SITE MEASUREMENTS
SCHARSTERRIJN BRIDGE 2009

Short-term Monitoring

Stevin: 6.09.02

May 2009

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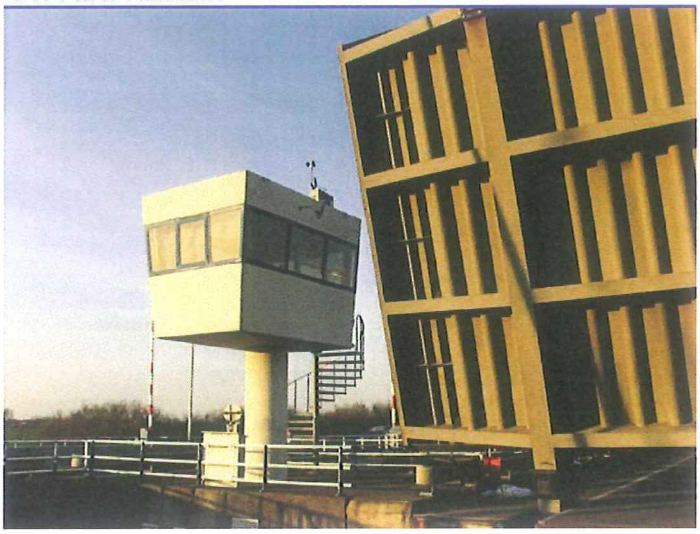

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2 Description of the Scharsterrijn Bridge

Scharsterrijn Bridge is located in Friesland, a northern province of the Netherlands, in the highway A6. The bridge is composed of two independent bridges, one for each traffic direction, both with a fixed and a movable part (Figure 1 and Figure 2). The main girders of the movable bridge have a total span of 8300 mm. The bridge deck consists of an orthotropic steel plate of 12 mm thickness, stiffened by "U-shape" longitudinal stiffeners and divided by 4 crossbeams of 2530 mm span (Figure 3). The nominal thickness of the epoxy surfacing system is 7 mm. The second steel plate of 6 mm thickness, 4200 mm width and 8200 mm length was bonded to the existing deck plate in the right lane of the movable bridge.


Figure 1 – Scharsterrijn Bridge (fixed part on the left side and movable part on the right side).

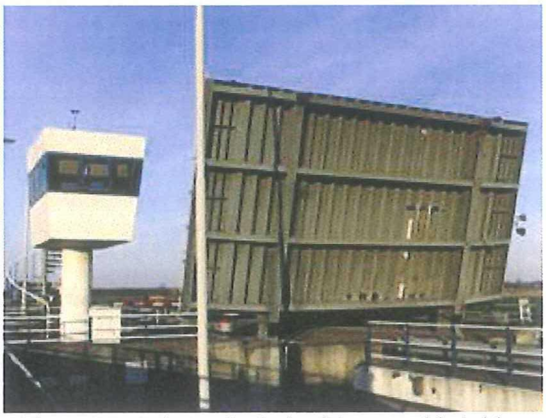


Figure 2 – Orthotropic deck of the movable bridge Scharsterrijn.

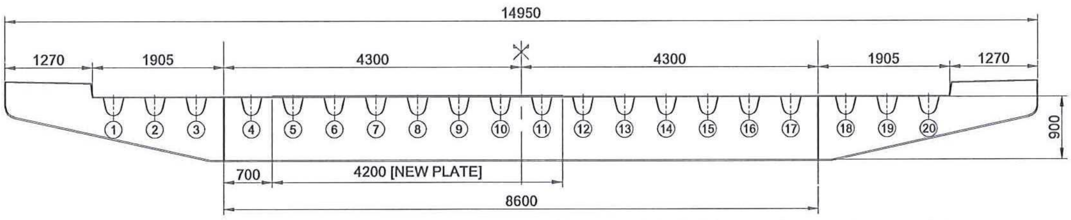


Figure 3 – General cross section of Scharsterrijn movable bridge and new plate position (dimensions in mm).

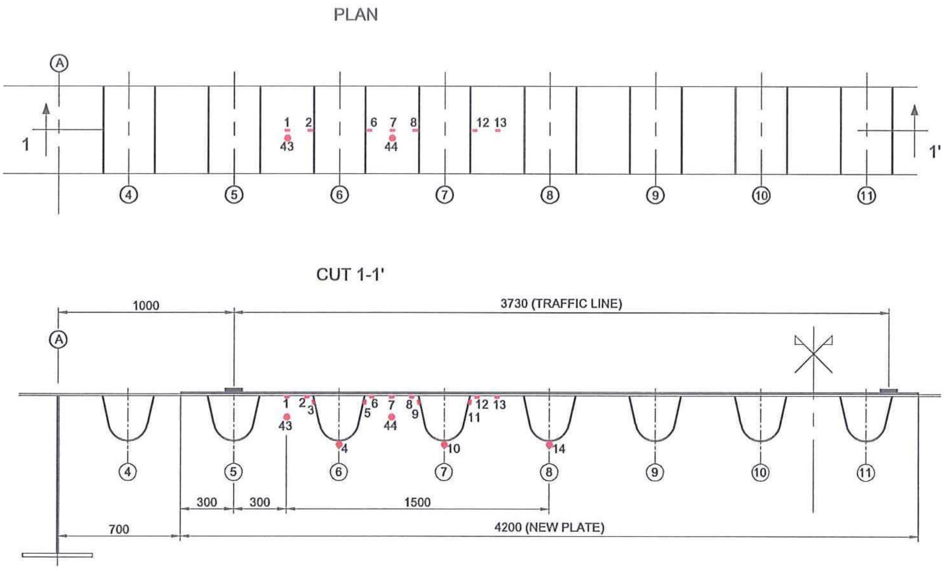


Figure 5 - Transverse location of the strain gauges for the short term monitoring - Cross section half way between crossbeam 2 and 3 (dimensions in mm).

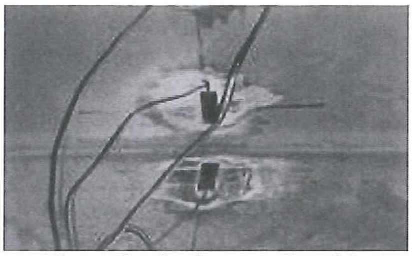


Figure 6 – Strain gauge 2 and 3.

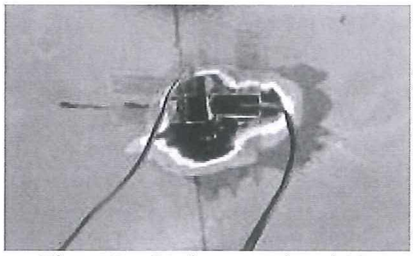


Figure 7 – Strain gauge 1 and 43.

3.2 Long term Monitoring

Considering the durability of the renovation, the critical points are the longitudinal edges of the new steel plate at the beginning and end of the movable bridge. The higher stress concentration on these points is due to the discontinuity of the new plate and the dynamic factors caused by the traffic. Above this, crossbeams are positioned close to those points, 250 mm and 460 mm from the edge of the bridge, where the regular stresses in the bridge are higher. If the delamination occurs it will probably take place there.

In two sections of the renovated bridge, one in the beginning (Lemmer) and other at the end (Joure), a total of 31 strain gauges were applied to the deck plate.

On the Joure cross section 15 strain gauges were applied (Figure 8). For the ones measuring transverse strains, the numbering is from strain gauge number 15 to strain gauge number 28. The strain gauges next to the welds (16, 18, 19, 21, 22, 24, 25 and 27) are positioned 15 mm from the weld toe. The strain gauges 17, 20, 23 and 26 are positioned half distance between stiffener's webs. The strain gauges 15 and 28 are positioned 50 mm from the end of the new plate. Strain gauge number 45 measures longitudinal strains on the deck plate between stiffeners webs.

All the 15 strain gauges are at a distance of 100 mm on the longitudinal direction from the cross beam number 1. The final location of the strain gauges in the Joure cross section is shown in Figure 8.

A total of 4 temperatures sensors were applied on the bridge. Two of them are measuring the temperature at the bottom of the existing deck plate. The other two are measuring the temperature at the top of the deck.

4 Measurements

In order to obtain information about the efficiency and durability of this renovation technique, several measurements are being carried out. The direct efficiency in reducing the strain values in the steel deck plate was evaluated by carrying out static strain measurements using a calibrated truck and dynamic strain history measurements during normal traffic conditions. In both cases measurements were performed before and after the renovation. In order to obtain an insight in the durability of the rehabilitation, once every month during the year after the renovation, dynamic strain values are being measured with a calibrated truck running in normal traffic conditions.

4.1 Short term Monitoring

The short term monitoring includes two types of measurements: static strain measurements using a calibrated truck and strain history measurements during normal traffic. Both were performed before and after the renovation. The measurements were recorded at the middle span cross section where the dynamic factors have less influence.

4.1.1 Static strain measurements

The strains on the deck plate were recorded using a calibrated truck when no traffic was running on the bridge. The lorry was placed at 15 transverse positions on the deck. These positions where located in the right lane where the rehabilitation took place (Figure 10). The transverse position of the calibrated truck was fixed by visual observation (Figure 11) and using laser equipment. From the measurements, influence lines of the strains along the deck plate can be drawn due to the axle load. The reference point for the wheel position is the middle of the tyre for the front wheel and the middle of the outside tyre for the rear wheel.

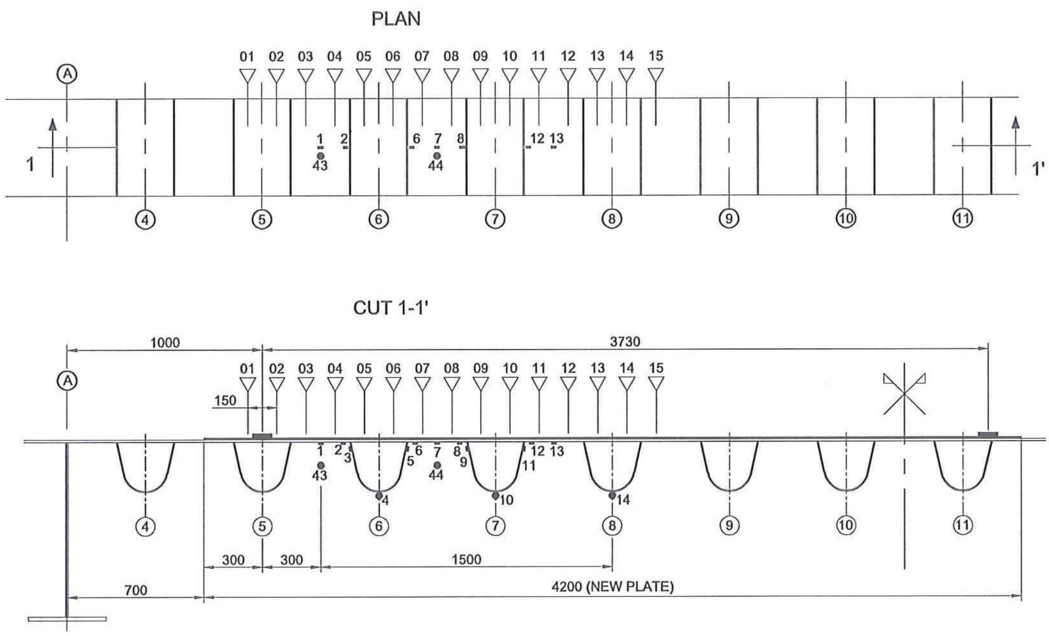


Figure 10 – Middle span cross section: 15 wheel load positions and strain gauge positions.

4.1.2 Strain history measurements

An important step in fatigue assessment of a certain detail or bridge component is the estimation of the stress history. After this collection, the most recognizable stress cycles can be extracted from the stress spectrum (after cycle counting) and provide input to the Miner's rule.
Therefore it was included on the monitoring plan strain history measurements carried out during normal traffic conditions. The strain values recorded correspond to the successive maximum and minimum values caused by each axle load. The strain history is then compared before and after the renovation for each strain gauge applied to the middle span cross section of the orthotropic deck of the movable bridge Scharsterrijn (Figure 5). The measurements were recorded during approximately one week in normal traffic conditions. The comparison between these two situations will give extra information in the efficiency of the renovation technique applied.

5 Results

This document reports only the results of the short term monitoring. When completed, the results from long term measurements will be presented in a further report.

5.1 Short term Monitoring

The test results were recorded for all the sixteen strain gauges applied to the deck plate at middle span cross section (see Figure 5). The results for all the strain gauges are presented in Annex A and B. In this chapter only the results of strain gauge number 7 are presented as an example. This strain gauge measures strain values on the deck plate between stiffener's webs.

