The joint train sits within the wheel track of lane 1 and experiences high vehicle loading and longitudinal bridge movements. The inspection confirmed earlier assessments that the joint had reached the end of its service life and that piecemeal replacement of parts were unlikely to be successful owing to the wear in complimentary elements, requiring a more holistic replacement strategy. The key areas of wear noted were:

- Excessive wear of the hinge pins and bushing allowing lateral movement between link plates and vertical movement of adjacent link plates
- Excessive wear of link plate feet,
- Excessive wear of slide track running surface,
- Excessive wear of tongue plate and anchor plate feet and bearing blocks,
- Excessive wear of tongue plate and anchor plate lateral restraints,
- Worn tongue plate edge and weakened/cracked holding down springs,
- Worn edges to adjacent deck plates and a drop in level (due to wear) of the joints.

The results of the inspection are included in Atkins report 5032119.125.002 Rev B ‘Options Report for Bridge Deck Joints’.

As a result of the inspection and the FMEA undertaken a number of maintenance and failsafe measures were designed and implemented. These included

- Replacement and upgrading of Tongue plate and Anchor plate holding down springs.

- Installation of secondary, passive, link plate hinges.
- Installation of secondary vertical/horizontal restraints to Tongue plate and Anchor plates
- Installation of link plate “end stops”

Procurement and installation was undertaken by FETA and undertaken during night time carriageway closures in 2009.

To allow an assessment of on-going wear to be made, the gap between each plate train was measured across the width of the bridge at each joint location. These measurements were repeated at 2-3 year intervals.

4.3. Joint Inspection October 2014

4.3.1. Access

The inspection was undertaken on the morning of Sunday 12th October utilising a northbound carriageway closure. The weather during the inspection was damp and cool. Other surfacing and maintenance works were undertaken concurrently to fully utilise the carriageway closure. During the closure the tongue plate and joint train of the main expansion joint at the North tower, joint train 3 were lifted allowing inspection to the underside of these elements and the tops of the slide track beams. The joint train had previously been lifted and inspected in January 2009, allowing a direct comparison of the change in condition over the intervening 5 years.

Access to the underside of the remaining North Tower main and side span carriageway expansion joints was also available.

4.3.2. Key Inspection Findings

The inspection indicated that all areas of wear had noticeably increased. In particular:

- Slide track wear to top surface increased in depth(maximum measured wear 9.0 mm (Photograph 10 - Photograph 11),
- Joint train feet excessively worn (Photograph 2 - Photograph 5, Photograph 12 - Photograph 14),
- Hinge pin holes and bushing excessively worn (Photograph 3 - Photograph 5, Photograph 12 - Photograph 14),
- Tongue plate and Anchor plate bearing blocks worn causing a step in the carriageway (Photograph 7 - Photograph 9, Photograph 16).
- Accumulated wear in components affecting carriageway running profile, leading to increased noise and dynamic effects.

In addition, the inside of the failsafe components were inspected and found to show signs of taking up load. The intention of the failsafe is to act as a passive system and only take load if the hinge fails.

Inspection photographs are included in Appendix B.

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5. Joint gap measurements

5.1. Measurement Methodology

A quantitative measure of the joint wear has been undertaken by FETA over a period of 5 years. Measurements were taken of the maximum gap between the individual plate train elements. Access to enable measurements of the joint gap is via the carriageway during a maintenance closure. The gap is measured at 6 locations across each plate, on each plate train and for all accessible joint gaps, making a total of 432 measurements for the bridge (including the side span joints). The joint is wedged apart using a steel wedge driven into the gap at the transverse centre of the joint with a hammer to ensure the maximum gap is checked. The gap is then measured using a steel rule. The measurements have been repeated at approximately 2-3 year intervals.

5.2. Gap Measurements

The last series of measurements were undertaken on 7 and 20 May 2014. The original gap as designed is stated on the original as built drawings as 2mm (Ref Drawing BE 6041a) measured with the joint flat. The maximum measured gap determined from the survey in-situ was 43mm, with an average over the plate of 35.5mm. The average measured gap over all joint plates was 22.5mm.

The inspection results indicate a range of gap sizes depending upon which train is measured and where the measurement is taken. A comparison of results for a given plate gap measured at successive inspections indicates that reproducibility of results at a particular position appears to be good (see original FETA report “Measurement difference gap survey sheets from 2012 to 2014”). A number of graphical representations of the measurement have been produced and are included in Appendix C.

The three sets of measurements taken span in time since the installation of the hinge failsafe linkages undertaken in 2009. It can be seen from inspection of the raw data line graphs (Appendix C) that the failsafe appear to be in operation, taking load and restricting further opening of the joint gap. Some evidence of wear in the failsafe components was noted during the inspection.

5.3. Failsafe Components

The failsafe components’ design intent is to act as a passive system, taking load only when the hinges or other components fail. The condition of the carriageway surface, slide rails, feet and bearings restrict free movement of the joint and increase frictional and dynamic load effects. The service loading on the failsafe components under these conditions is unknown but likely to have increased beyond the limited design basis loading.

From the inspection undertaken wear on the hinges, slide rails, feet and bearings continues to accrue as the movement of the bridge continues. Wear on the failsafe components, particularly the bolted hinge plates, will occur as load is passed from the hinges to the failsafes. It is anticipated that wear on the bolts, and wear and plastic deformation of the bolt holes will occur as load is shared from the hinges. The failsafe hinge linkages are not robust enough to replace the main hinges under full service loading should the original hinges fail.

6. Conclusions and Recommendations

6.1. Condition of the Existing Roller Shutter Deck Joint

The opening and Inspection of the roller shutter joint has confirmed the condition of the joints is as previously assessed. The wear on the joint was observed to be increased from the last opening of this train in 2009. The wear rate is broadly as anticipated and indicative of a continuation in the rate of wear previously observed.

The previous opening and inspection of the joint at the South Tower, main and side span, southbound carriageway was undertaken in 2012. The joint was selected as noticeable deterioration in the joint had occurred over a short period. Upon inspection a bolt was found to be wedged between the plate foot and slide train, restricting the plate movement on one side. In the original as-built condition the gaps between plates were too small to allow ingress of debris to cause damage to the joint. The joint gaps, hinge pin holes and slide track wear were all noted as being excessive, allowing the possibility of debris entering the joint, adversely affecting its functioning and increasing wear.

The original inspection findings, that the joint has passed its service life, remain applicable.

6.2. Recommended Actions

The failsafe hinge linkages currently show signs of taking up load. Excess loading on the linkages will cause wear and plastic deformation. It is recommended that linkages are inspected and checked to ensure bolts remain undamaged and bolt holes not unduly enlarged. This will require some disassembly and reassembly of suspect components.

The routine inspection of the joints should continue as currently undertaken with any change to the condition of components recorded.

As the joint wears the carriageway level becomes more uneven and the gaps in the carriageway increase in size, more debris can accumulate on the slide track. This has the possibility of causing the joint to lock. Locking of the joint can increase the load exerted onto the hinges and anchor plate bearings. The current regime of regular cleaning and inspection of the slide track and joint components should continue. This will reduce the risk of debris locking up the joint, but not remove the risk altogether.

The failsafe hinge linkages from inspections appear to be engaged. Consideration has been given to extending the range (by enlarging the linkage) but this is not thought to provide any significant benefit to the joint. The gap opening measurements should be continued to determine if detectable wear in the failsafe hinge linkages is occurring.

6.3. Intervention levels

Currently the joint condition is maintained in a safe condition by a regime of regular inspection and routine maintenance, this should continue.

Wear on the joint is caused by a combination of traffic loading and bridge movement resulting from wind, temperature and vehicle loads. As wear levels increase, “nests” worn into the top of the slide beams increase in depth. Under extreme movement ranges, the force required to move the joint feet up and out of the “nests” increases. It is therefore important to define the movement of the joint at which loading on the hinge components will be increased. Monitoring of the joint to ensure the movement range remains within the slide track “nests” should be undertaken. When the movement range falls outside of this range, additional inspection and monitoring of the joint to ensure correct functioning should be undertaken.

The current management of the joint is a product of an ALARP assessment of the comparison of the effects of replacing the joint (additional travel risks and delay costs) compared to continuing with an inspection based approach with the installation of a failsafe backup. The opening of the new Queensferry Crossing will allow improved access for replacement of the roller shutter joint and alter the ALARP balance. It is recommended that the joint replacement is undertaken as soon as possible following the commissioning of the new Crossing.

The smoothness of the carriageway running surface is affected by the wear to the various components of the joint. Corrections to these levels has proven difficult to instigate owing to the nature of the wear. Steps in carriageway levels is typically limited to 12mm for a carriageway and gap widths to 65mm for an expansion joint as per DMRB guidelines (BD 33/94 and BA 26/94).

Under extreme movement ranges, joint feet will be pulled up and out of the “nests”, increasing the undulation of the carriageway surface and increasing dynamic loading from vehicles crossing the joint. It is therefore important to define the movement of the joint at which the joint train will be raised from the worn area of the slide track. Monitoring of the joint to ensure the movement range remains within the slide track “nests” should be undertaken. When the movement range falls outside of this range, additional inspection and monitoring of the joint shall be undertaken and corrective measures shall be designed to keep the movement of the joints within track “nests”.

The effects of increasing wear on the carriageway running surface should be considered and monitoring undertaken to ensure this remains within acceptable limits.

Appendix A. General Arrangement Drawings of Existing Joints

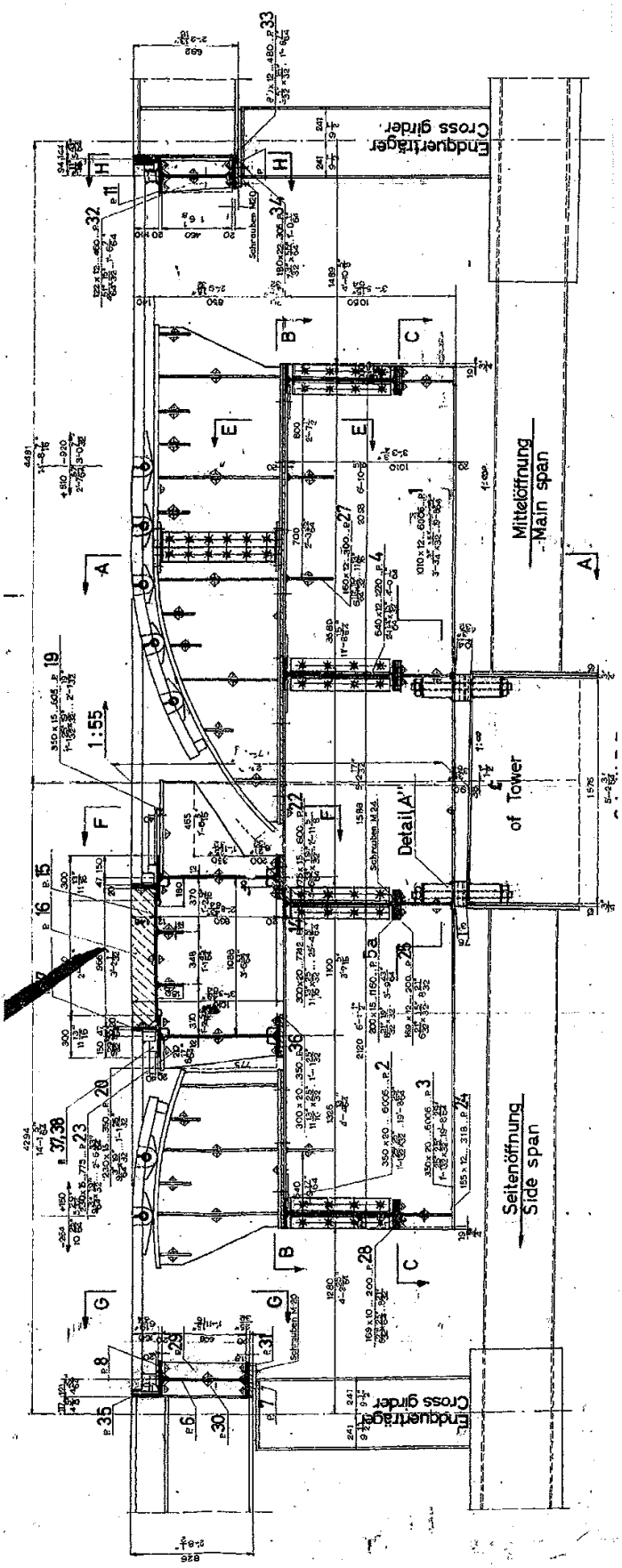


Fig 1 – Typical Section through Roller Shutter Joint

Appendix B. Photographs

Photograph 1 – Overview of plate train, after removal and up-turned. Note failsafe linkages have been removed prior to lifting.