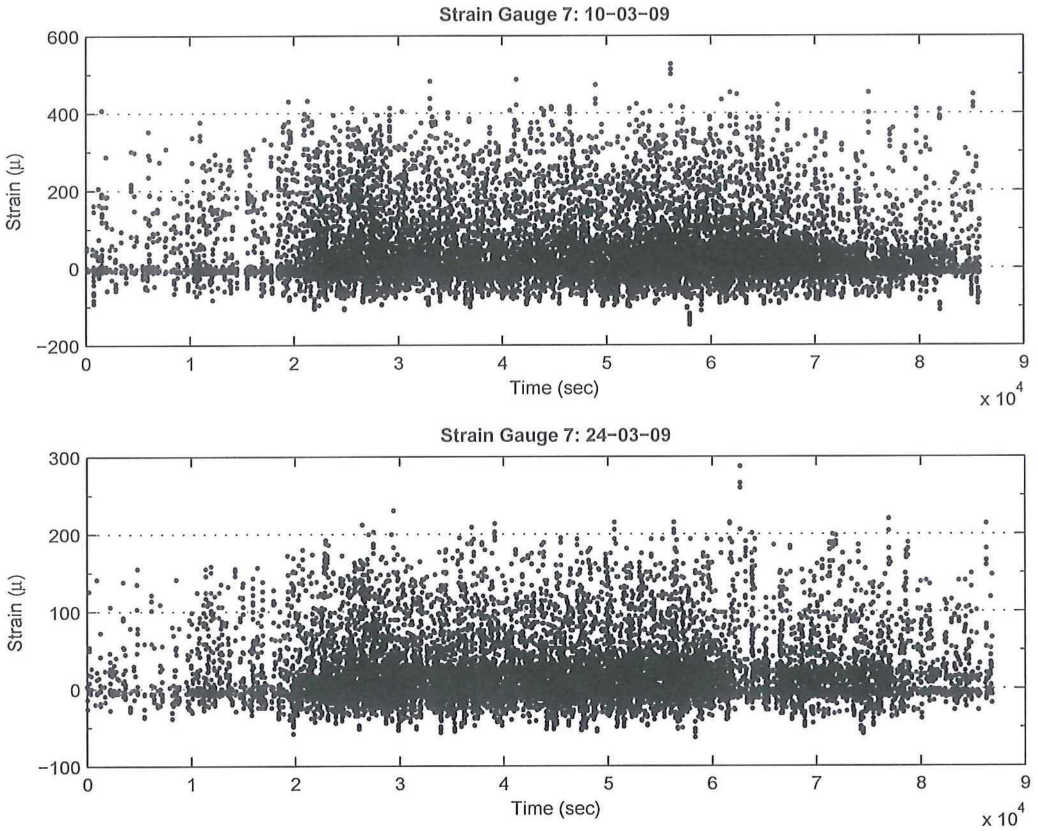
5.1.1 Static strain measurements

The measurements carried out using the calibrated truck positioned in several transverse positions on the deck plate were used to draw the strain influence lines. For each strain gauge, the eight series result in eight influence lines: Series 1 to 4 before the renovation and Series 5 to 8 after the renovation (see Table 1).
In Figure 13, the influence lines recorded for these eight series are plotted for strain gauge number 7. For easier comparison of the different results, each graph plots two strain influence lines: front wheel vs. rear wheels or Series *i* vs. Series *j*. The results for the other fifteen strain gauges are shown in Annex A.
The results for different series using the same load on the same deck plate situation show that the rear wheels series are more scattered then the front wheel series. The measurements recorded before the renovation, in Series 1 and 2 for front wheel and Series 3 and 4 for the rear wheels, are presented in Figure 13 (a) and (b), respectively. The measurements in Series 1 and 2 (Figure 13 (a)) are more similar between each other than for Series 3 and 4 (Figure 13 (b)). The rear wheels exact position is much harder to achieve than the front wheel. This result in a bigger difference between series for the rear wheels measurements. The same can be observed on the measurements performed after the renovation for Series 5 and 6 using the front wheel and Series 7 and 8 using the rear wheels (Figure 13 (e) and (f)).
Plotting together the strain values measured using front wheel loads and using rear wheel loads shows that the strain values are higher for the front wheel than for the rear wheels (Figure 13 (c), (d), (g) and (h)). Having approximately the same load, the front wheel has a smaller wheel print than the rear wheels and therefore induces higher load stress on the deck plate. This can be observed on both measurements performed before or after the renovation.
Looking at the difference between the maximum strain values before and after the renovation, it can be observed that the strains after the renovation are considerably lower than before the renovation. This can be seen both for front wheel load (Figure 13 (a) vs. Figure 13 (e)) and for the rear wheels load (Figure 13 (b) vs. Figure 13 (f)).

5.1.2 Strain history measurements

The strain history is being recorded to all the strain gauges applied on the bridge deck. For the short term monitoring only the results of the strain gauge applied to the middle span cross section (see Figure 5) are being analysed. The strain history values are recorded per day. Before the renovation, the measurements were taken during 8 days, from 6th March 2009 to 13th of March 2009 (Friday to Friday). After the renovation, the measurements started on the 22nd of March and are being continuously recorded since then.

As an example, the strain history recorded on strain gauge number 7 (deck plate between stiffener's webs) is presented in this chapter during one day before and after the renovation (Figure 14 (a) and (b)). In order to compare the results before and after the renovation, the same week day is presented. The days plotted are Tuesday 10th of March (Figure 14 (a)) and Tuesday 24th of March (Figure 14 (a)), before and after the renovation respectively. The same graphs are presented in Annex B for the other 15 strain gauges.



(a) (b)

Figure 14 – Strain history measurements of strain gauge 7 before renovation at 10-03-09 and after renovation at 24-03-09

The x-axle corresponds to 24 hours plotted in seconds. The origin of the x-axle is 00.00 of each day. The data is successive maximum and minimum values caused by each axle load running on the bridge. The data was previously corrected to take into account the temperature that affects the measurements of the strain gauges.

Looking at the difference between the maximum strain values before and after the renovation, it can be observed that the strains after the renovation are lower than before the renovation.

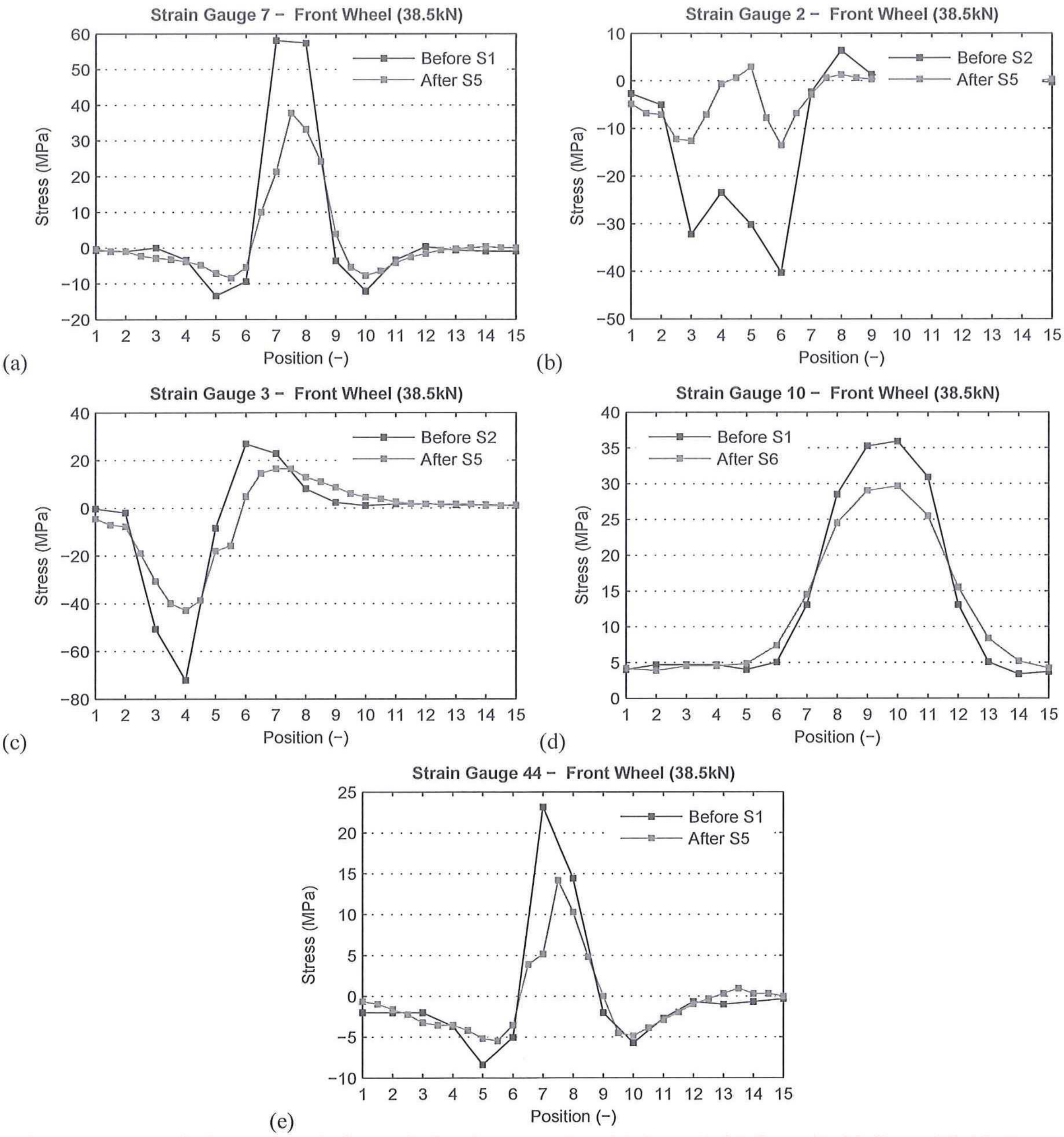


Figure 15 – Stress influence lines before and after the renovation: (a) Group I, (b) Group II, (c) Group III, (d) Group IV and (e) Group V (*Si: Series i*)

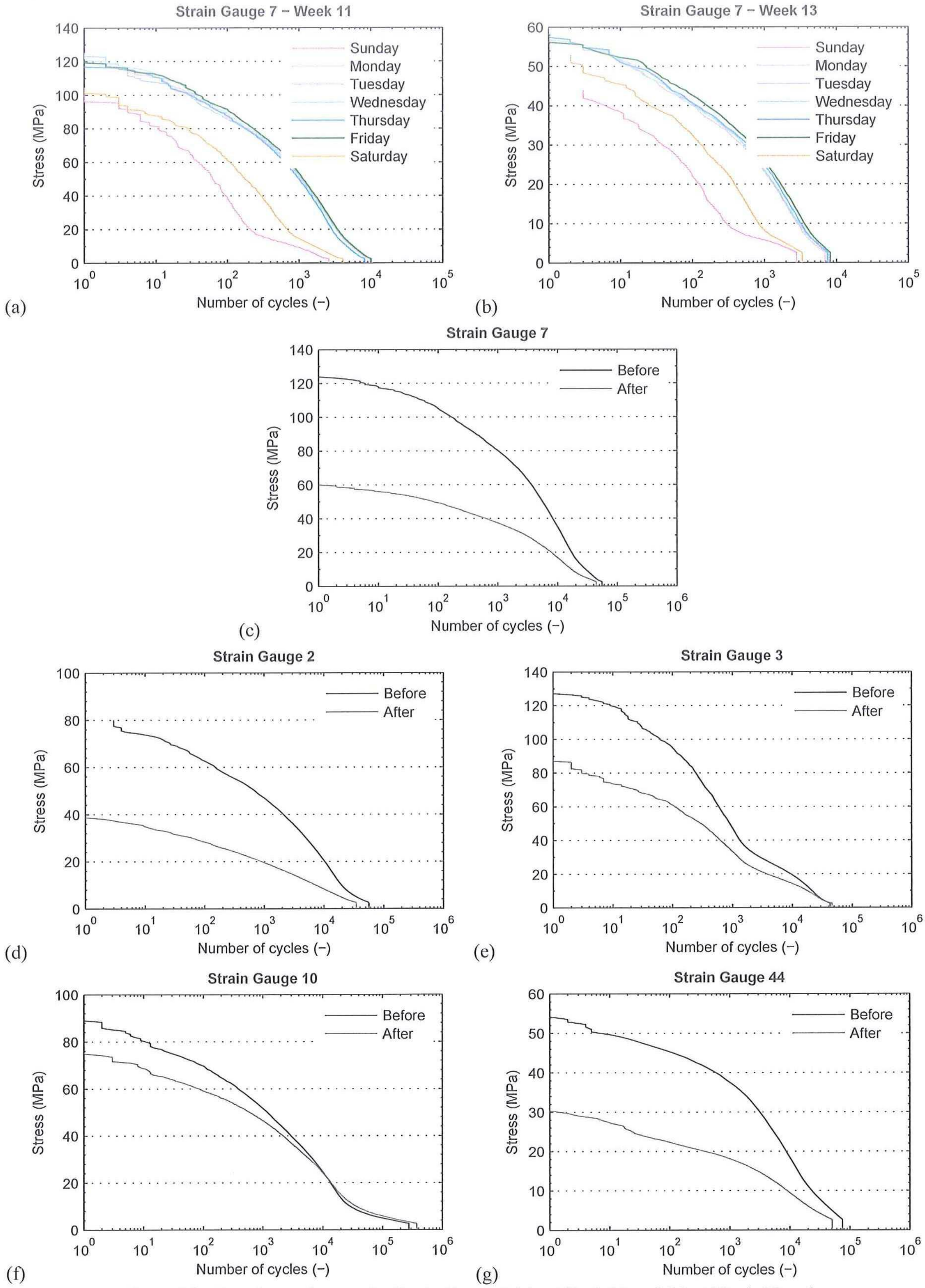


Figure 16 – Day Stress Spectra for Strain Gauge 7 (a) at Week 11 and (b) at Week 13 and Week Spectra before (Week 11) and after (Week 13) for Strain Gauge 7 (c), 2 (d), 3 (e), 10 (f) and 44 (f).

the strain gauge number 14. Finally, the longitudinal stresses in the deck plate between the stiffeners webs reduce about 50 % after the renovation.

6.1.3 Comparison between influence lines and spectra

On both analysis stress influence lines and stress spectra, the stress reduction factor was determined. Table 4 summarizes the values for both analyses and shows the average stress reduction factor of each strain gauge group.

Group	Strain Gauge	SR_i		Location
		Influence lines	Spectra	
Group I	1	55%	57%	Transverse stress at the deck plate at middle span between stiffeners webs.
	7	38%	53%	
	13	45%	50%	
	$\overline{SR_I}$	46%	54%	
Group II	2	63%	55%	Transverse stress at the deck plate 15 mm from the welded connection between deck plate and stiffeners web
	6	53%	55%	
	8	59%	55%	
	12	57%	52%	
	$\overline{SR_{II}}$	56%	54%	
Group III	3	37%	35%	Transverse stress at the stiffeners web 15 mm from the welded connection between deck plate and stiffeners web.
	5	37%	36%	
	9	35%	34%	
	11	39%	26%	
	$\overline{SR_{III}}$	37%	32%	
Group IV	4	18%	12%	Longitudinal stress at the bottom of the stiffeners.
	10	14%	14%	
	14	7%	0%	
	$\overline{SR_{IV}}$	13%	8%	
Group V	43	57%	54%	Longitudinal stress at the deck plate at middle span between stiffeners webs
	44	47%	49%	
	$\overline{SR_V}$	52%	51%	

Table 4 – Average stress reduction factor of each strain gauge group determined using influence lines and stress spectra.

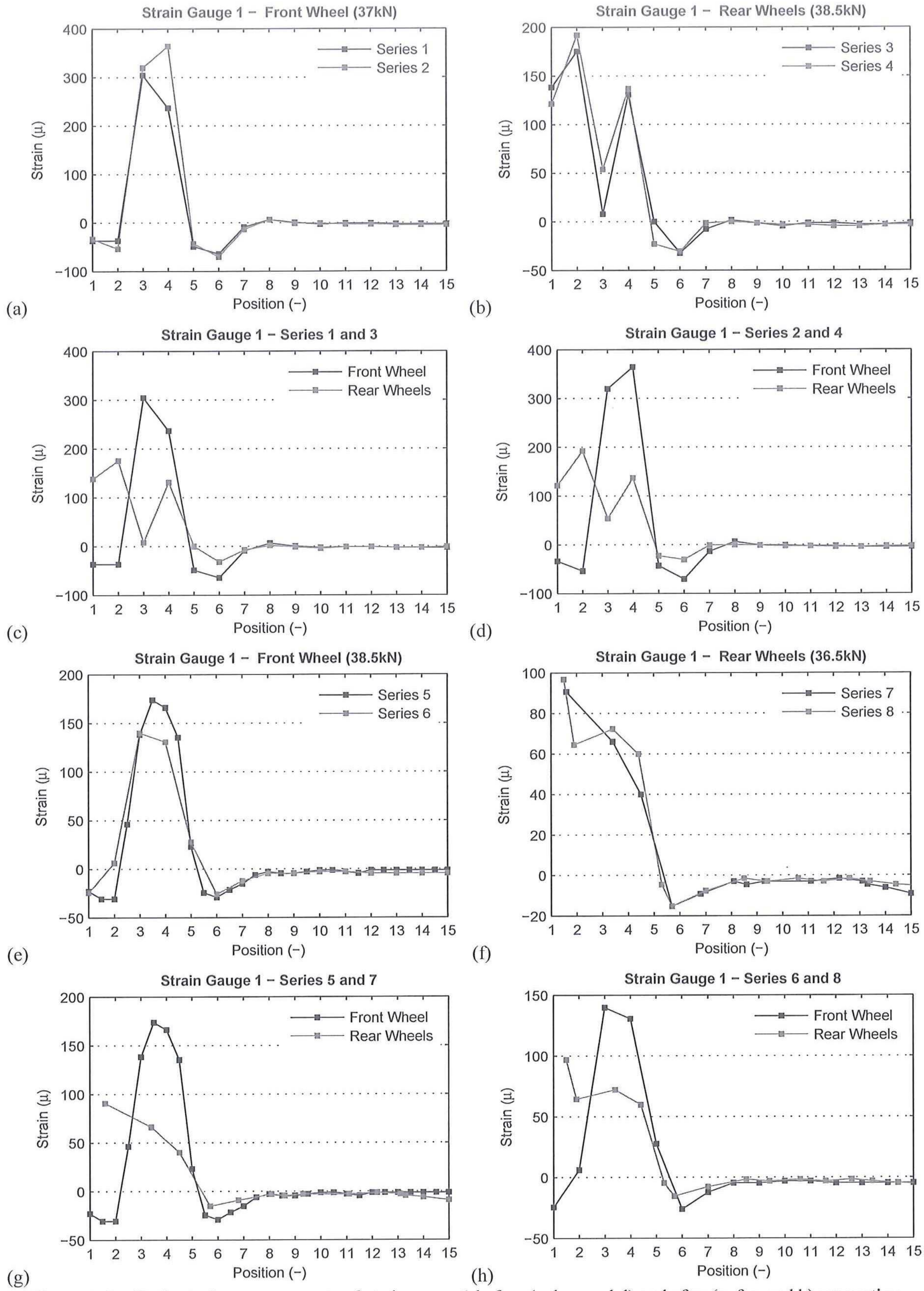


Figure A-1 – Static strain measurements of strain gauge 1 before (a, b, c and d) and after (e, f, g and h) renovation.

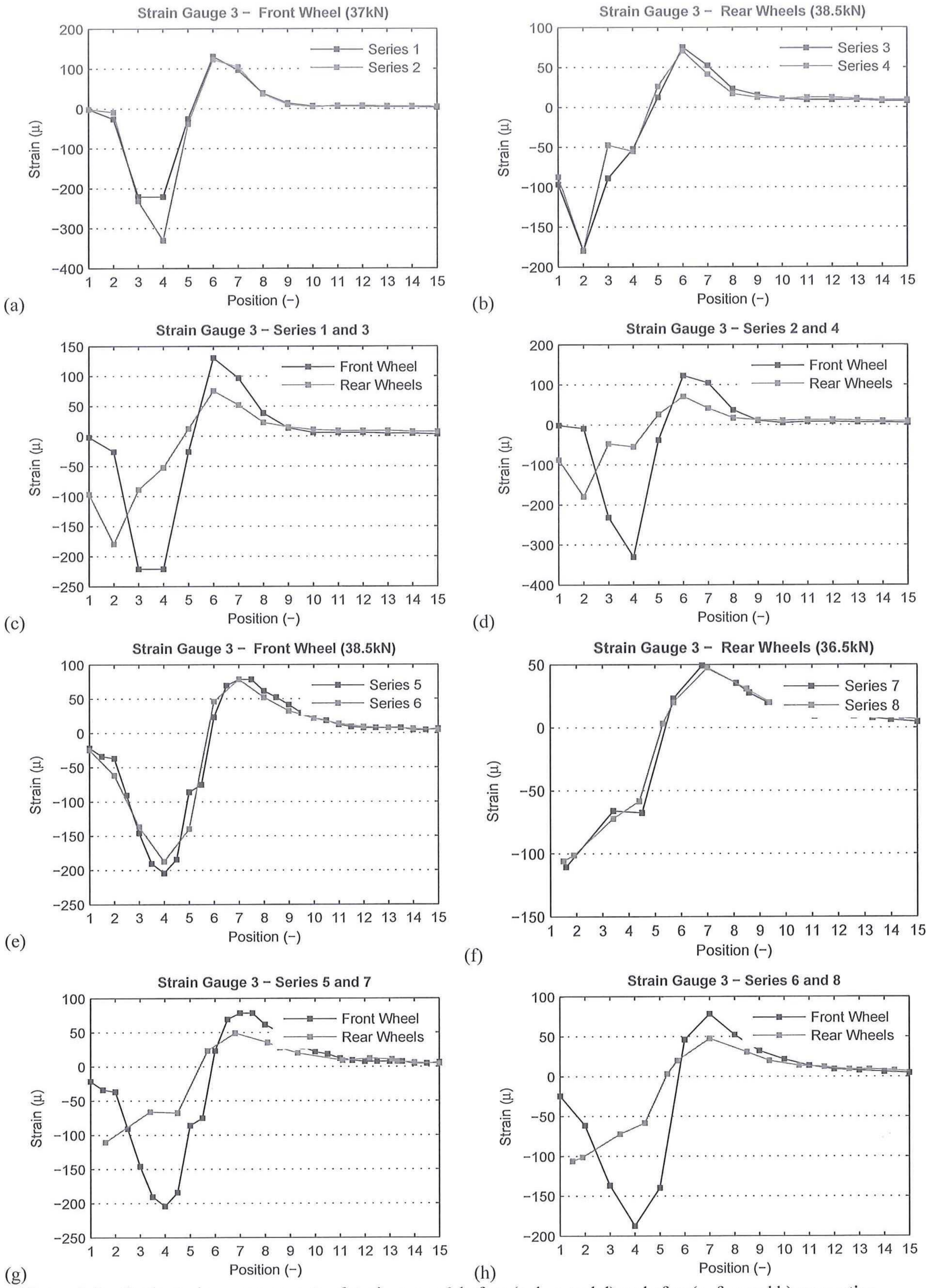


Figure A-3 – Static strain measurements of strain gauge 3 before (a, b, c and d) and after (e, f, g and h) renovation.

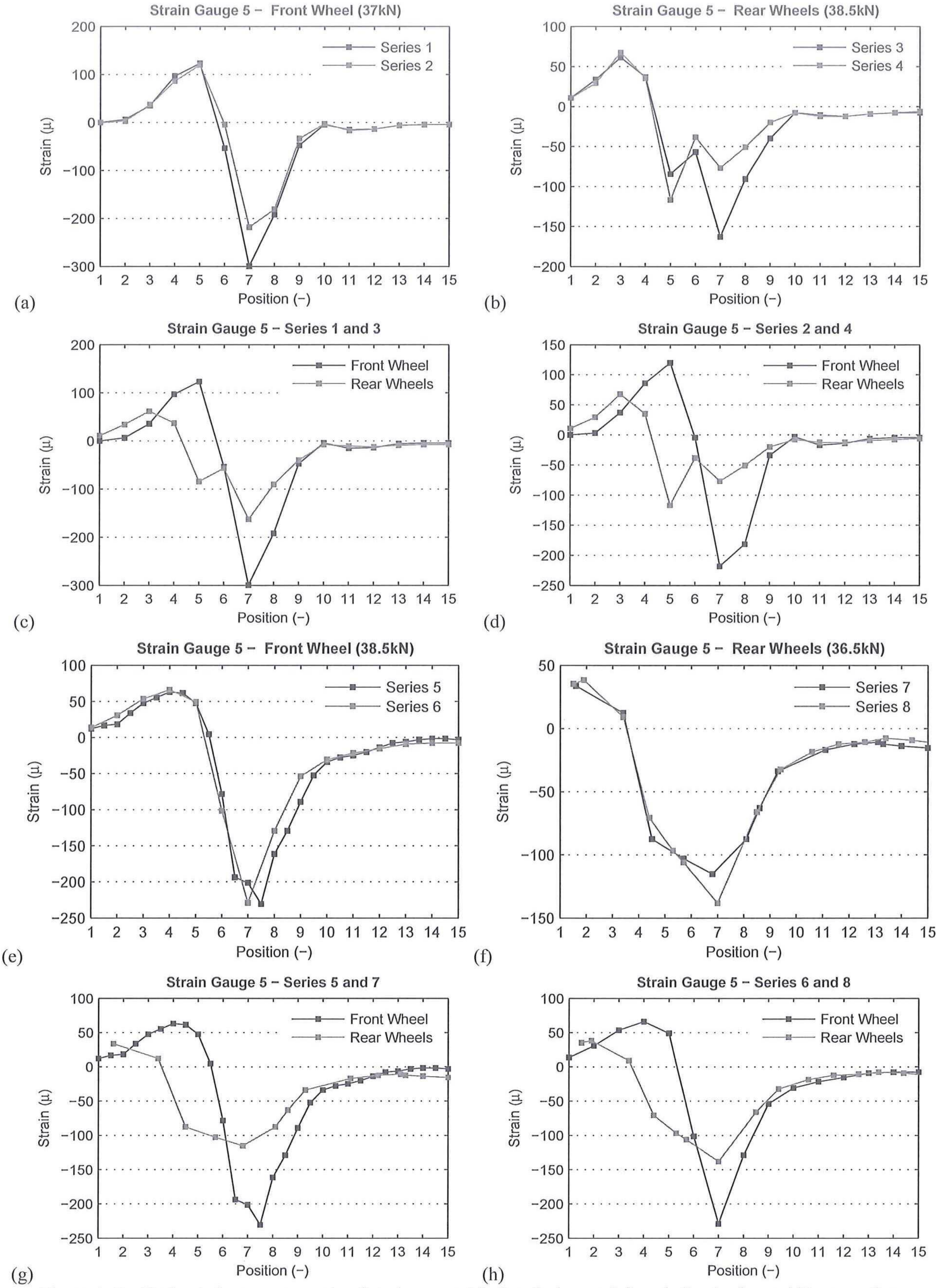


Figure A-5 – Static strain measurements of strain gauge 5 before (a, b, c and d) and after (e, f, g and h) renovation.

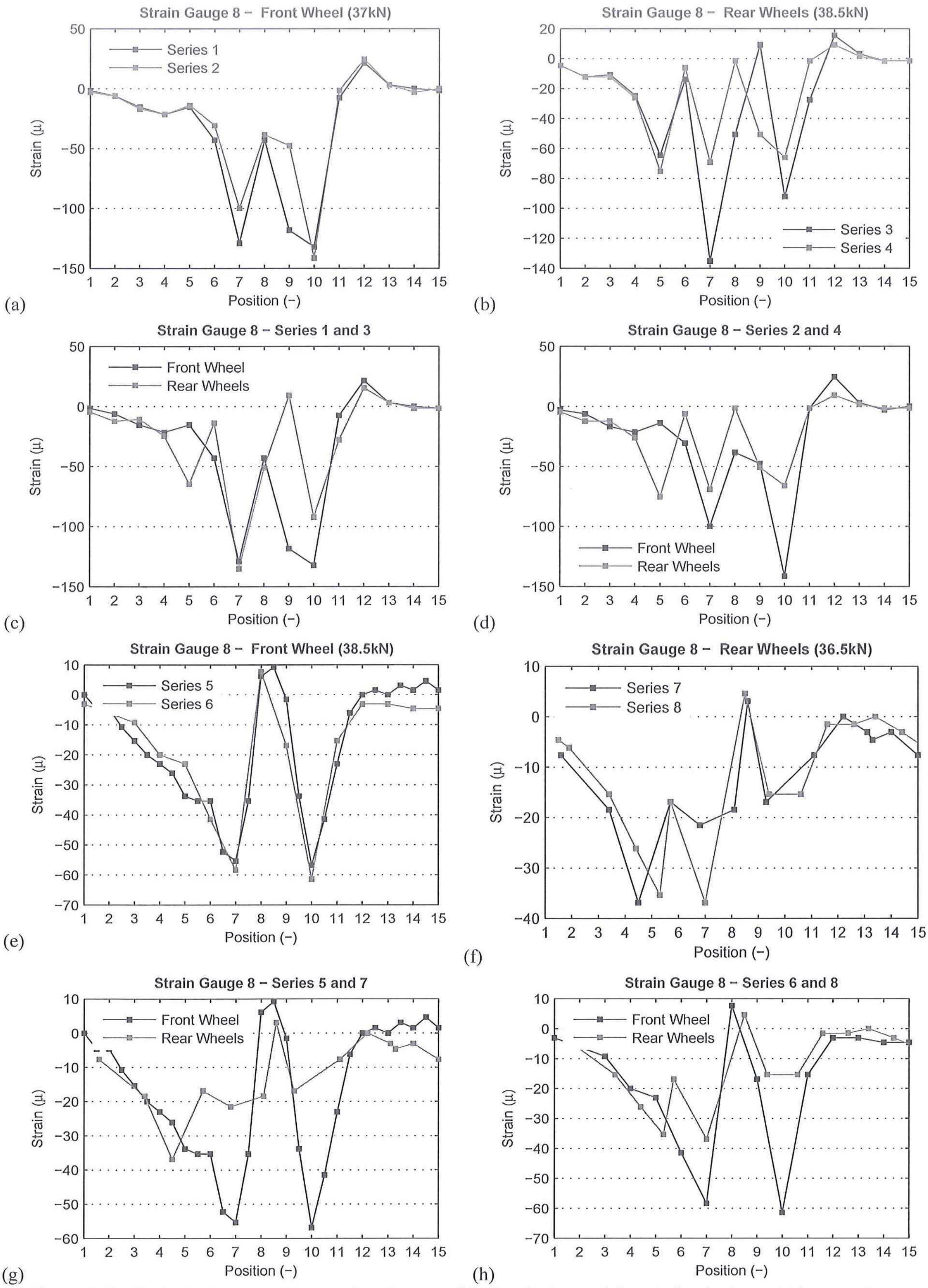


Figure A-7 – Static strain measurements of strain gauge 8 before (a, b, c and d) and after (e, f, g and h) renovation.