Photograph 2 – Hinge at extreme end of Joint showing original condition of hinge pin and foot profile (note foot profile is slightly flattened).

Photograph 3 – Typical wear to hinge and foot

Photograph 4 – Note previous weld repairs to foot, now worn, and wear to hinge

Photograph 5 – Worn and deformed pin hole. Bushing worn and loose. Worn foot profile.

Photograph 6 – Worn tongue plate. Note thinning where grooves are worn where tongue plate rides over raised plate hinges. Tongue plates ends are trimmed to remove sharp edges created by wear.

Photograph 7 – Worn anchor plate bearing.

Photograph 8 – Worn edges and uneven ride surface. Note drop in joint level due to wear on bearings.

Photograph 9 – Worn lateral restraint at tongue plate and bearing blocks.

Photograph 10 – General view of slide tracks showing wear at foot locations.

Photograph 11 – Wear in slide track at typical hinge positions. Note uneven carriageway level.

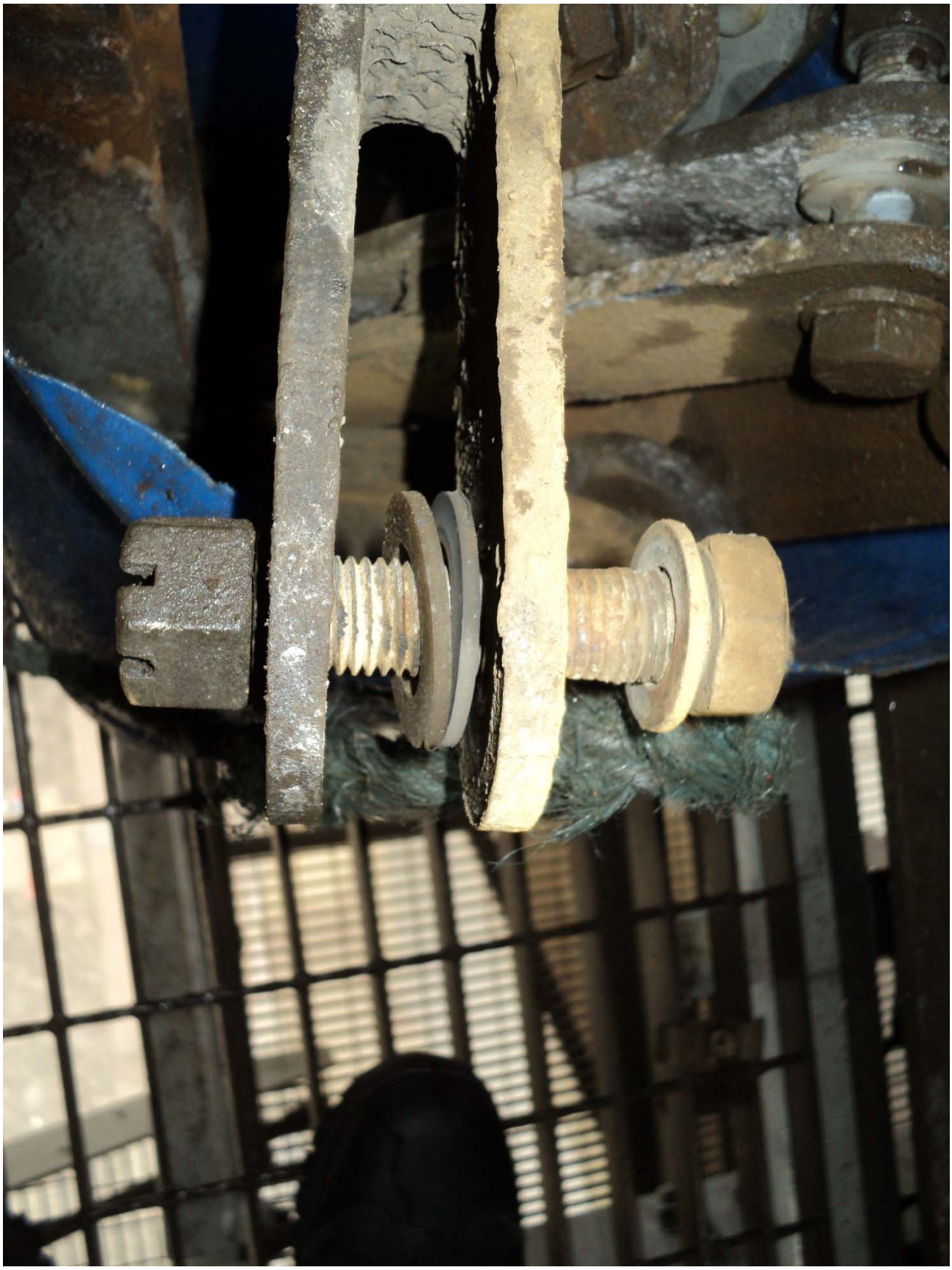
Photograph 12 – Excessive wear on foot and hinge

Photograph 13 – Excessive wear on foot and hinge, gap opening between joints.

Photograph 14 – Excessive wear on hinge, gap opening between joints and hinge pin lateral rotation.

Photograph 15 – Hinge pins appear in good condition with little wear evident.

Photograph 16 – Wear in anchor plate support bearings, causing drop in height.



Photograph 17 – Wear on bolt thread of failsafe hinge linkage. Note bolt thread originally had nylon sleeve.

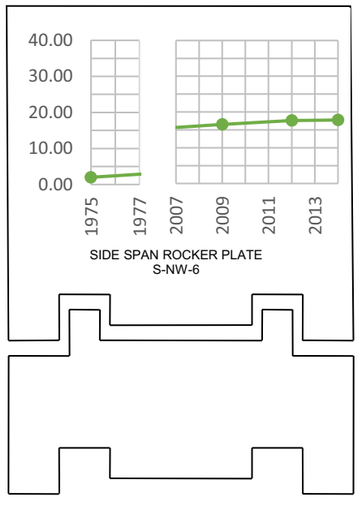
Photograph 18 – Typical debris accumulating at joint.

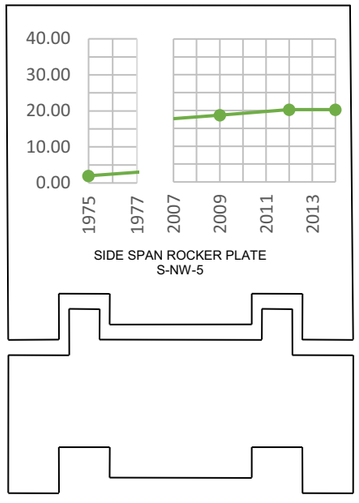
Photograph 19 – Rippling in edging steelwork to carriageway surfacing.

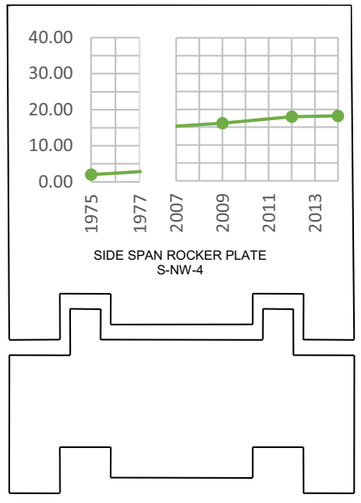
Appendix C. Gap Measurement Data

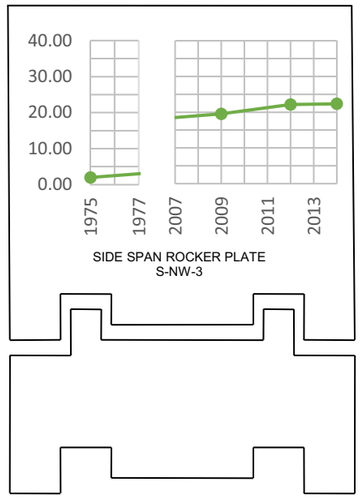
Note: The gaps vary in width across the plate train. Data has therefore been averaged across each half of the plate as well as for the whole plate to reflect this.

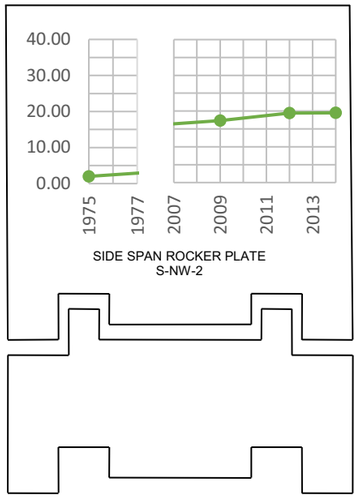
Forth Road Bridge - North West Expansion Joint