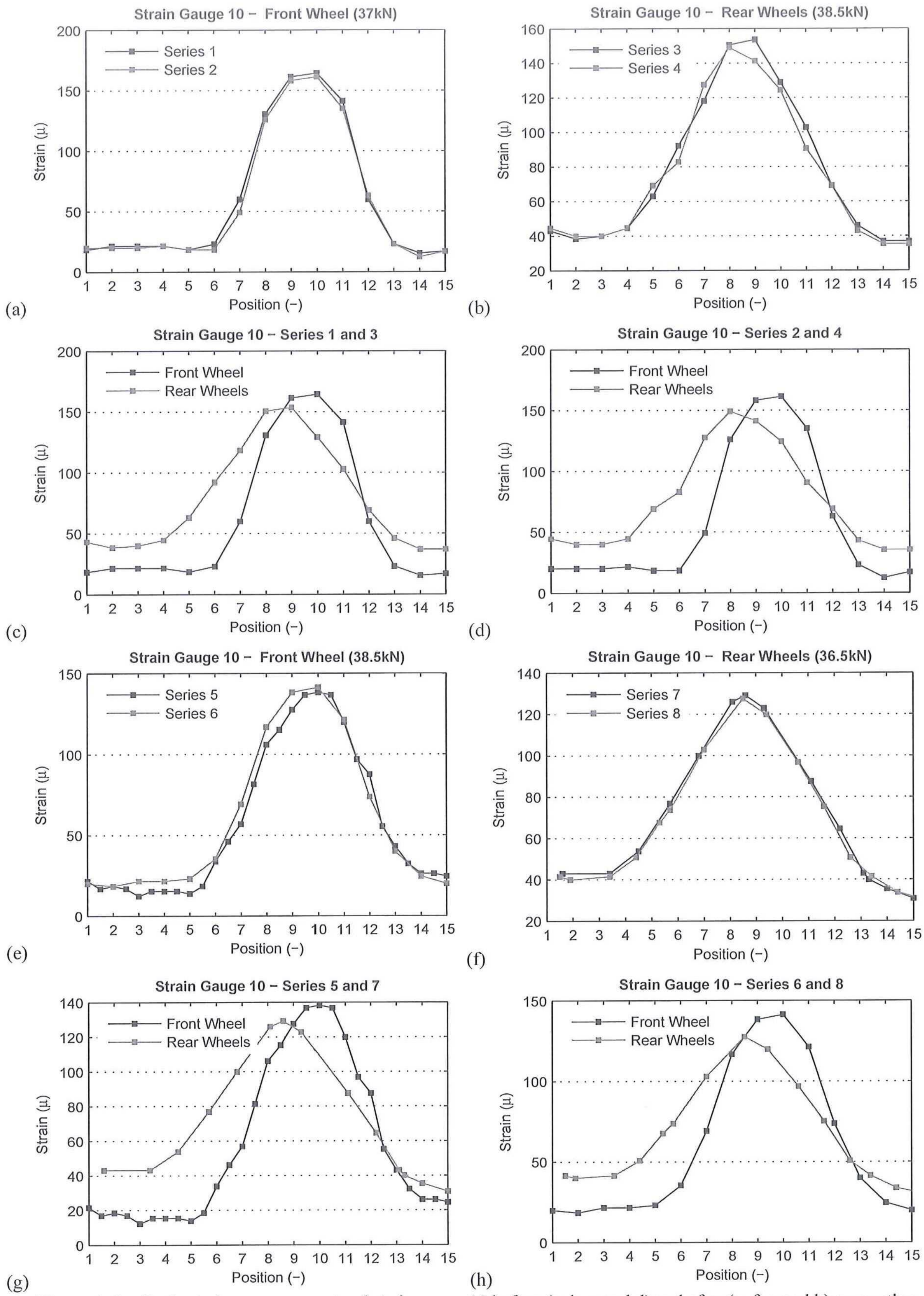


Figure A-9 – Static strain measurements of strain gauge 10 before (a, b, c and d) and after (e, f, g and h) renovation.

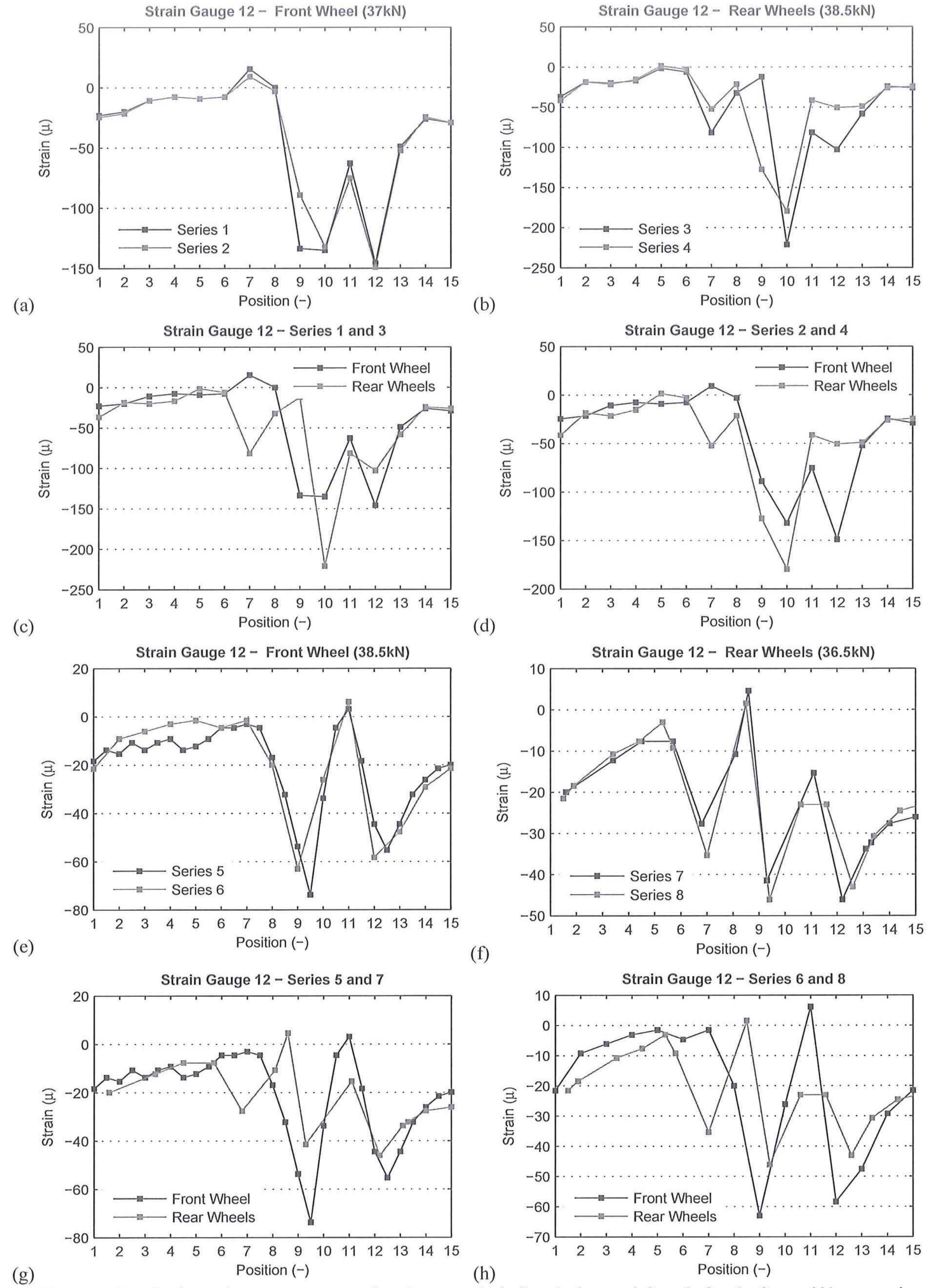


Figure A-11 – Static strain measurements of strain gauge 12 before (a, b, c and d) and after (e, f, g and h) renovation.

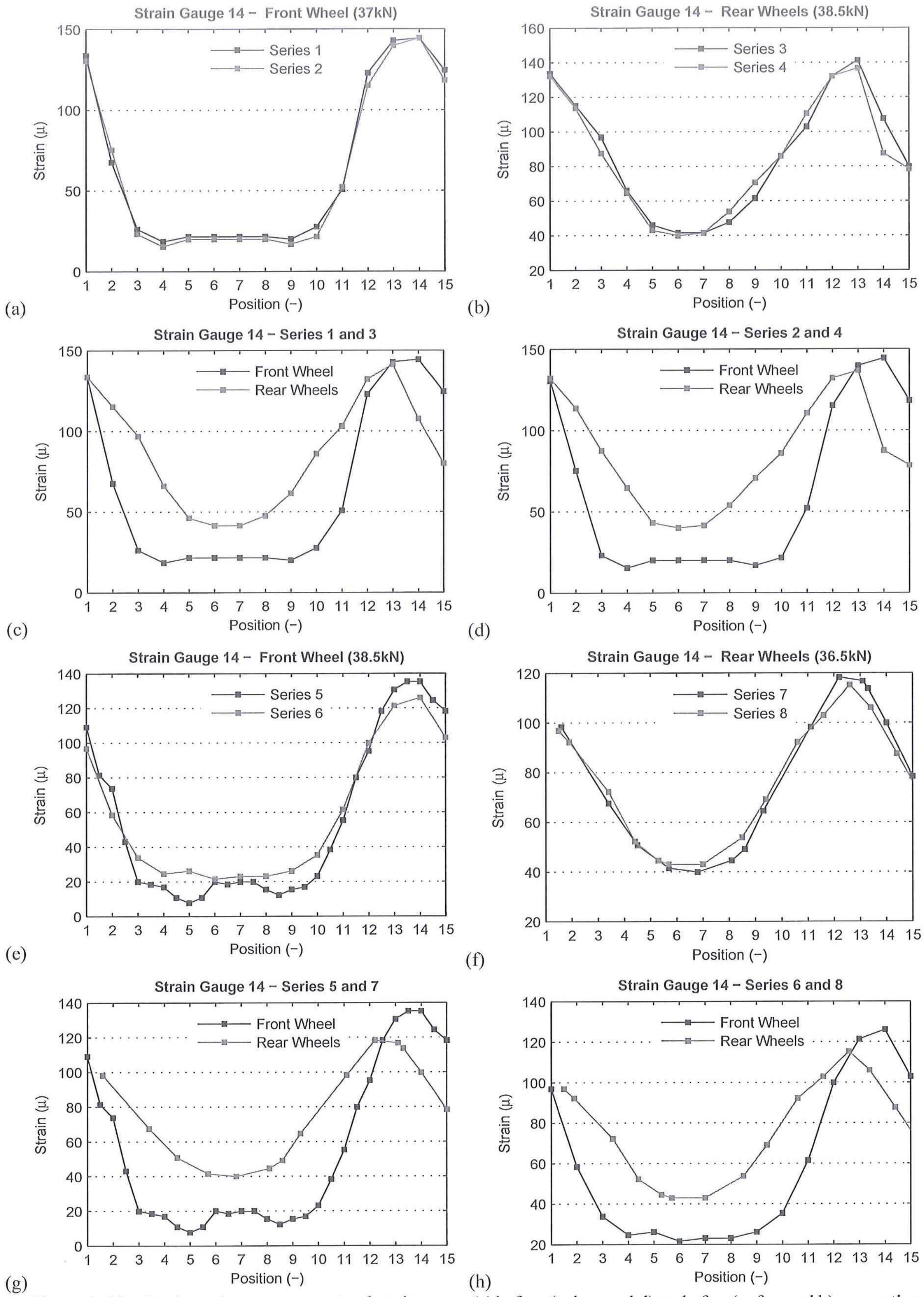


Figure A-13 – Static strain measurements of strain gauge 14 before (a, b, c and d) and after (e, f, g and h) renovation.