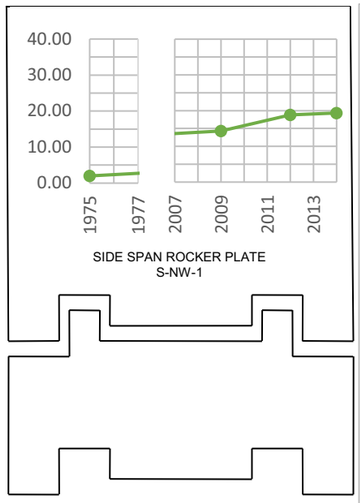


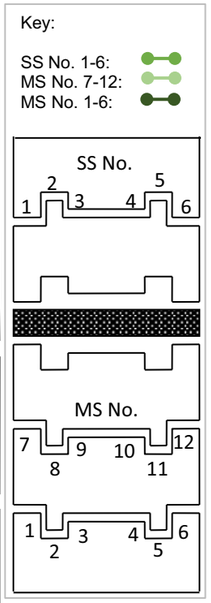


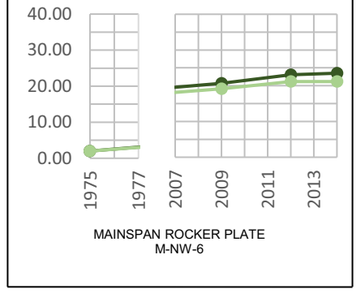


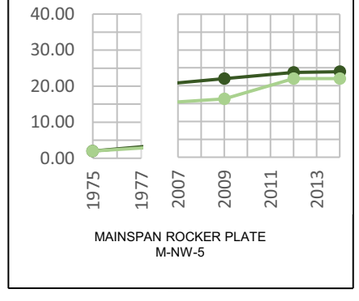


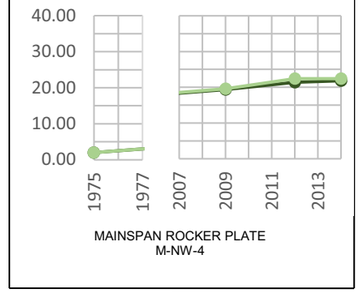


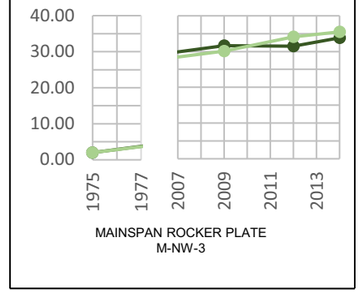


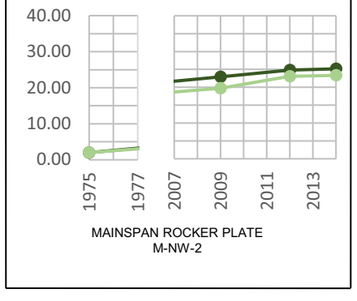




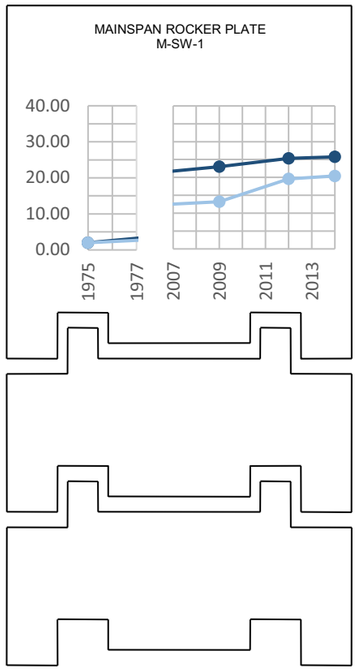


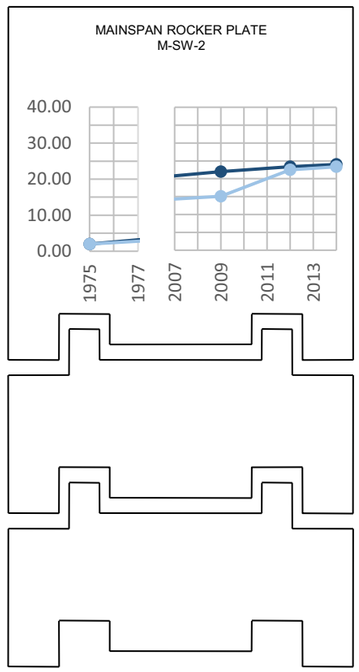


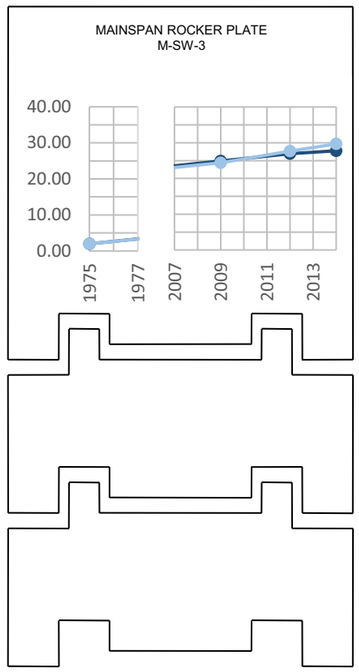


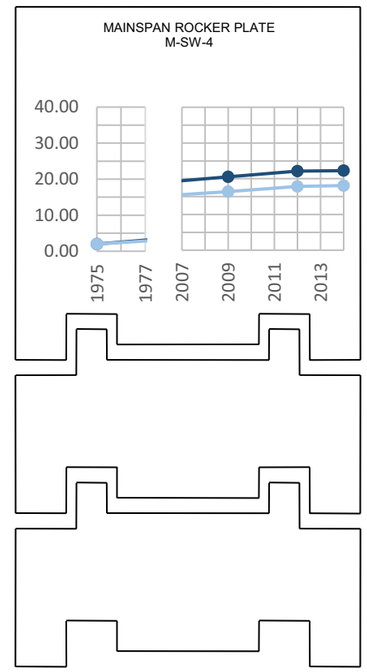


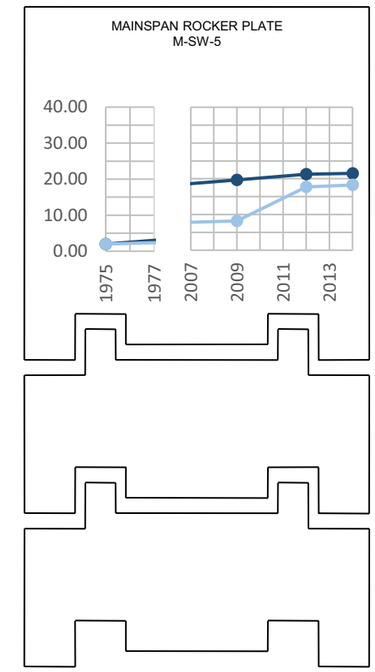
Forth Road Bridge - South West Expansion Joint

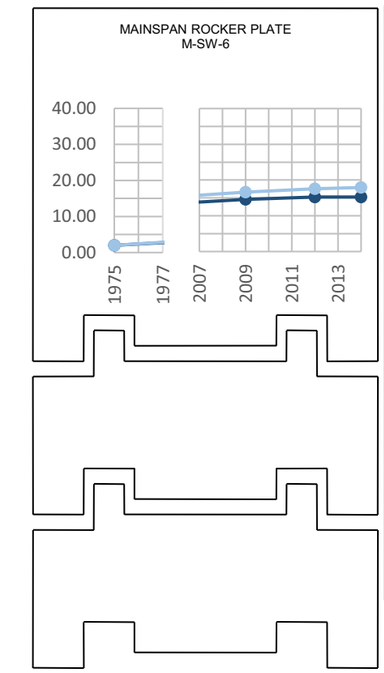


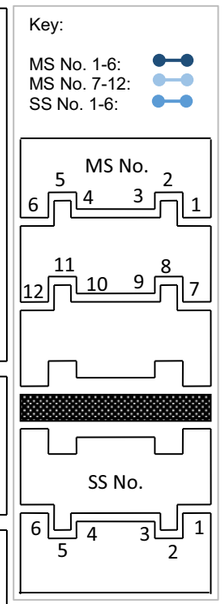


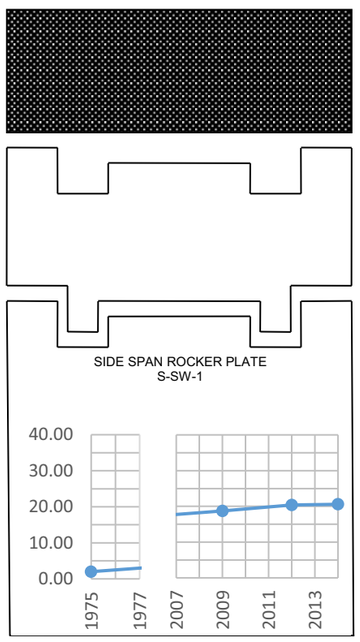


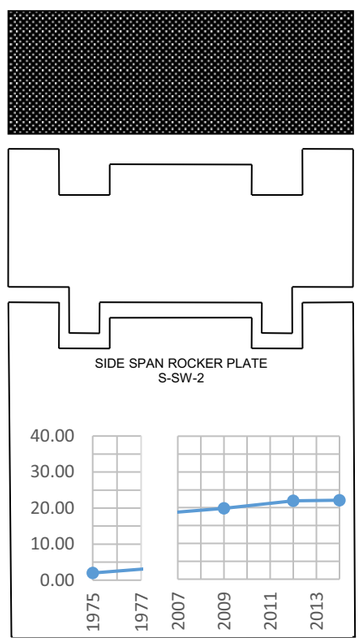


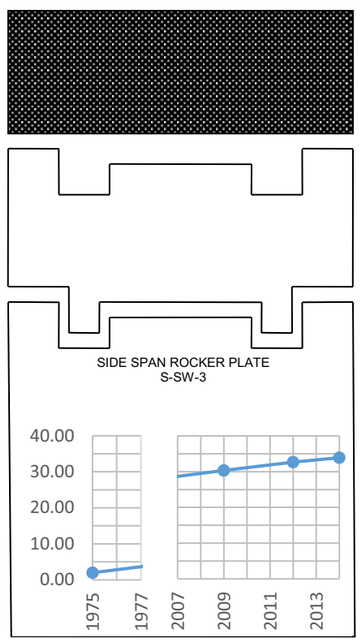


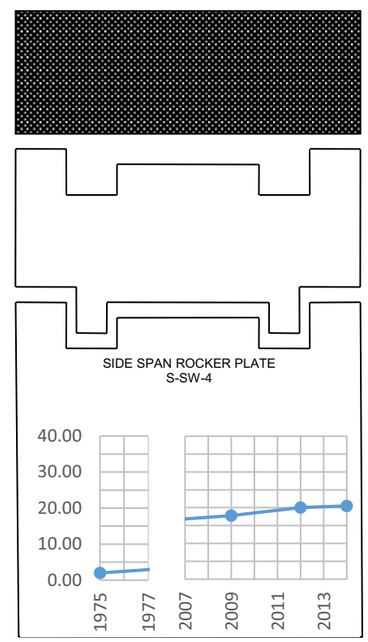


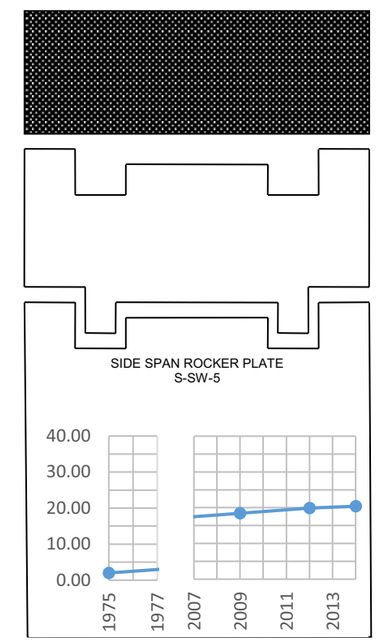


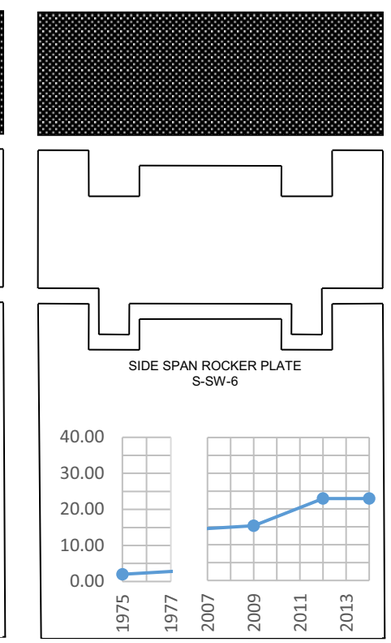




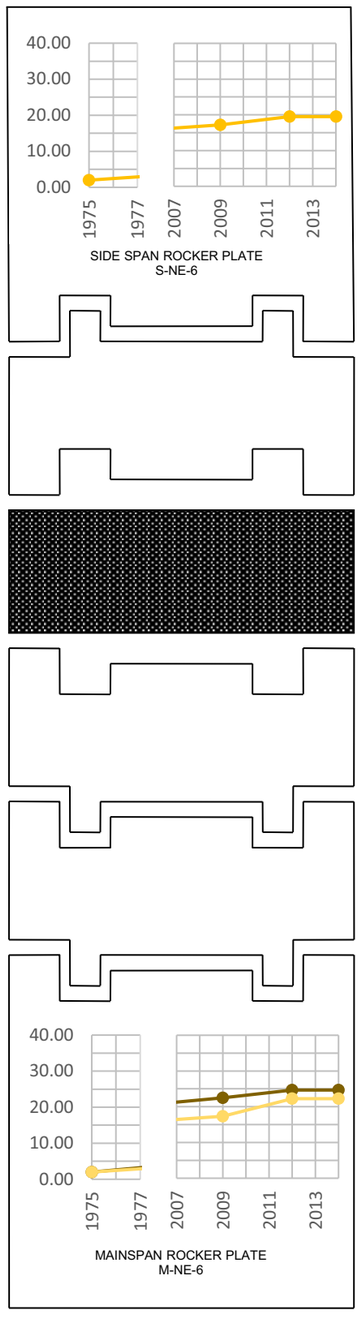


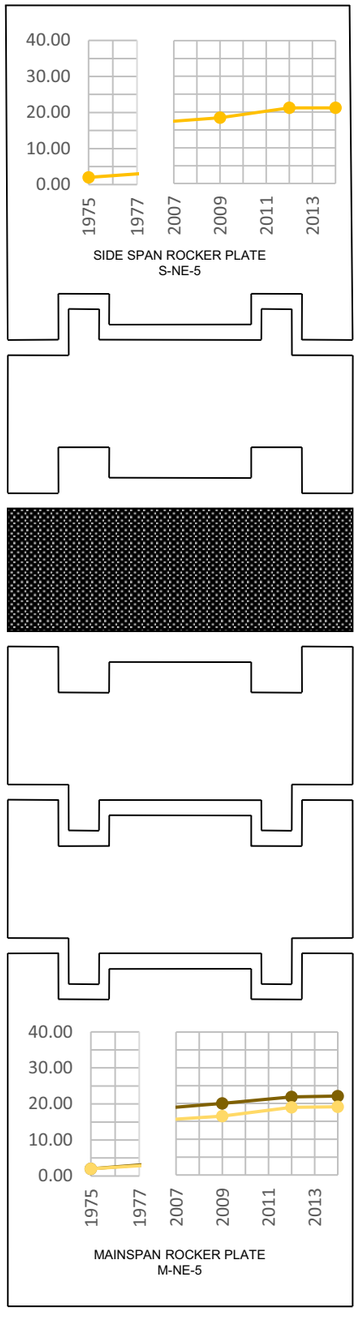


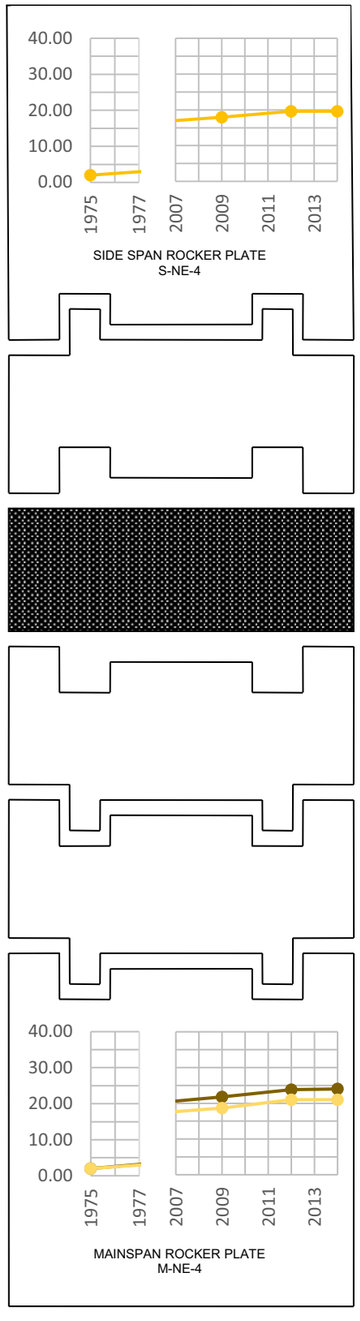


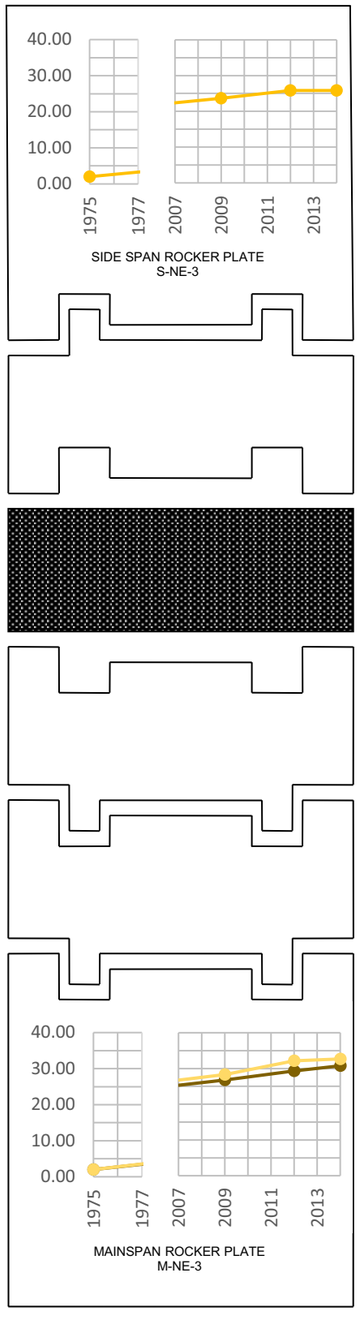


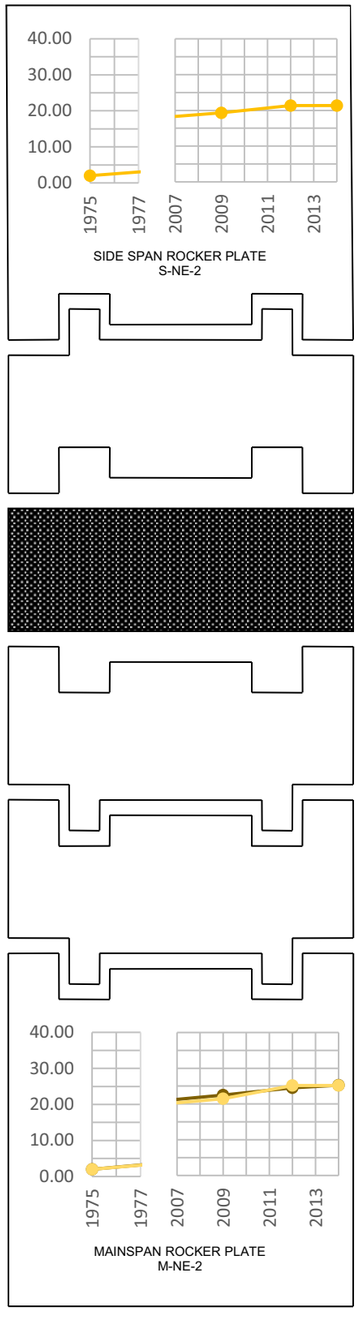
Forth Road Bridge - North East Expansion Joint