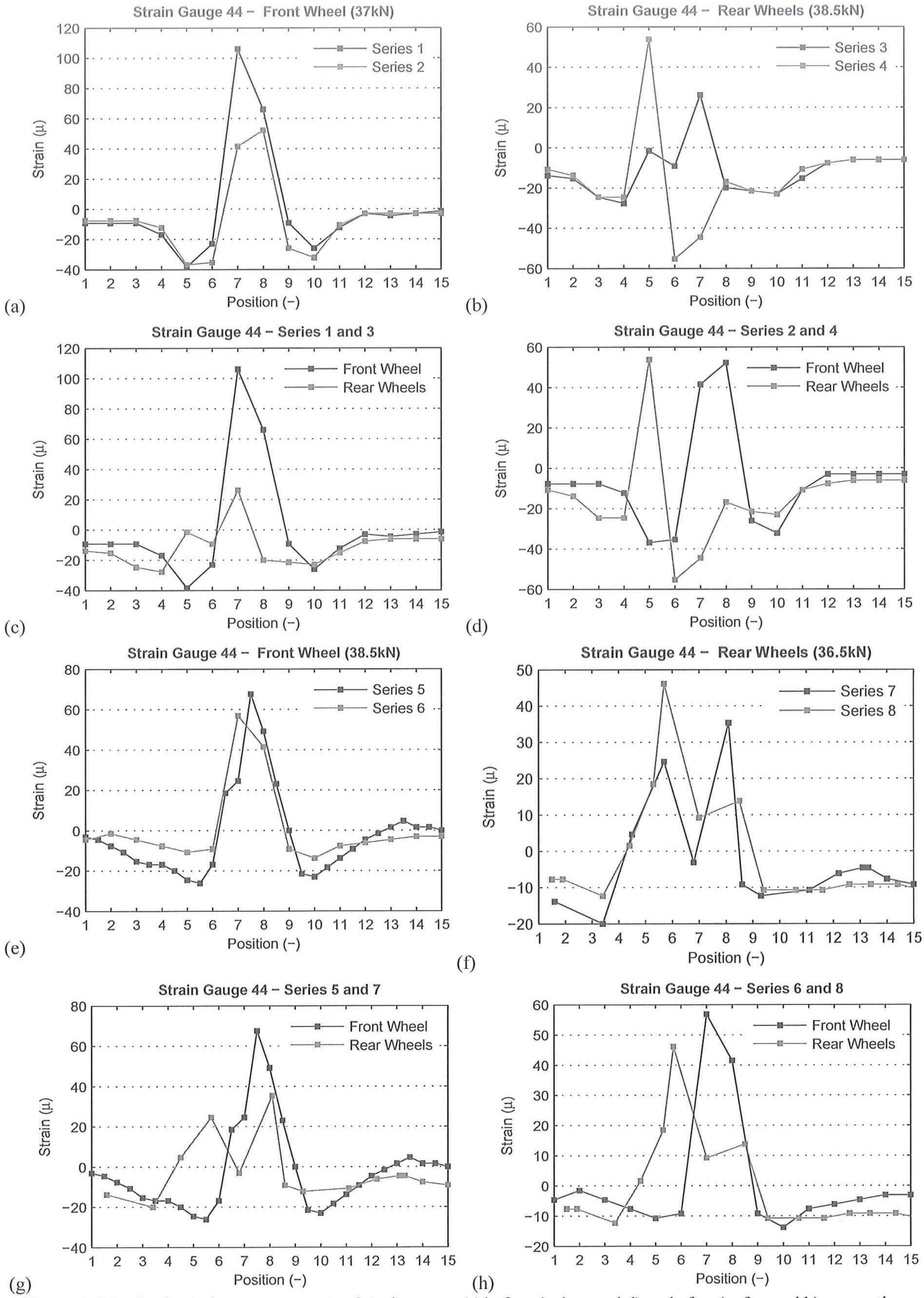
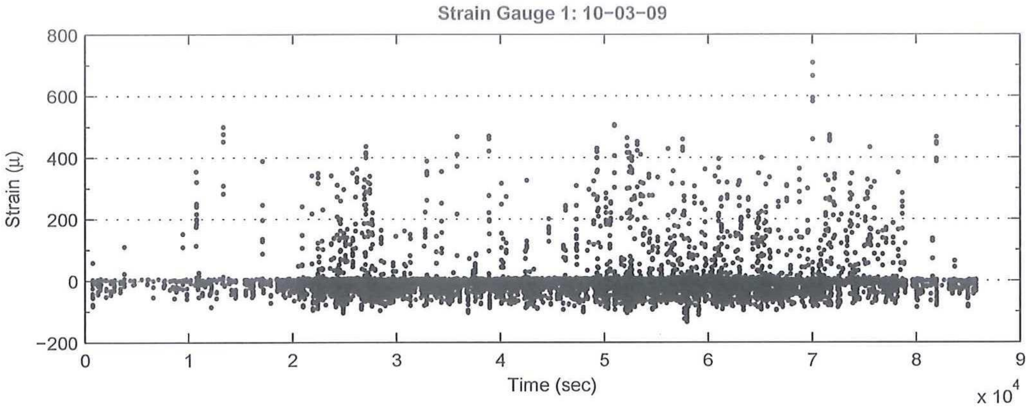
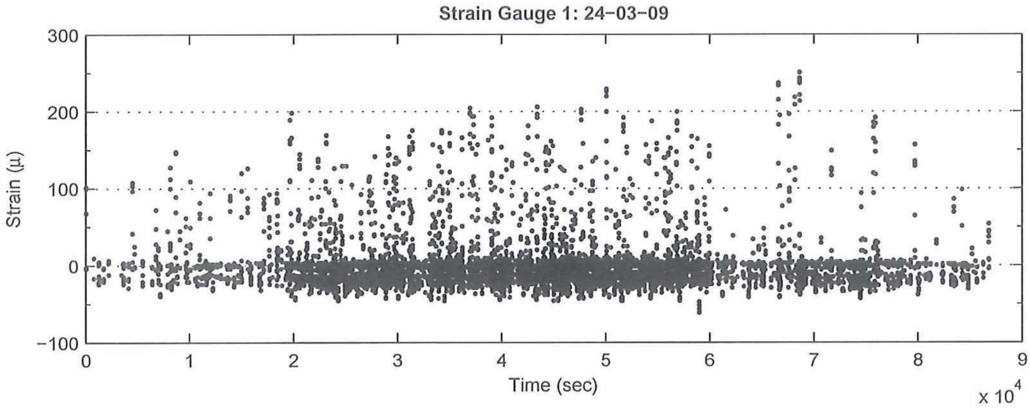


Figure A-15 – Static strain measurements of strain gauge 44 before (a, b, c and d) and after (e, f, g and h) renovation.

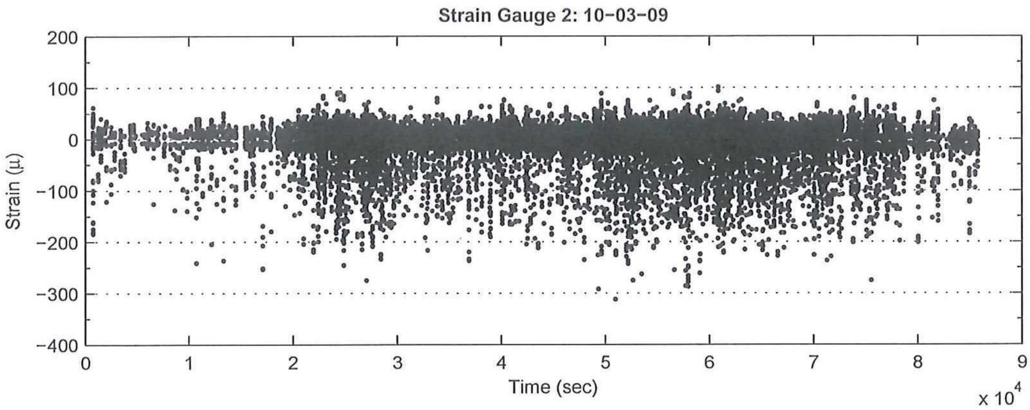


(a)

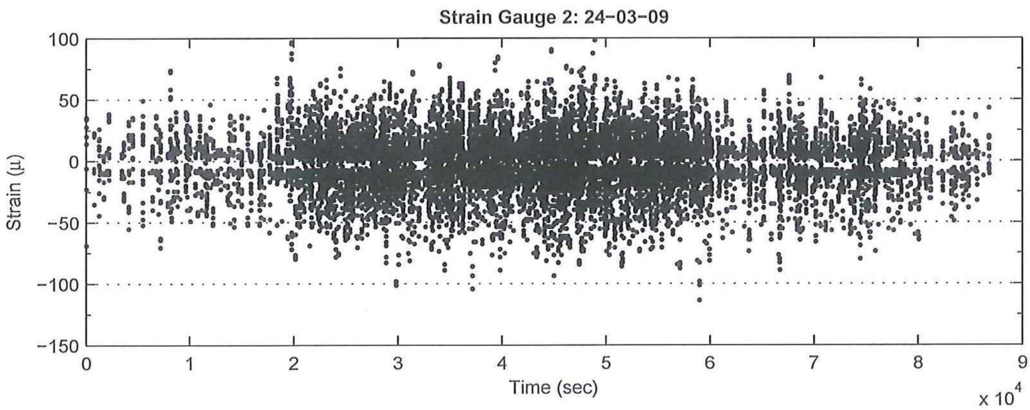


(b)

Figure B-1 –Strain history measurements of strain gauge 1 at (a) 10-03-2009 and (b) 24-03-2009.

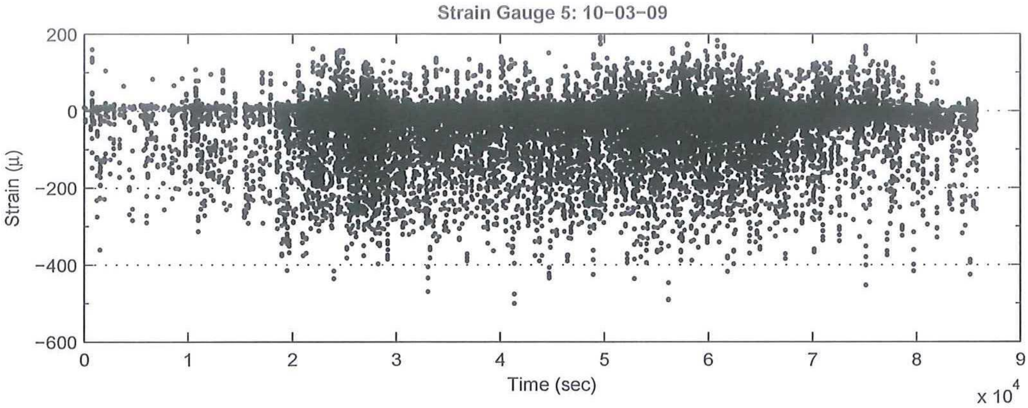


(a)

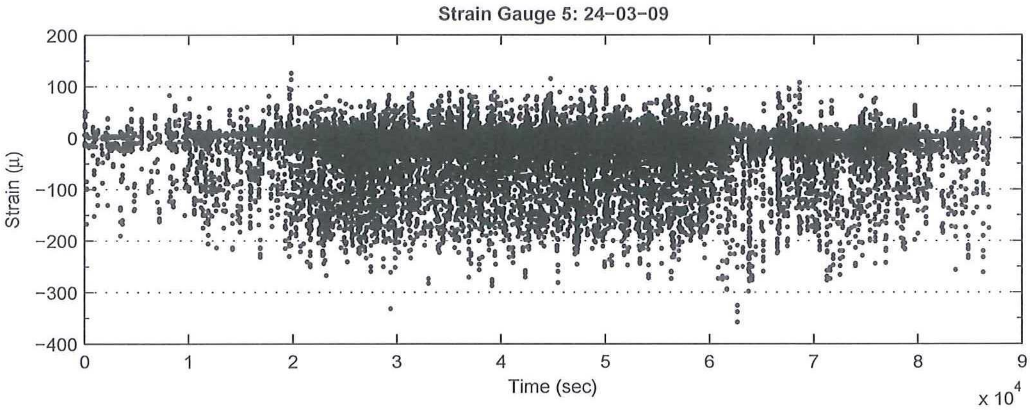


(b)

Figure B-2 –Strain history measurements of strain gauge 2 at (a) 10-03-2009 and (b) 24-03-2009.

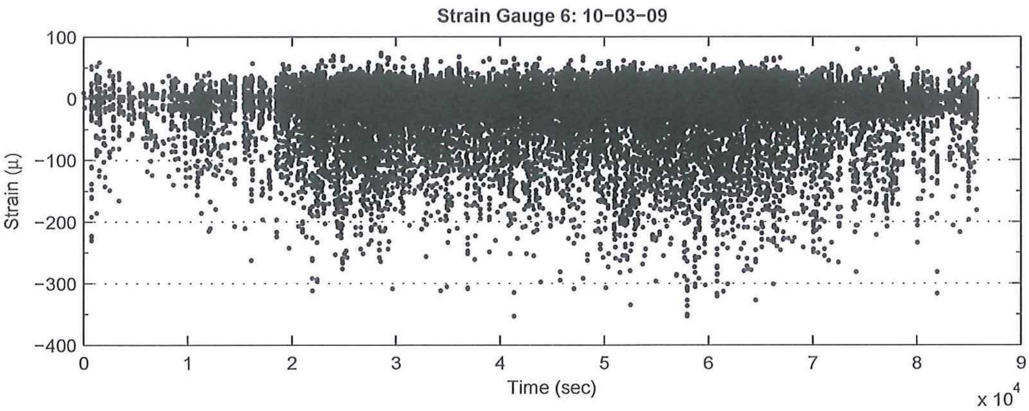


(a)

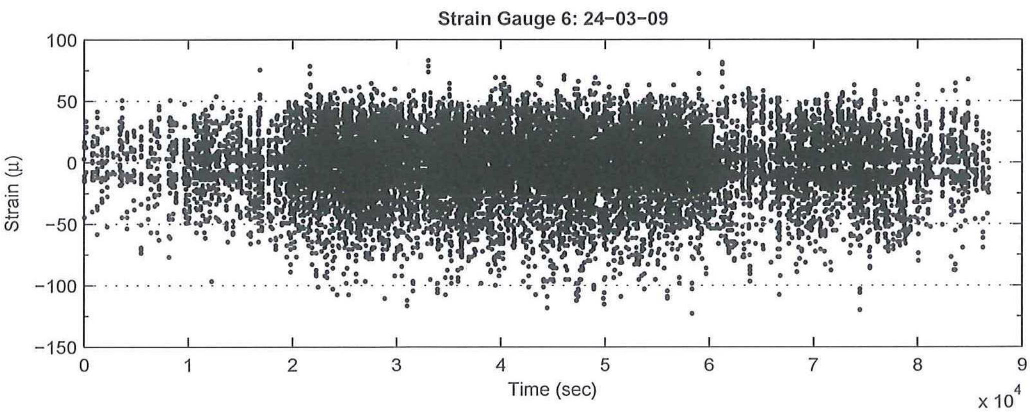


(b)

Figure B-5 –Strain history measurements of strain gauge 5 at (a) 10-03-2009 and (b) 24-03-2009.