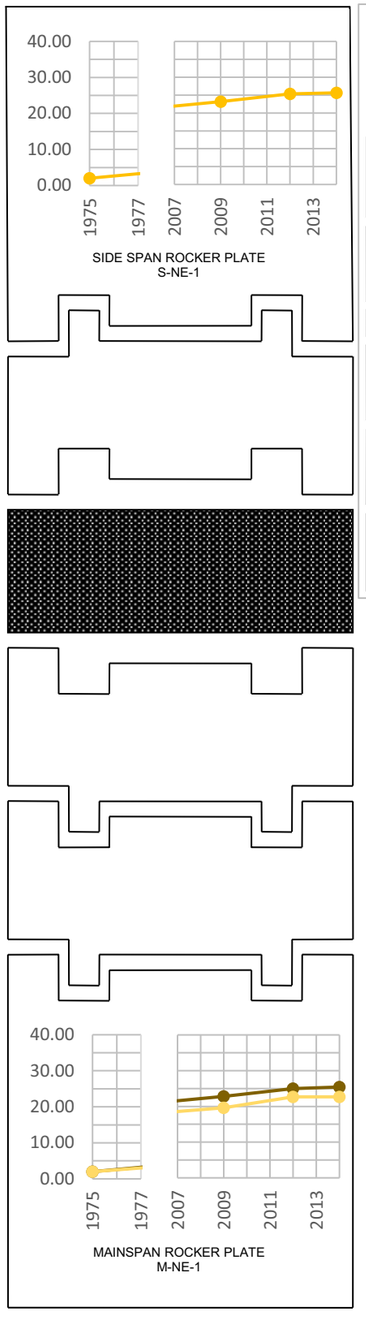


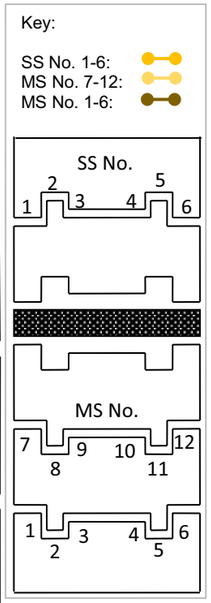




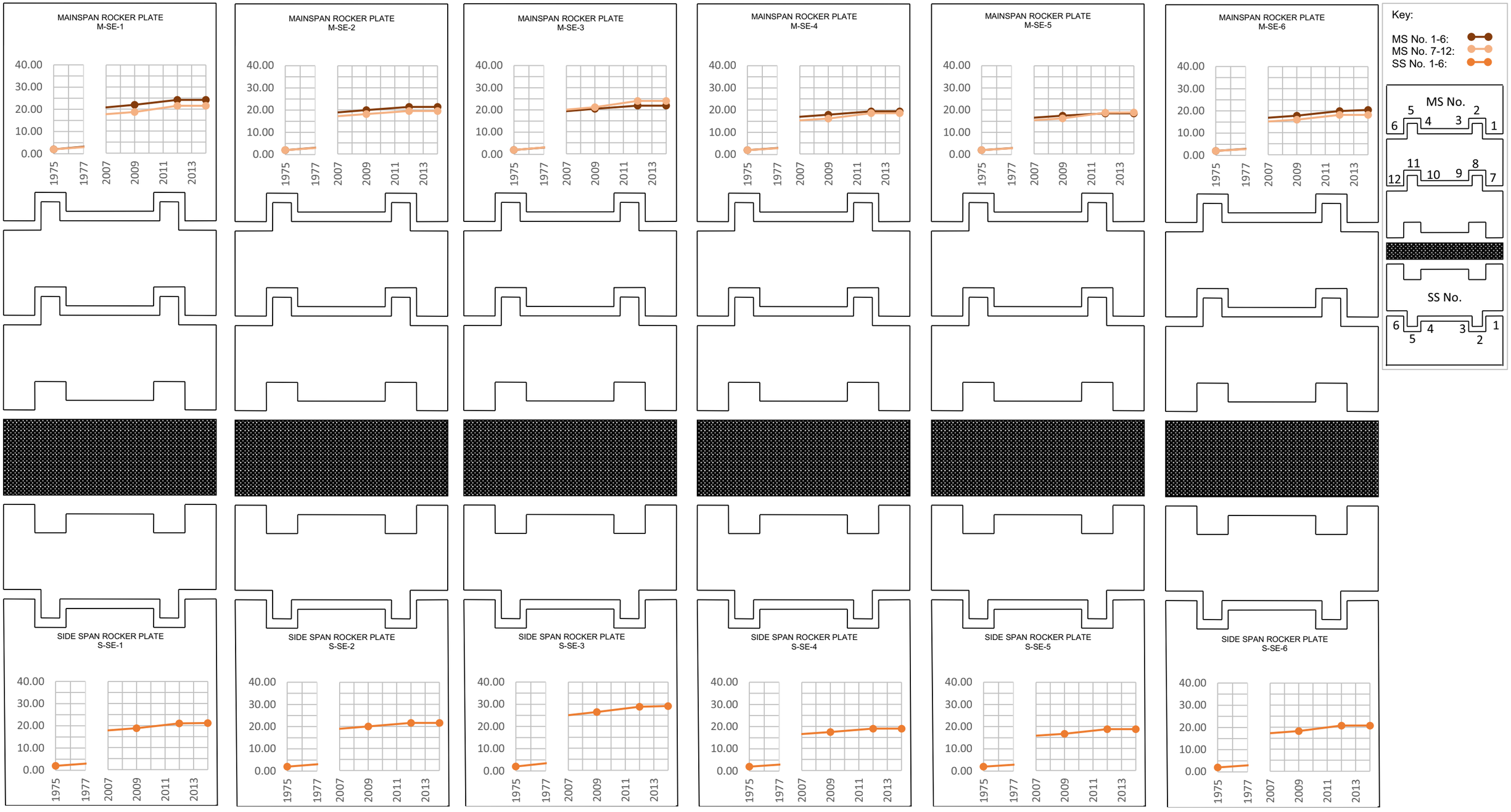




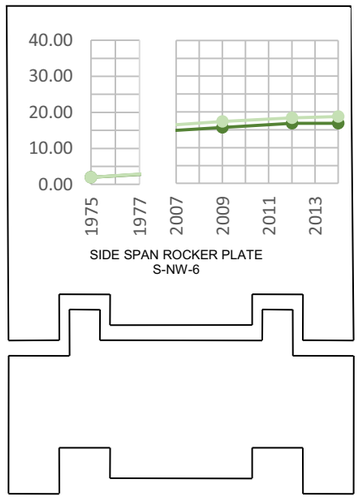


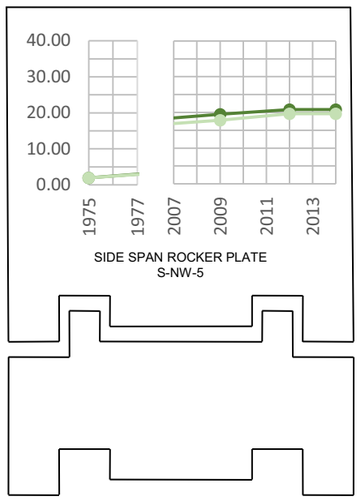


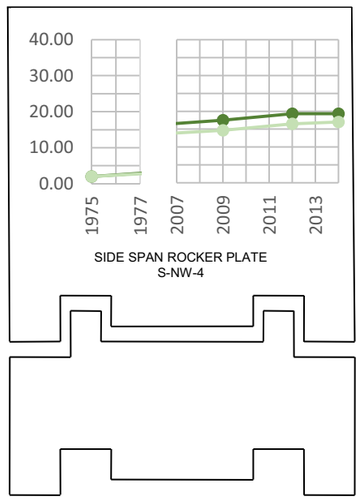
Forth Road Bridge - South East Expansion Joint

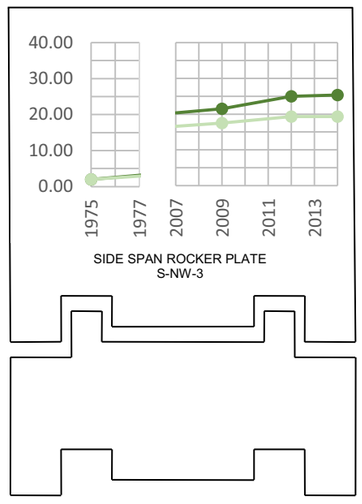


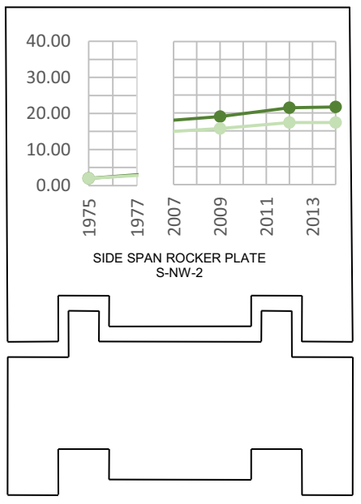
Forth Road Bridge - North West Expansion Joint