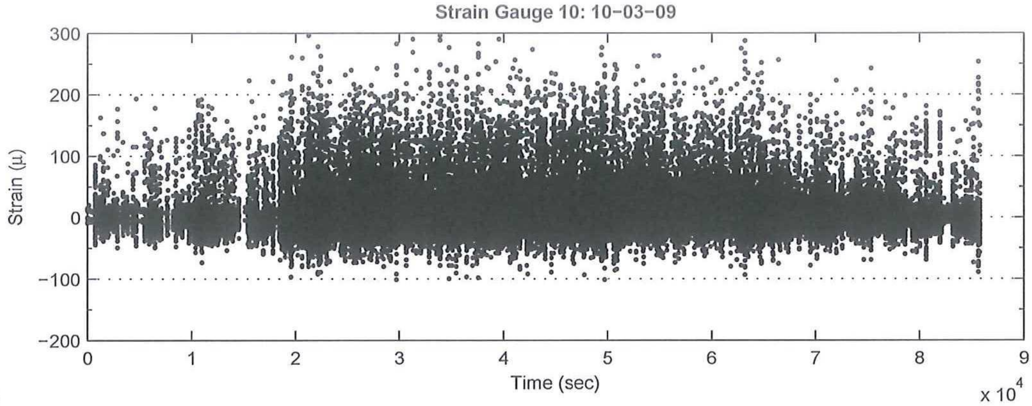


(a)

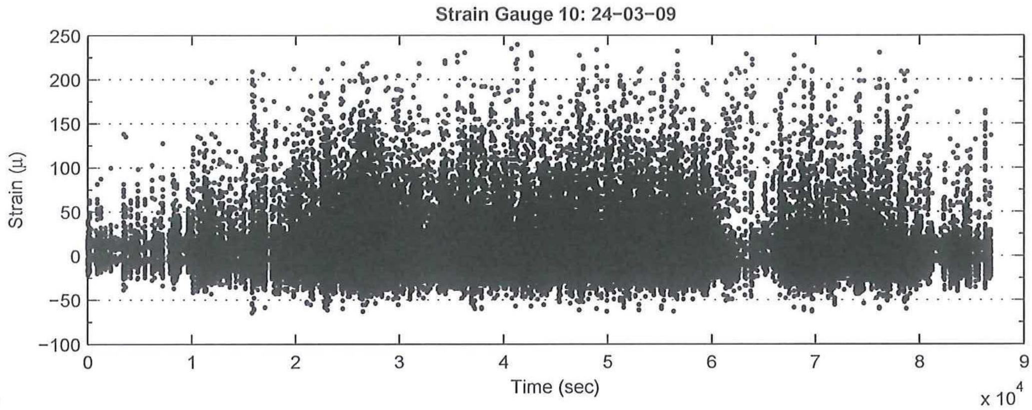


(b)

Figure B-6 –Strain history measurements of strain gauge 6 at (a) 10-03-2009 and (b) 24-03-2009.

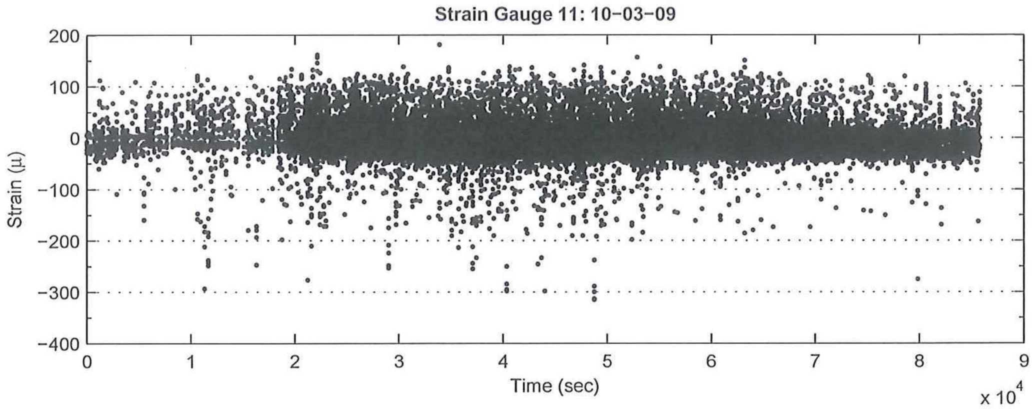


(a)

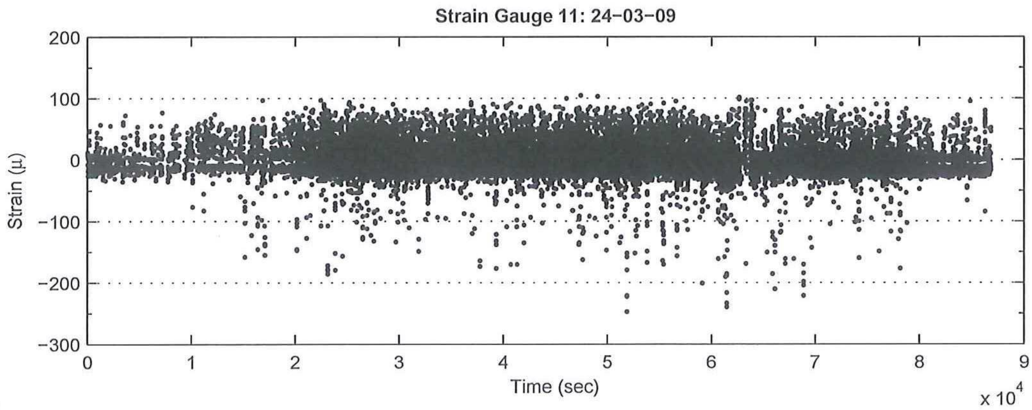


(b)

Figure B-9 –Strain history measurements of strain gauge 10 at (a) 10-03-2009 and (b) 24-03-2009.

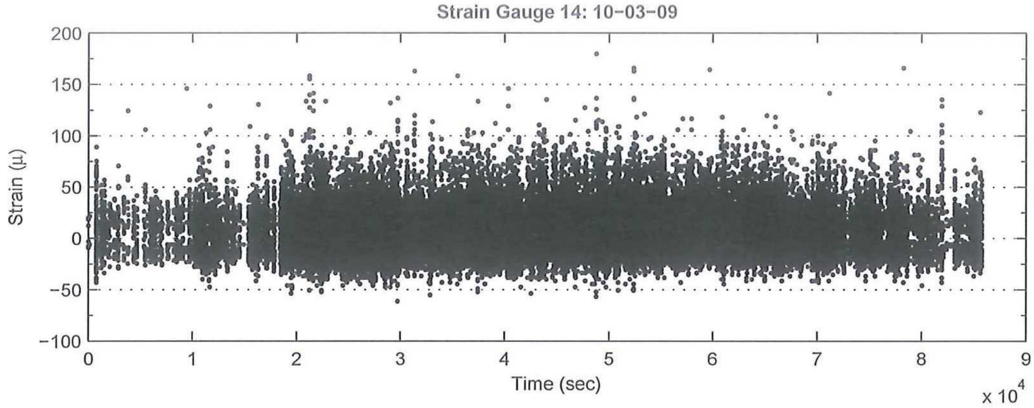


(a)

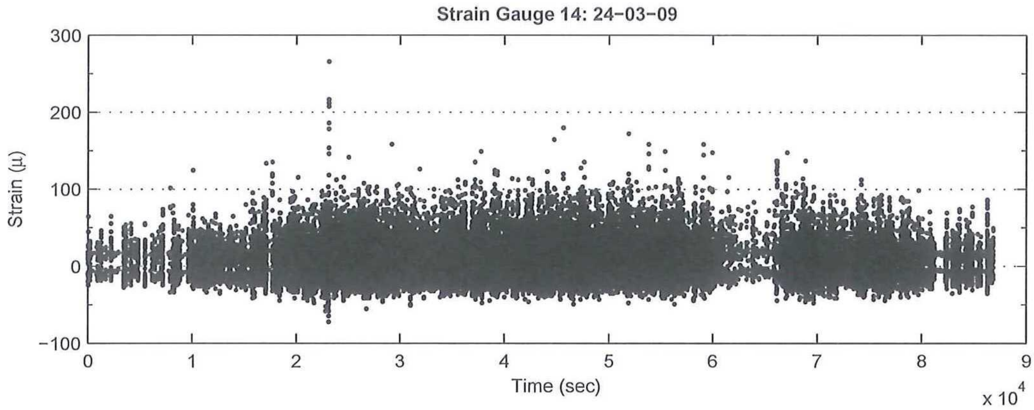


(b)

Figure B-10 –Strain history measurements of strain gauge 11 at (a) 10-03-2009 and (b) 24-03-2009..

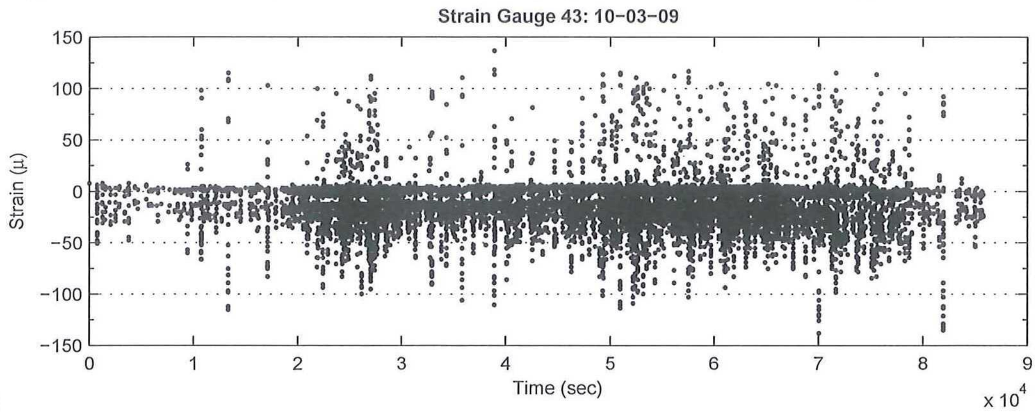


(a)

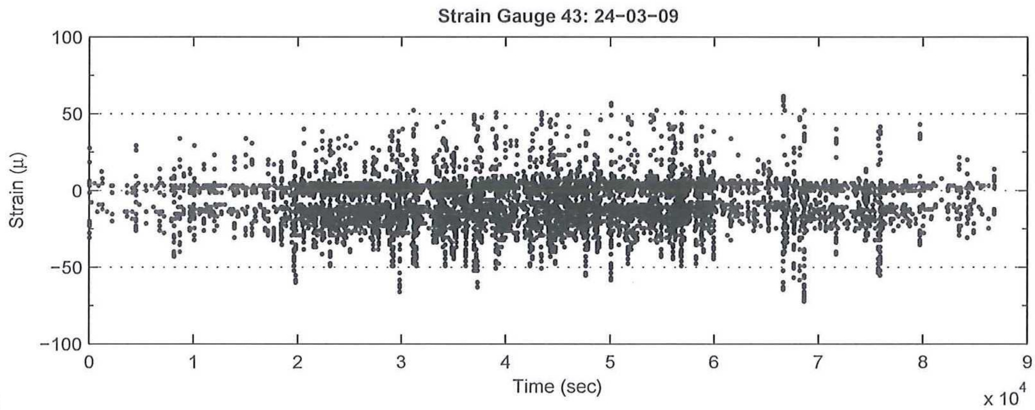


(b)

Figure B-13 –Strain history measurements of strain gauge 14 at (a) 10-03-2009 and (b) 24-03-2009.



(a)



(b)

Figure B-14 –Strain history measurements of strain gauge 43 at (a) 10-03-2009 and (b) 24-03-2009.

C. Annex C: Stress Influence Lines before and after the renovation

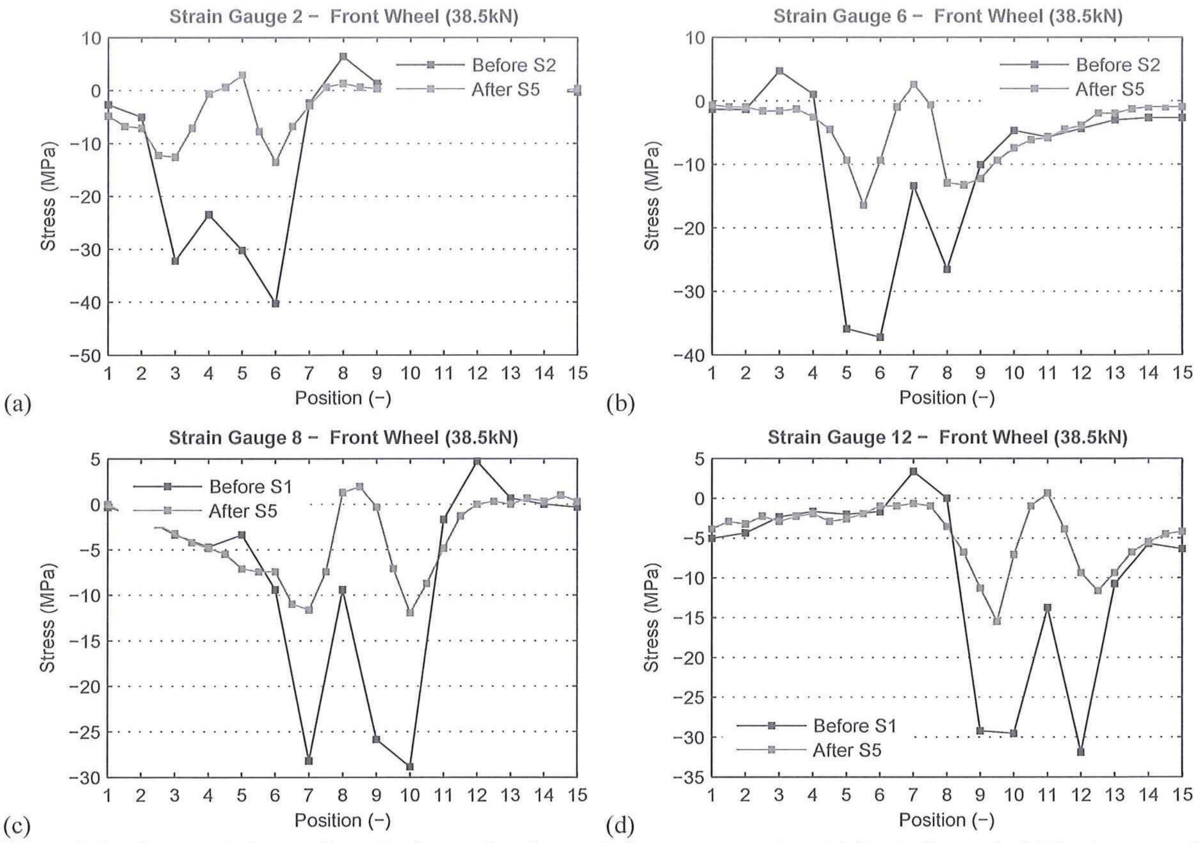
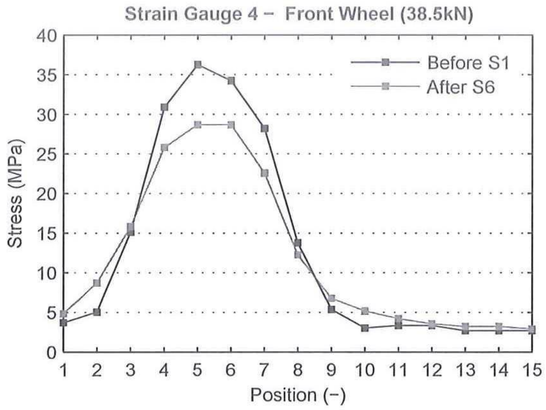


Figure C-2 – Stresses influence lines for Group II before and after the renovation: (a) Strain Gauge 2, (b) Strain gauge 6, (c) Strain gauge 8 and (d) Strain gauge 12.