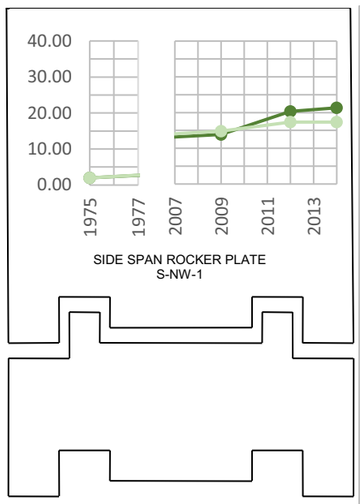


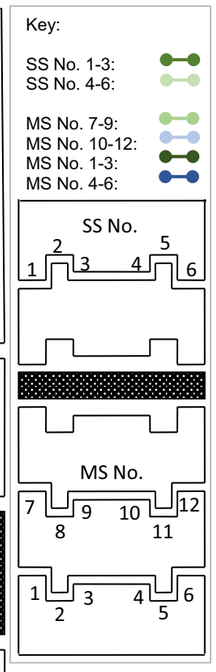


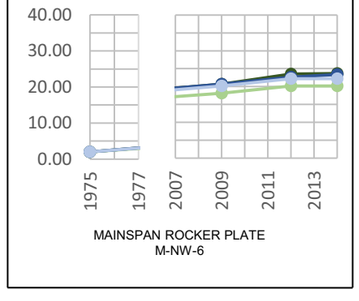


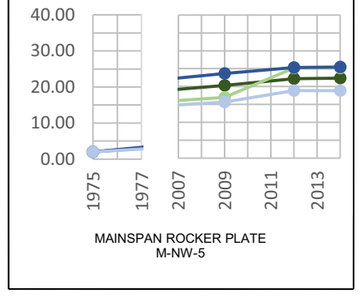


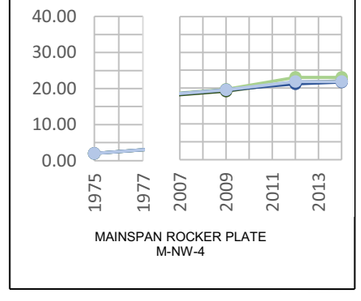


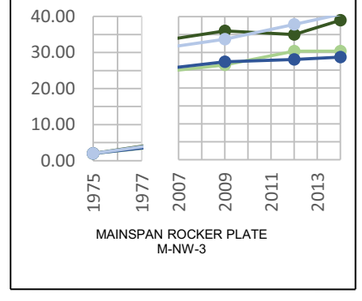


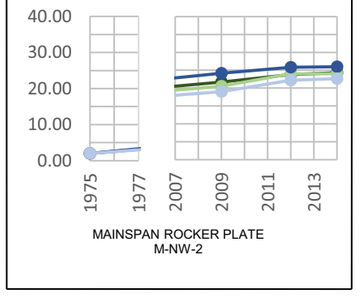


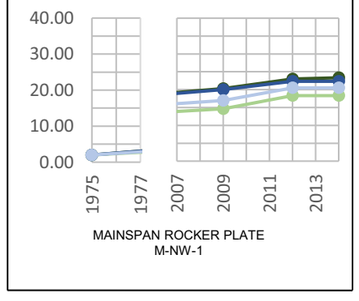




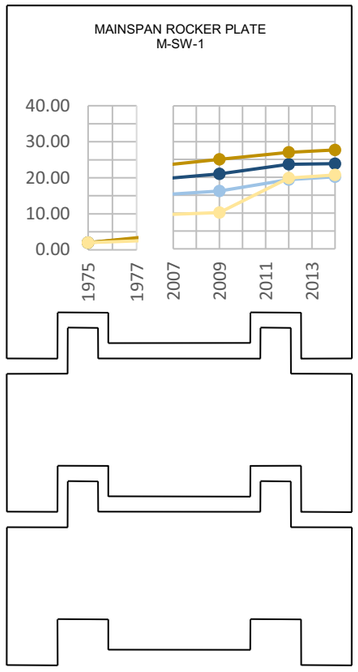


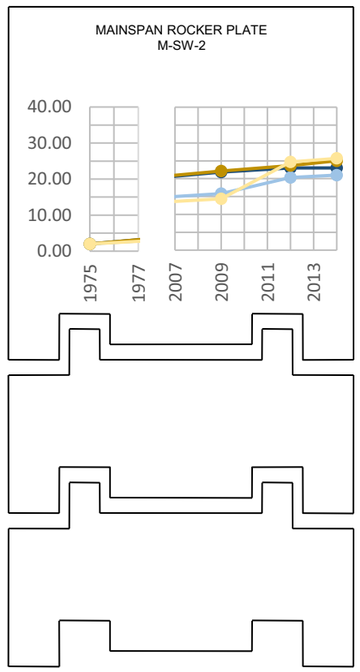


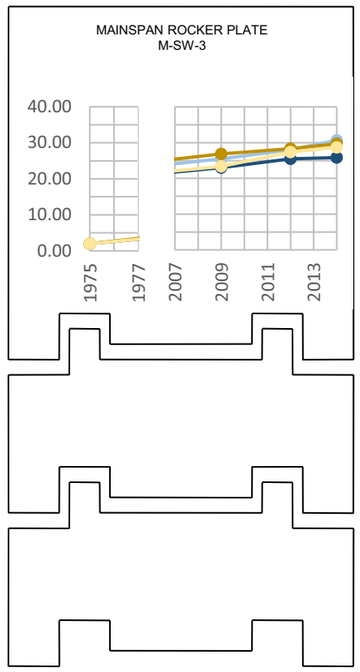


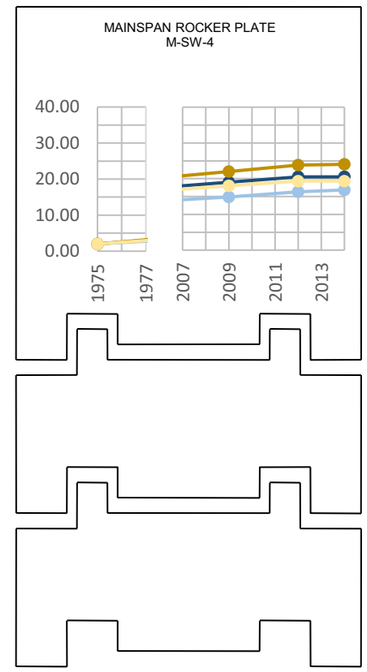


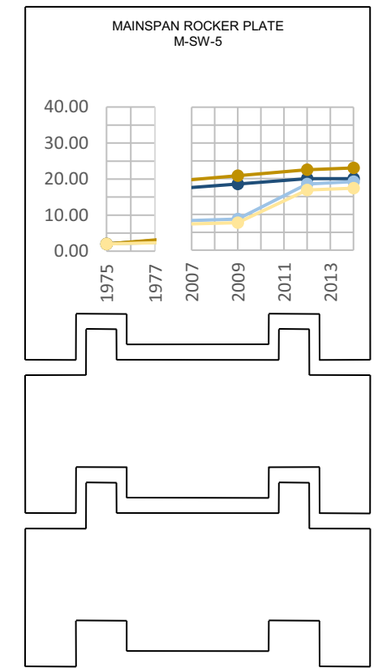
Forth Road Bridge - South West Expansion Joint

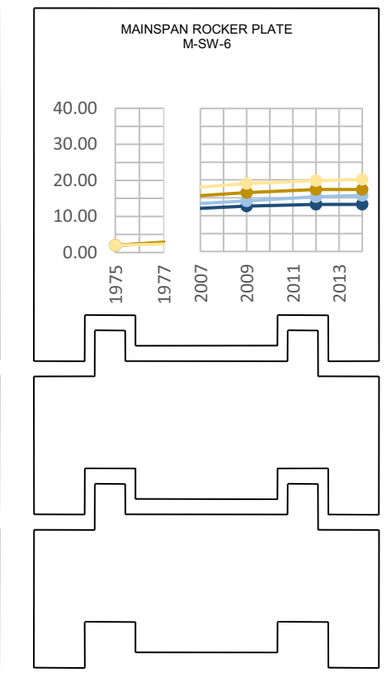


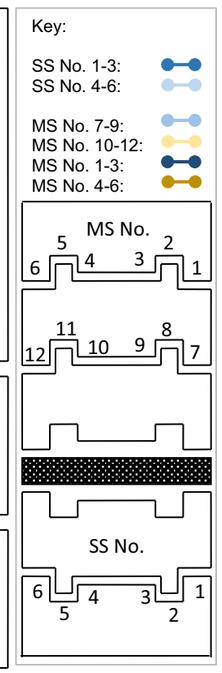


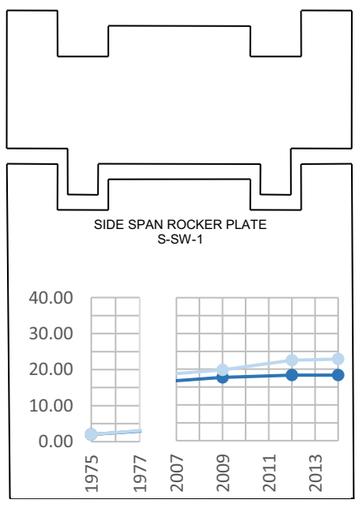


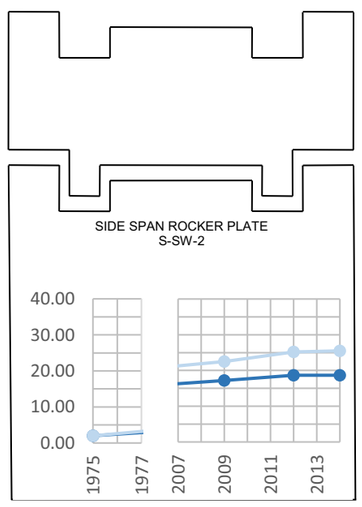


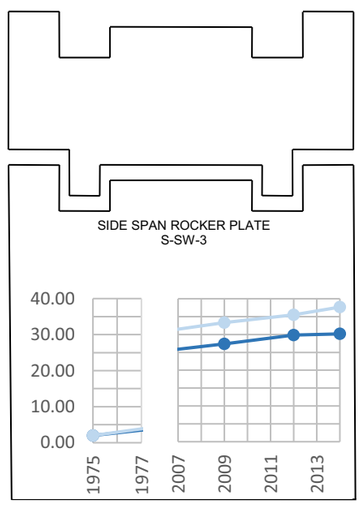


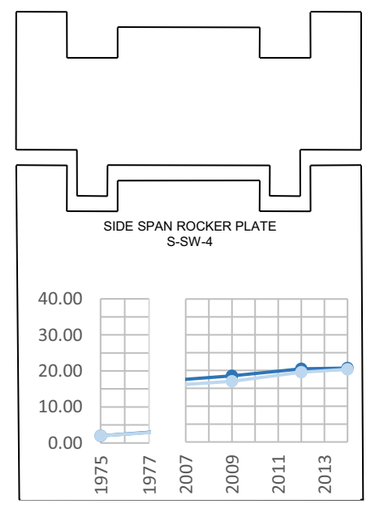


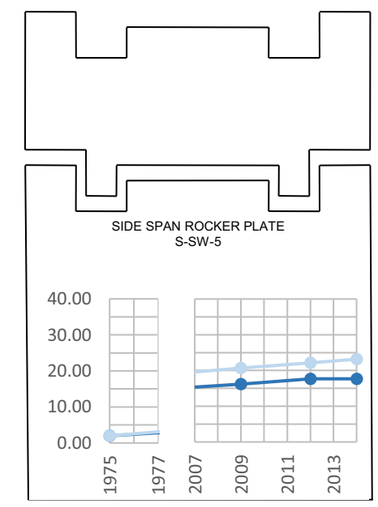


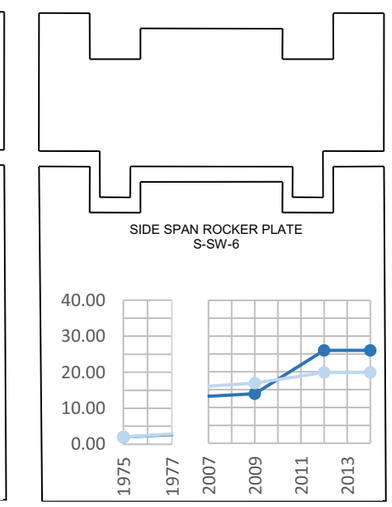




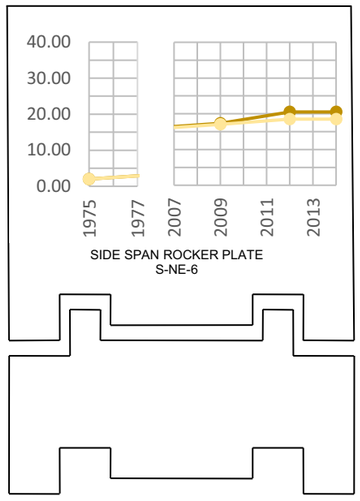


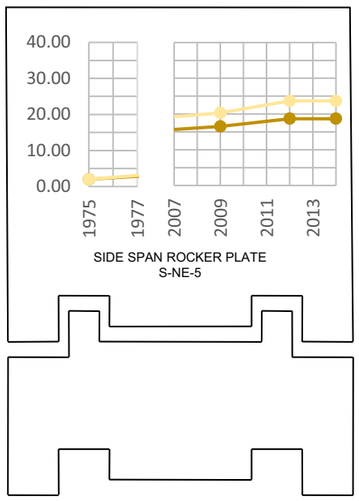


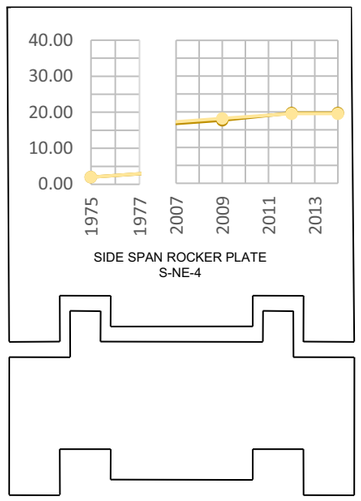


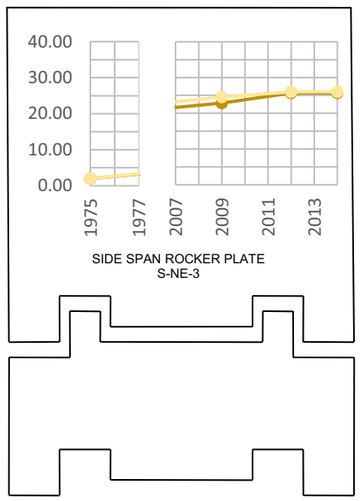


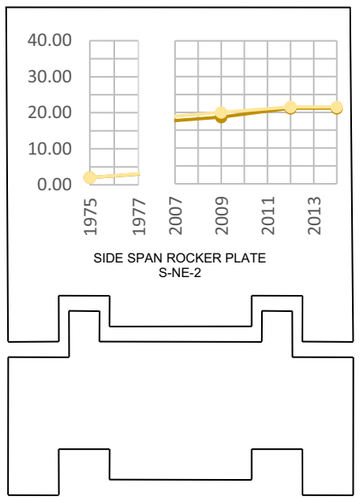
Forth Road Bridge - North East Expansion Joint