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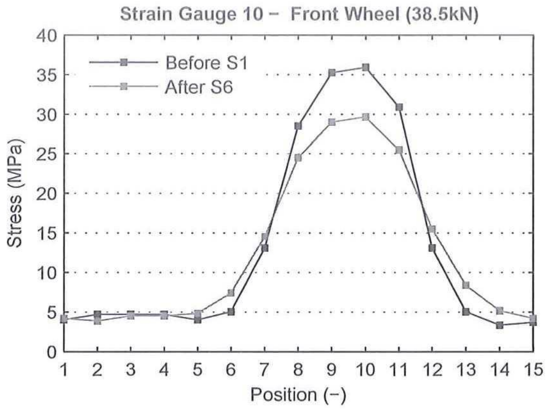

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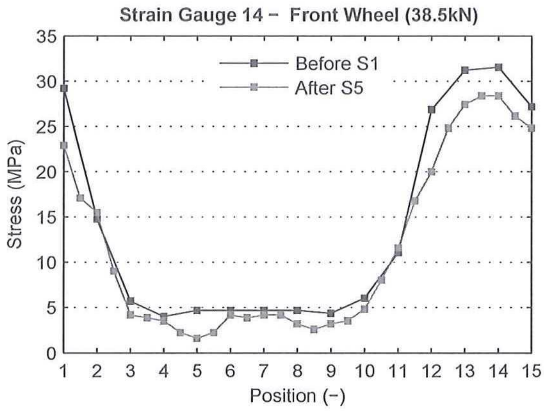
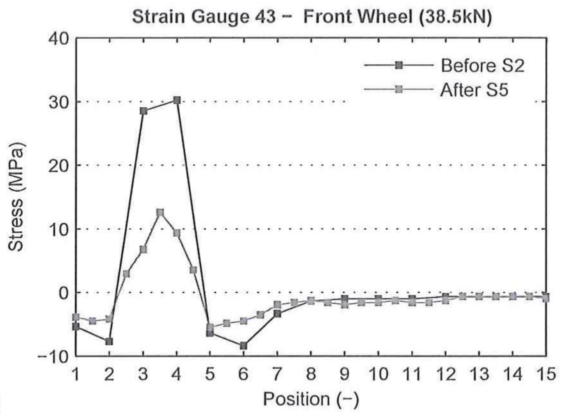
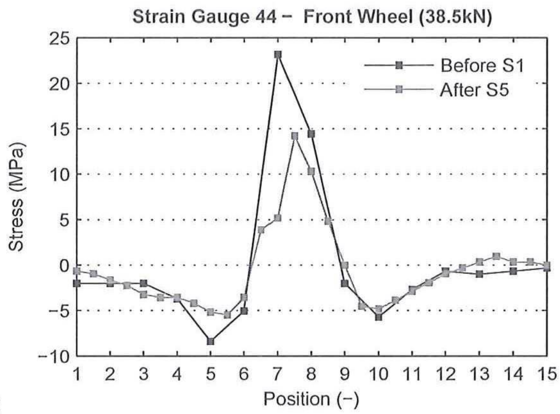


(c)

Figure C-4 – Stresses influence lines for Group IV before and after the renovation: (a) Strain Gauge 4, (b) Strain gauge 10 and (c) Strain gauge 14.



(a)



(b)

(c)

Figure C-5 – Stresses influence lines for Group V before and after the renovation: (a) Strain Gauge 43 and (b) Strain gauge 44.

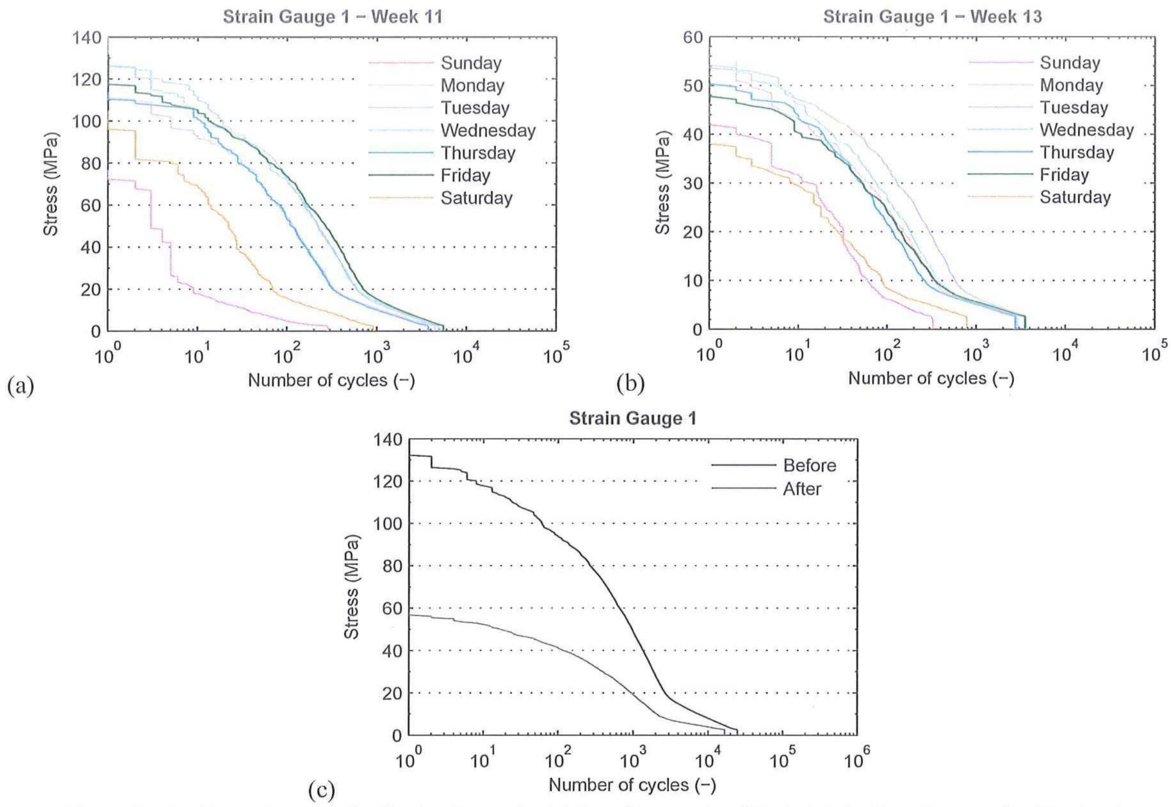


Figure D-1 – Stress Spectra for Strain Gauge 1: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).

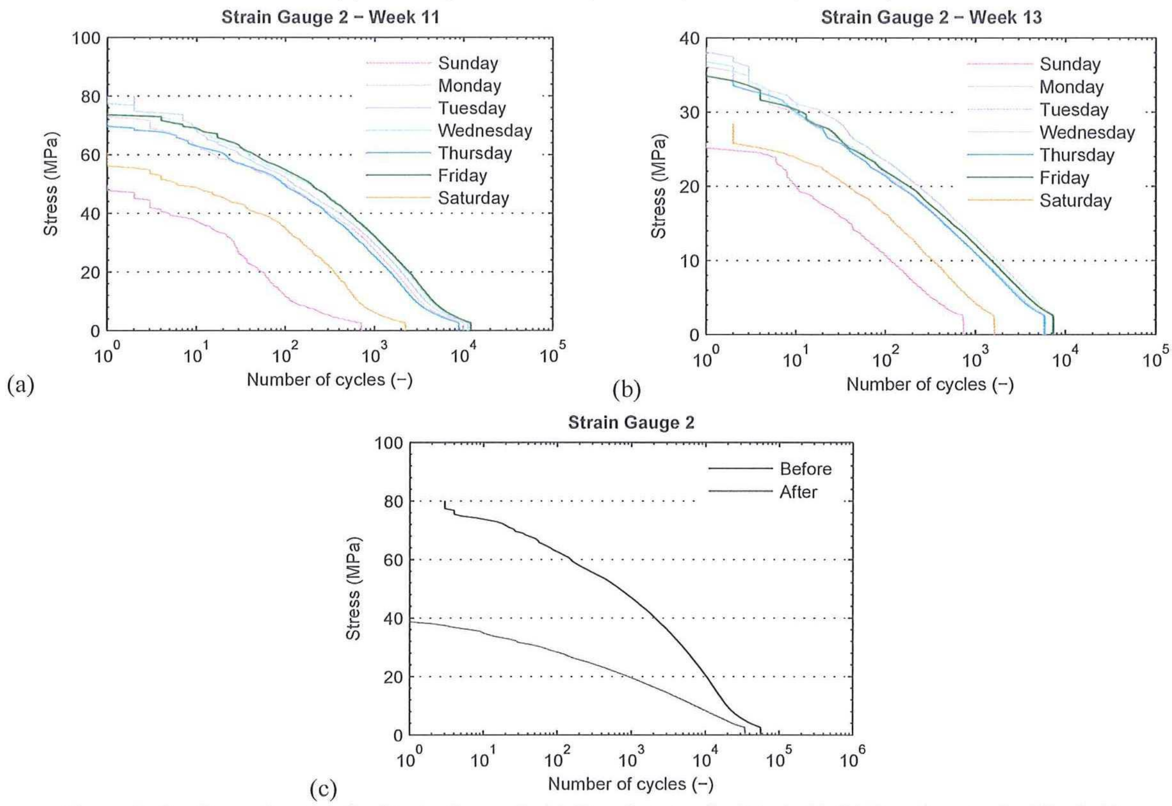


Figure D-2 – Stress Spectra for Strain Gauge 2: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).

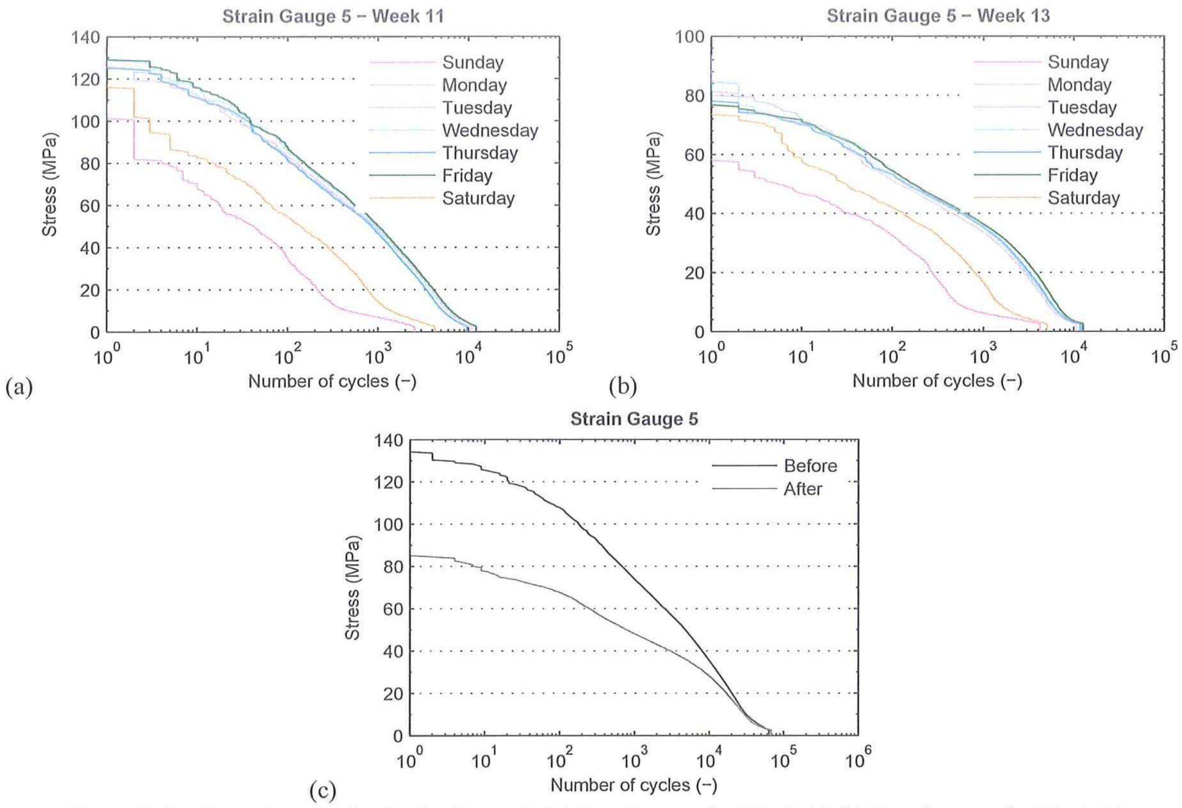


Figure D-5 – Stress Spectra for Strain Gauge 5: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).

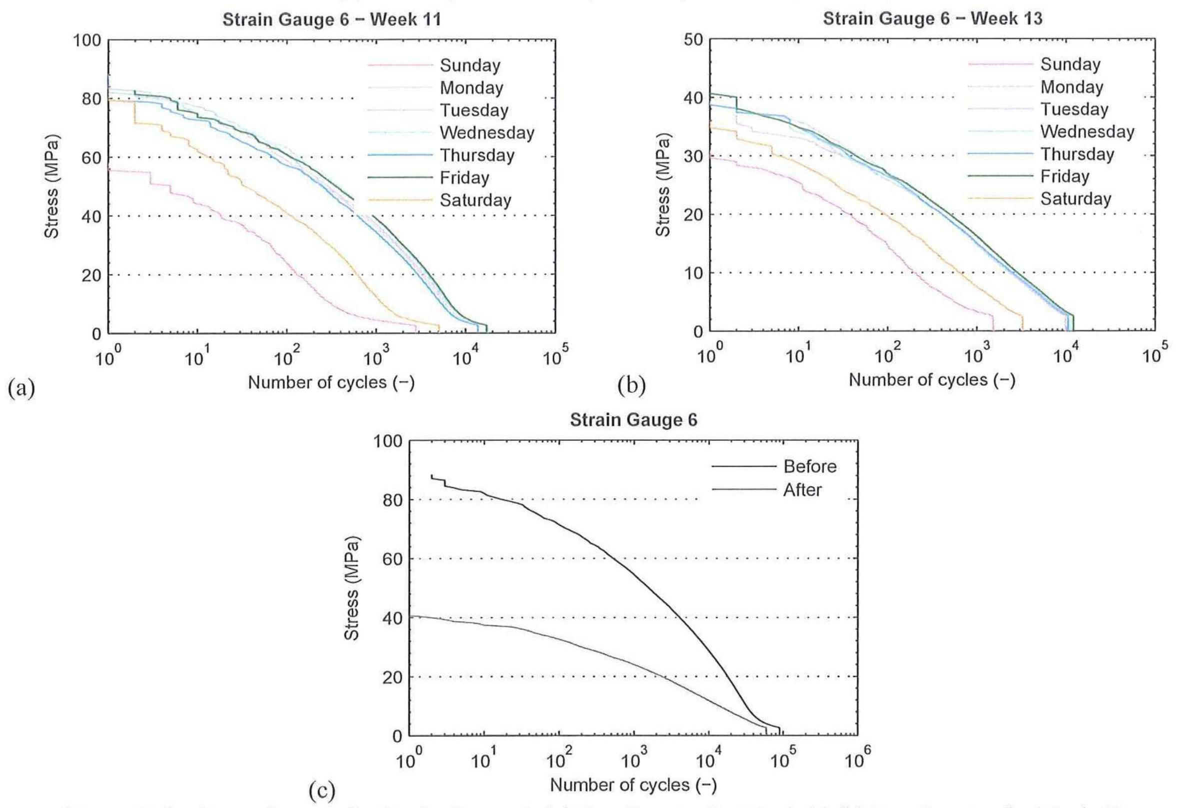
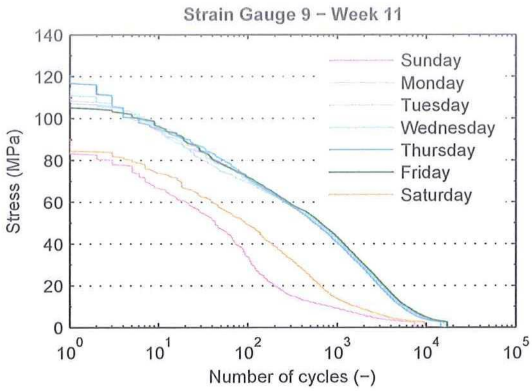
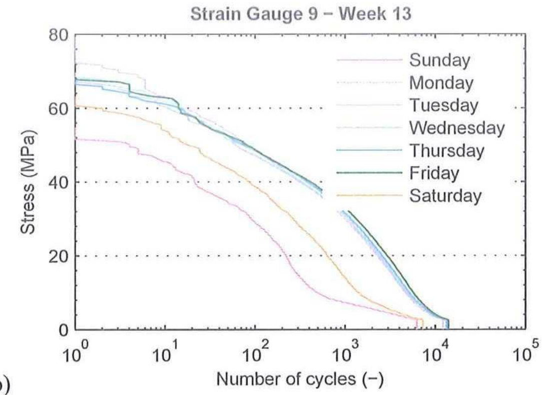


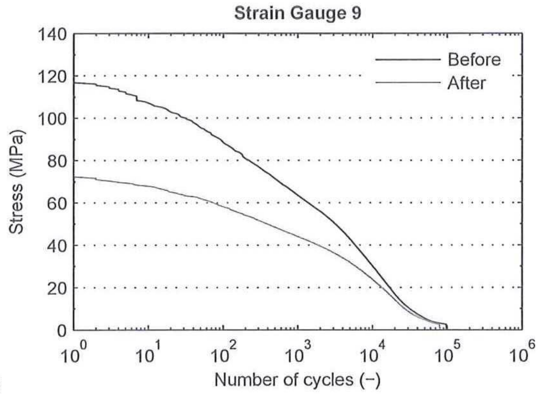
Figure D-6 – Stress Spectra for Strain Gauge 6: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).



(a)

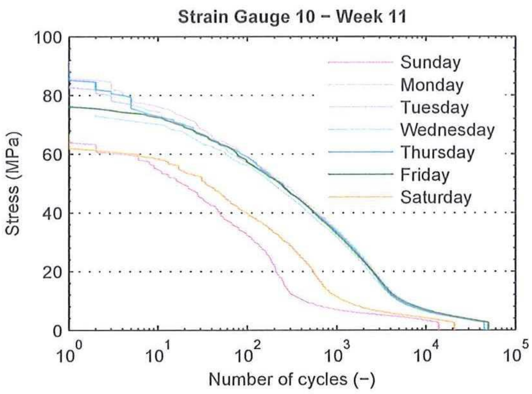


(b)

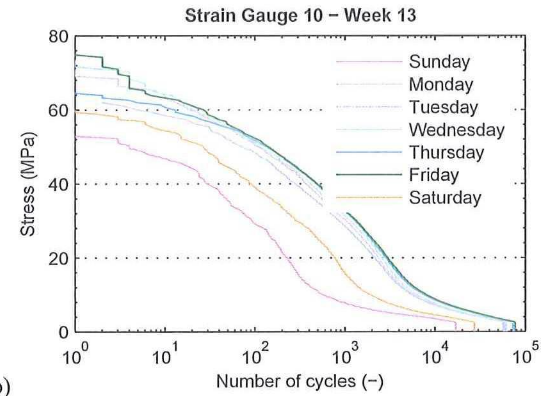


(c)

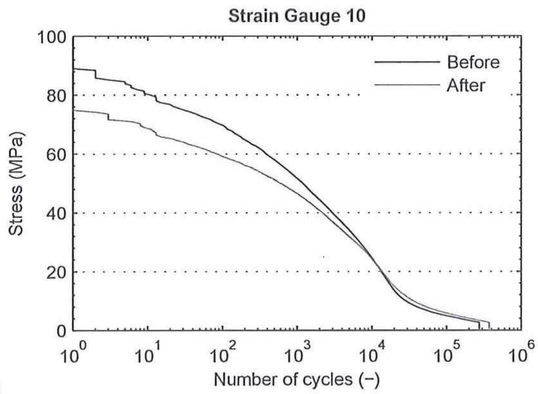
Figure D-9 – Stress Spectra for Strain Gauge 9: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).



(a)

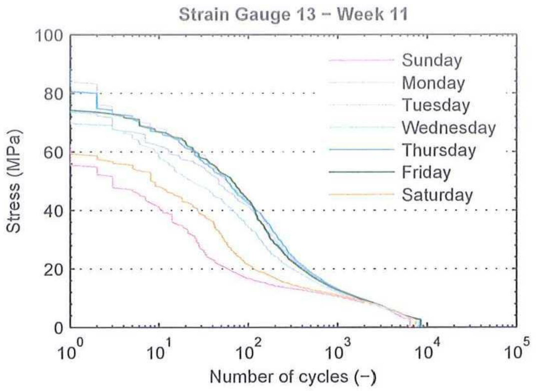


(b)

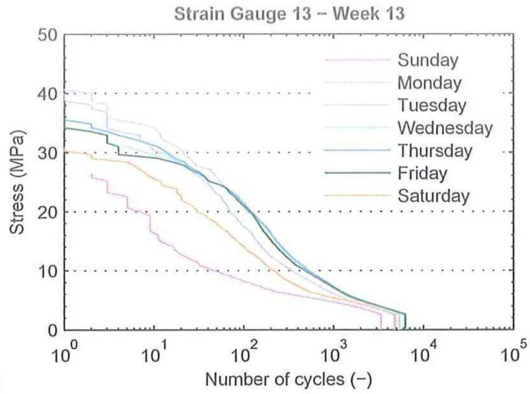


(c)

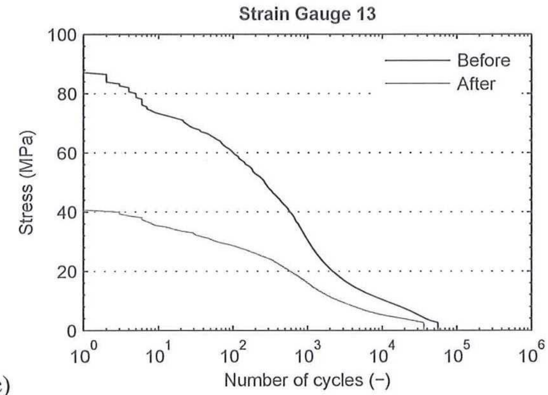
Figure D-10 – Stress Spectra for Strain Gauge 10: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).



(a)

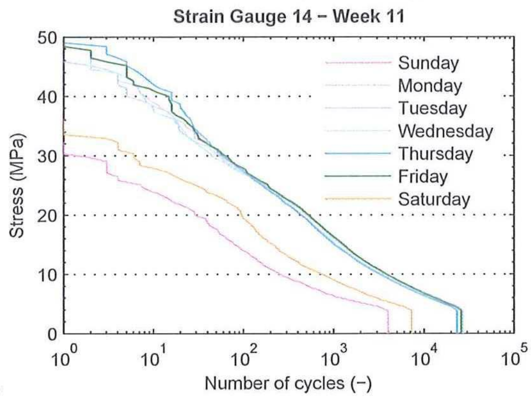


(b)

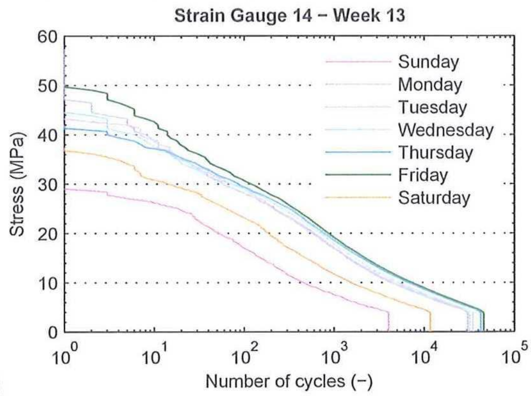


(c)

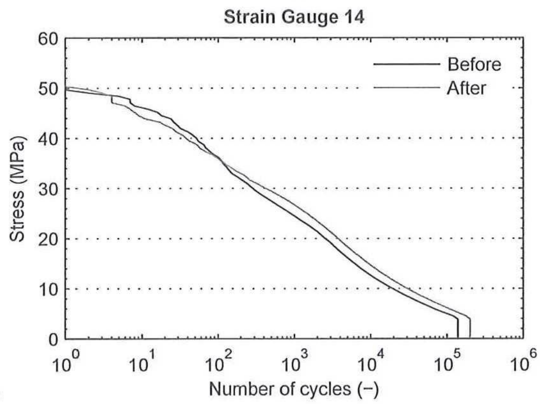
Figure D-13 – Stress Spectra for Strain Gauge 13: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).



(a)



(b)



(c)

Figure D-14 – Stress Spectra for Strain Gauge 14: (a) Day Spectra for Week 11 (b) Day Spectra for Week 13 and (c) Week Spectra before (Week 11) and after (Week 13).

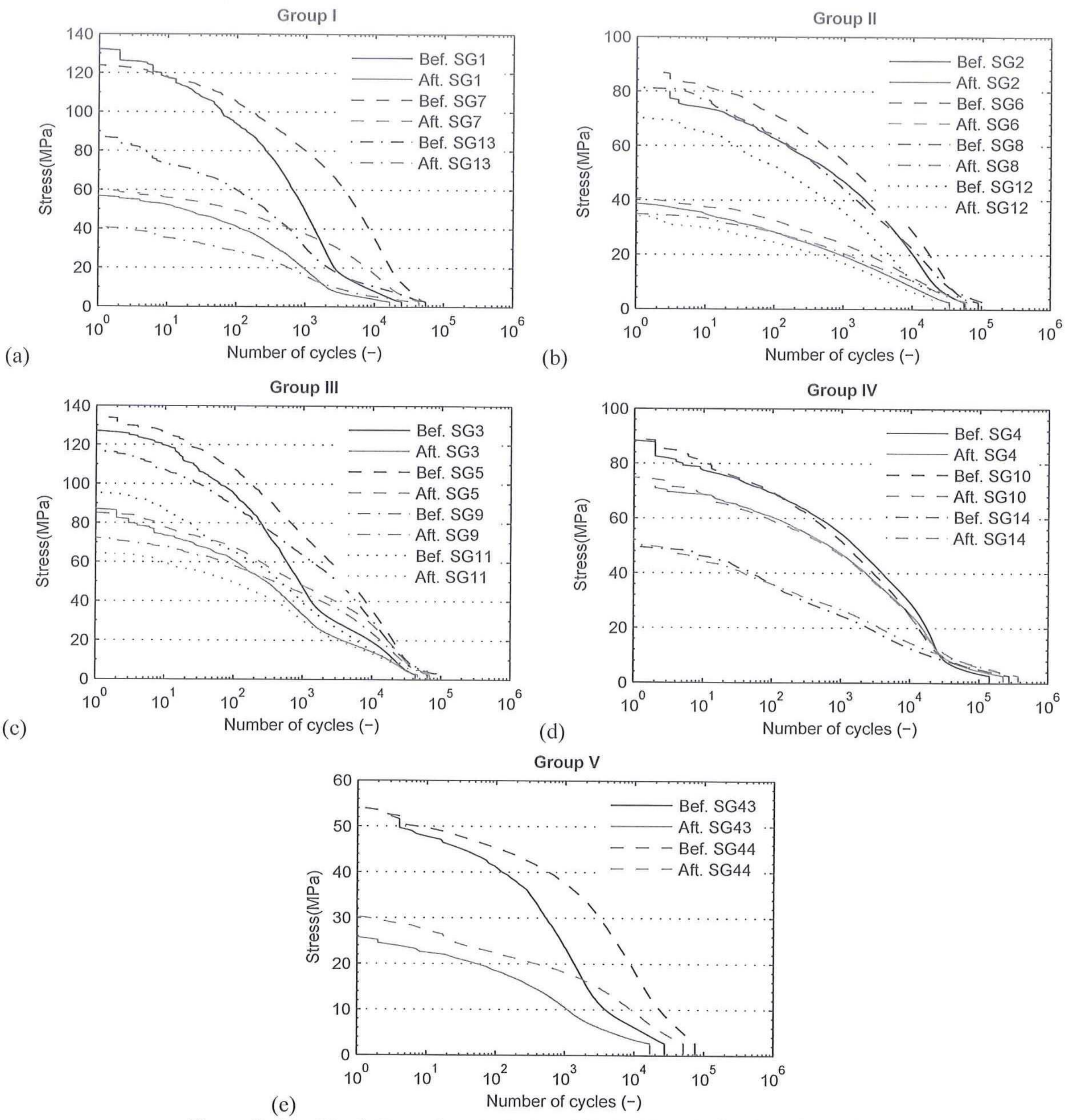


Figure D-17 – Week Stress Spectra before (Week 11) and after (Week 13) for (a) Group I – Strain gauge 1, 7 and 13; (b) Group II – Strain gauge 2, 6, 8 and 12; (c) Group III – Strain gauge 3, 5, 9 and 11; (d) Group IV – Strain gauge 4, 10 and 14 and (e) Group V – Strain gauge 43 and 44.