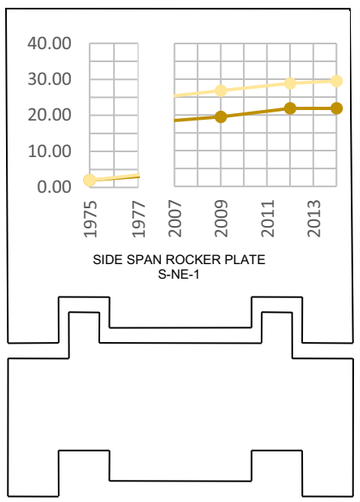


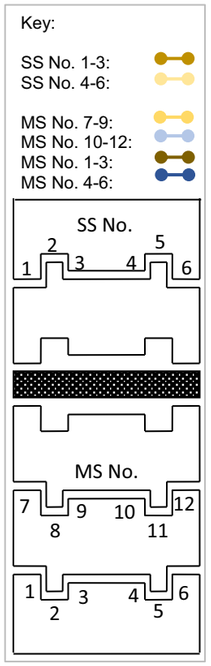


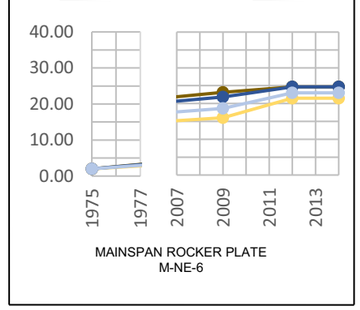


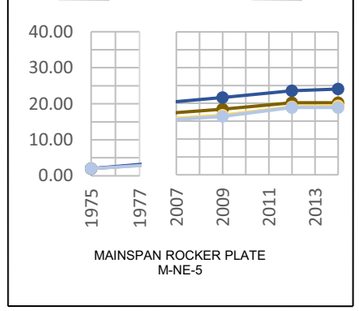


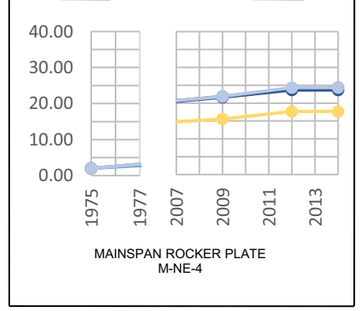


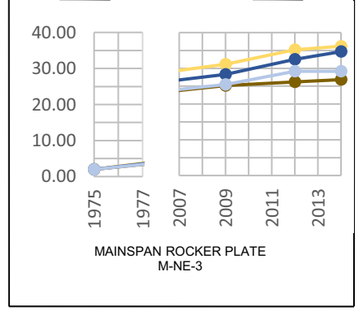


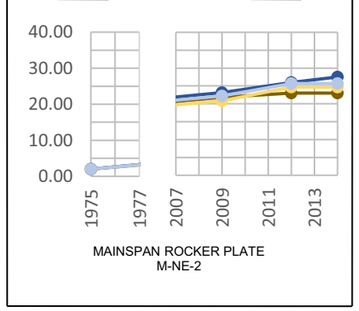


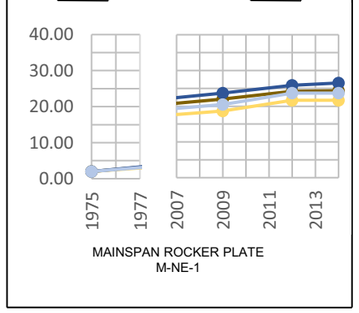




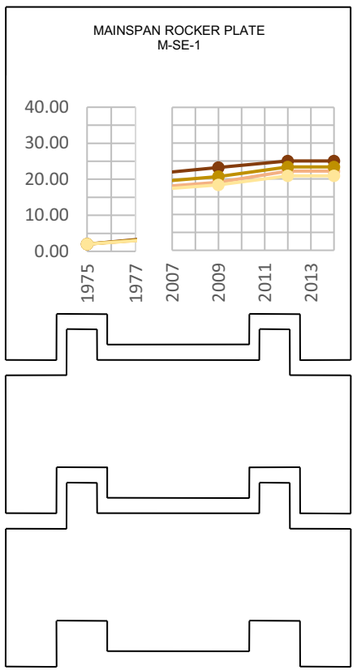


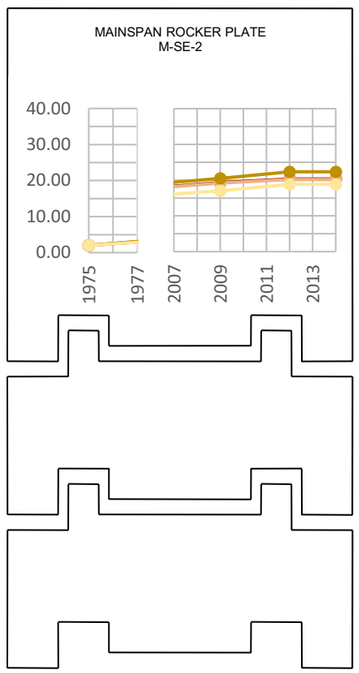


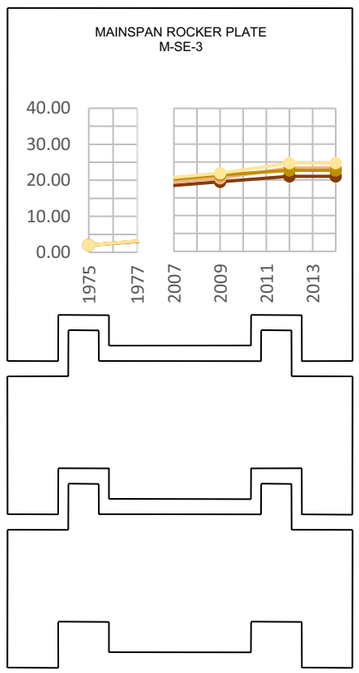


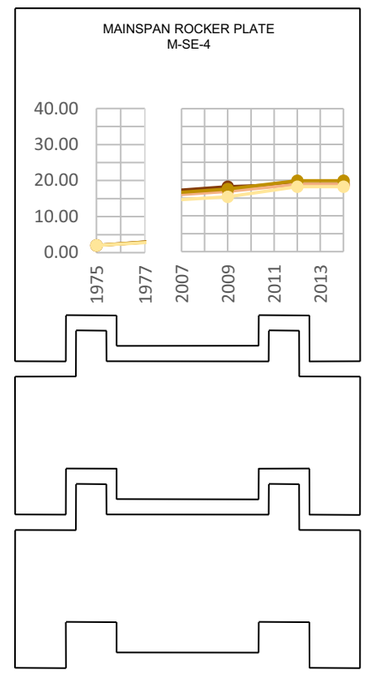


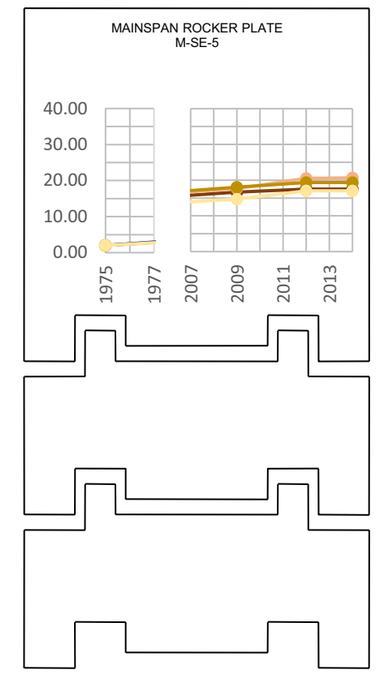
Forth Road Bridge - South East Expansion Joint

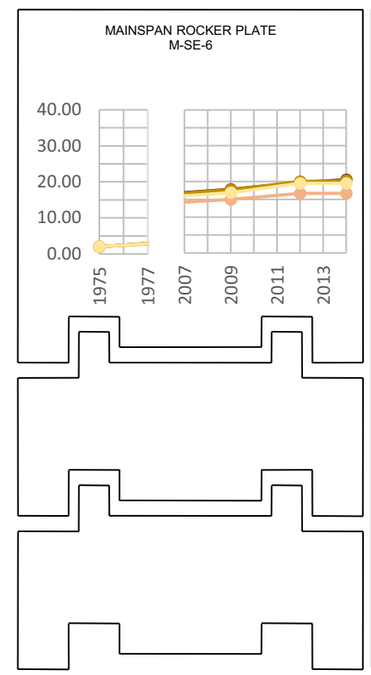


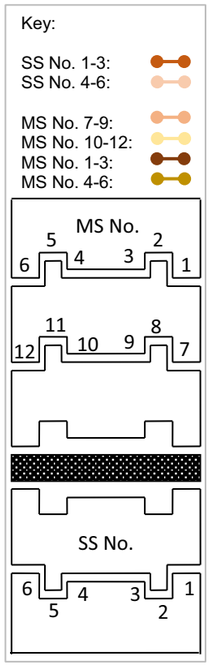


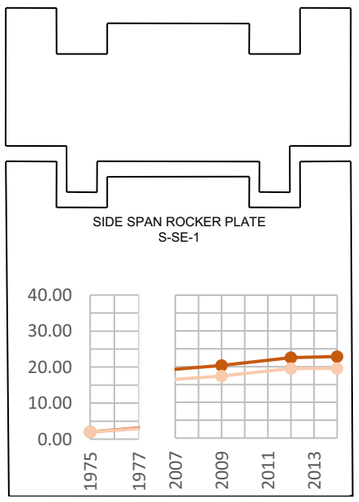


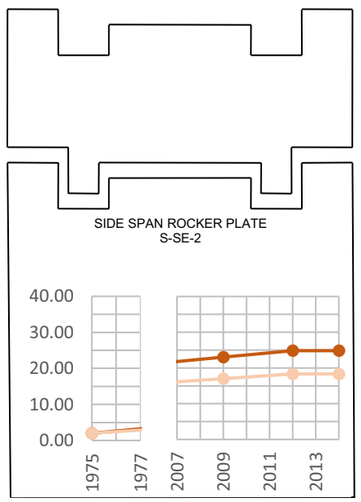


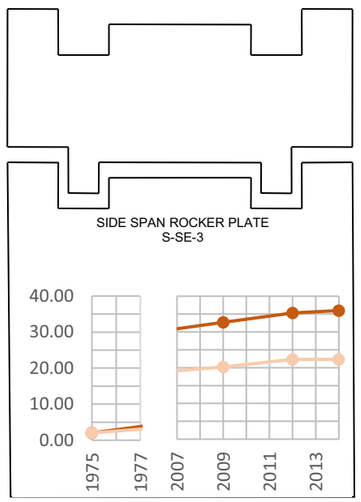


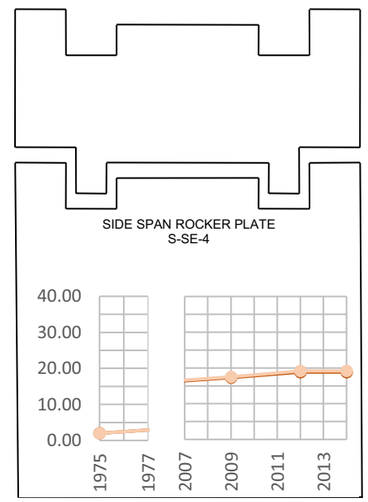


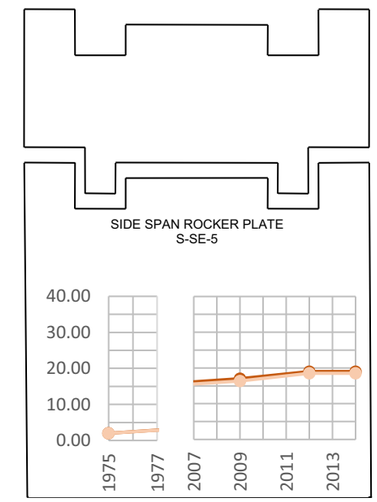


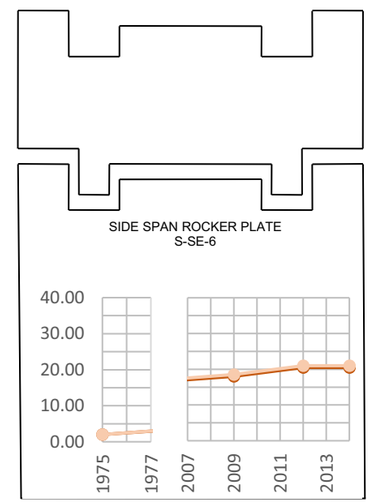












SOUTH WEST EXPANSION JOINT																								
Year			2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014
Side Span Rocker Plate	S-SW-6	1-6	12	26	26		13.5	26	26		16	26	26		16	21	21		16.5	19	19		18	19.5	19.5
	S-SW-5	1-6	14.5	16	16		15.5	17	17		18.5	20	20		21	22.5	23.5		20.5	22	22.5		20.5	22	23.5
	S-SW-4	1-6	18	20	20		18	20	20		19.5	21.5	22		19	21	22		16.5	19.5	20		15.5	18	19
	S-SW-3	1-6	26	28	29		27	30.5	30.5		29	31	31		33	34.5	36.5		33	35.5	37.5		34	36.5	39
	S-SW-2	1-6	16	17.5	17.5		16	17.5	17.5		19.5	21	21		23	25	26		22	25	25		22.5	25.5	25.5
	S-SW-1	1-6	16.5	17.5	17.5		17	17	17		19.5	20.5	20.5		21	23	24		18.5	21.5	21.5		20	23	23
Mainspan Rocker Plate	M-SW-6	1-6	11.5	12.5	12.5		12	12	12		14.5	15	15		16.5	17.5	17.5		16	17	17		17	17.5	17.5
		7-12	13	13.5	14.5		13	15	15		16.5	17.5	17.5		19	20	20		19	20.5	20.5		19	19	20
	M-SW-5	1-6	17	19	19		18.5	20	20		20	21	21		21	22.5	23		20.5	23	23		21	22	23
		7-12	8.5	19	19		8	18	19		9.5	18.5	19.5		8.5	17	18.5		5.5	15.5	15.5		9	18	18
	M-SW-4	1-6	17.5	19	19		18.5	20.5	20.5		21	22	22		22	24	24		22	23.5	24		22	24	24
		7-12	14.5	16	16		14	15	16.5		16	18	18		17	19	19		17.5	19	19		19.5	20	20
	M-SW-3	1-6	21.5	25	25		22.5	25	26		25	26.5	26.5		27	28	29.5		26.5	28	29.5		27	29	30
		7-12	25.5	28	31		26	28	31		25	28	30		24	28	30		23	27	28		23	27	28
	M-SW-2	1-6	21	22	22		21.5	23	23		23	24	24		22.5	24	25		22	23	25		22	24	25
		7-12	16	20	20		15.5	20	21		16	21	22		15	24	25		13.5	24.5	25		14.5	25.5	27
	M-SW-1	1-6	20.5	23	23		20.5	23.5	23.5		22	24.5	25		25	27	27		25	27	28		25	27	28
		7-12	16.5	18.5	19.5		15.5	19	20		16.5	20.5	21		13.5	21	22		8.5	19.5	20		8.5	19	20
SOUTH EAST EXPANSION JOINT																								
Year			2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014
Side Span Rocker Plate	S-SE-6	1-6	17.5	20	20		18	20	20		18.5	21.5	21.5		19	22	22		17.5	20	20		19	21	21
	S-SE-5	1-6	17	19.5	19.5		16	18	18		18	19.5	19.5		18	20	20		15	17.5	17.5		16	18	18
	S-SE-4	1-6	18	19	19		16	17.5	17.5		18	20	20		19	20.5	20.5		16.5	18	18		17	19	19
	S-SE-3	1-6	34	37	38		33	35	35		31	34	35		23	26	26		18.5	20.5	20.5		19	20.5	20.5
	S-SE-2	1-6	21	23	23		24	26.5	26.5		24	25	25		19	21	21		18	19	19		14	15	15
	S-SE-1	1-6	19.5	22	22		21.5	23	23		20	22.5	23.5		18	21	21		18	19.5	19.5		16	18	18
Mainspan Rocker Plate	M-SE-6	1-6	16	18.5	21		18.5	20	20		19	20.5	20.5		19	21.5	21.5		19	21	21		15	17.5	18
		7-12	13	15	15		16	17	17		16	18	18		17.5	20	20		17	19.5	19.5		16	19	19
	M-SE-5	1-6	16	16.5	16.5		16	17	17		18	19	19		19	20	20		19	20	20		16	18	18
		7-12	18	21	21		17	20	20		18	20.5	21		16	18	18		14	16	16		14	17	17
	M-SE-4	1-6	16.5	18	18		18	18.5	18.5		20	20	20		19	21	21		17	19.5	19.5		16.5	19	19
		7-12	16	19	19		16.5	17.5	17.5		18	20	20		17	19.5	19.5		13	16.5	16.5		16	18.5	18.5
	M-SE-3	1-6	18	20	20		19.5	21	21		21	22	22		22	23	23		22	23	23		20	22	22
		7-12	19.5	22.5	22.5		20	23	23		22	24.5	24.5		22.5	25.5	25.5		22	24.5	24.5		21	24	24
	M-SE-2	1-6	18	19	19		19	20	20		21	22	22		21	23	23		21.5	23	23		19	21	21
		7-12	18	19.5	19.5		19.5	20	20		20	21	21		18	20	20		16	18	18		17	18.5	18.5
	M-SE-1	1-6	23	25	25		23	25	25		23.5	25	25		21.5	24	24		21	23.5	23.5		19.5	22.5	22.5
		7-12	19	22	22		17	20.5	20.5		21	24	24		20	22.5	22.5		17.5	20	20		17.5	20	20
NORTH EAST EXPANSION JOINT																								
Year			2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014
Side Span Rocker Plate	S-NE-6	1-6	16	19.5	19.5		18	21.5	21.5		18	20.5	20.5		18	19.5	19.5		18	19	19		15	17	17
	S-NE-5	1-6	15	17.5	17.5		16.5	18.5	18.5		18	20	20		20	23	23		20	23	23		21	25	25
	S-NE-4	1-6	16	18	18		19	21	21		18	20	20		19	20	20		18	20	20		17.5	18.5	18.5
	S-NE-3	1-6	22	25.5	25.5		22.5	25	25		24	26.5	26.5		25	27	27		25	26	26		23.5	25	25
	S-NE-2	1-6	18	21	21		18.5	21	21		19.5	21.5	21.5		20.5	22	22		20.5	22	22		19	20.5	20.5
	S-NE-1	1-6	17.5	20	20		19.5	21.5	21.5		21.5	24	24		26	28.5	28.5		27	29	29		27.5	29	31
Mainspan Rocker Plate	M-NE-6	1-6	23	24	24		23.5	25	25		23	25	25		22	25.5	25.5		22.5	25	25		21	23.5	23.5
		7-12	17	22.5	22.5		14.5	20.5	20.5		16.5	21.5	21.5		18.5	23	23		17.5	22	22		20	24	24
	M-NE-5	1-6	17.5	19.5	19.5		18.5	20	20		19	21	21		21	23	23		22	24	25		22	23.5	24
		7-12	17	20	20		16.5	19	19		16.5	18	19		16	18.5	18.5		16	19	19		17	19	19
	M-NE-4	1-6	21.5	24	24		22	24	25		22	24	24		22	24	24		22	24	24		21	23	23
		7-12	15	17	17		14.5	17	17		17	19	19		19.5	22.5	22.5		23	25	25		23	25.5	25.5
	M-NE-3	1-6	24.5	25	25		25	26	27		26	27.5	28.5		28	31.5	34		29	33	35		28	33	35
		7-12	31.5	36	37		31	34.5	35.5		31	35	36		27	31.5	31.5		24.5	27.5	27.5		25	28.5	28.5
	M-NE-2	1-6	21.5	22	22		22	23	23		22	24	24		23	25.5	27		23.5	26.5	28		23	26	27.5
		7-12	21	24.5	24.5		20	24	24		21.5	25.5	25.5		23.5	27	27		21	24.5	24.5		22	25.5	25.5
	M-NE-1	1-6	21.5	24	24		22	24	24.5		22.5	24.5	24.5		23.5	26	26.5		23.5	25.5	27		24	26	26
		7-12	19	22	22		18	21	21		19	22	22		20	23.5	23.5		19.5	23	23		22	24.5	24.5
NORTH WEST EXPANSION JOINT																								
Year			2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014		2009	2012	2014
Side Span Rocker Plate	S-NW-6	1-6	14.5	15.5	15.5		15	16	16		17.5	19	19		18	18	19		17	18.5	18.5		17	18.5	18.5
	S-NW-5	1-6	18.5	19.5	19.5		21	22	22		19	21	21		19.5	20.5	20.5		17.5	20	20		16.5	18.5	18.5
	S-NW-4	1-6	17	19	19		18	20	20		17.5	19	19		16	17.5	18		15	16.5	17		13	15.5	16
	S-NW-3	1-6	22	25	26		21.5	25	25		21	25	25		19.5	21	21		17.5	19	19		15.5	18	18
	S-NW-2	1-6	19	22	22		19.5	21.5	22		18.5	21	21		16.5	18	18		16.5	18	18		14	16	16
	S-NW-1	1-6	12	19	20		14	21	22		15.5	21	22		15.5	19	19		15	17	17		14	16	16
Mainspan Rocker Plate	M-NW-6	1-6	20.5	23	23		20.5	23.5	24		21	24	24		21.5	23.5	24.5		20.5	23	23.5		20	21.5	22
		7-12	18	20	20		17.5	19.5	19.5		19	21	21		20	22	22		19.5	21.5	21.5		21	23	23
	M-NW-5	1-6	20	21.5	22		20	22	22		21	23	23		22.5	24.5	25		24	25.5	25.5		24.5	26	26
		7-12	18	26.5	26.5		16.5	25	25		16.5	24	24		16	20	20		15	18	18		16	18.5	18.5
	M-NW-4	1-6	18.5	21	22		20	22	22		19	22	22		20	21.5	22		19.5	21	21		19	21	22
		7-12	20	23	23		19.5	23	23		19.5	23	23		20	22	22		18	21	21		20.5	22.5	22.5
	M-NW-3	1-6	37	35.5	39		37	35.5	40		34	34	38		29	29	30		27	28	29		26	27	27
		7-12	26	30	30		25	29	29		28.5	32	32		32.5	36.5	39		33.5	37	40		35	40	43
	M-NW-2	1-6	20.5	23.5	24		21.5	23.5	24		23	24.5	25		24	26	26		24.5	26	26		24	25.5	26
		7-12	20	24	24		21.5	24	24		20	24	24		18.5	21.5	22		17.5	21	21		21	24	25
	M-NW-1	1-6	19.5	22.5	23		20.5	23	23		21	23.5	24		20.5	22.5	22.5		20	22.5	22.5		19.5	22	22
		7-12	14	18	18		14	18	18		16	19	19		17	20.5	20.5		17	20.5	20.5		17	20.5	20.5

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