



Vienna Consulting  
Engineers ZT GmbH

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# TU1402 Monitoring Case Studies

Relevant cases for the proof of concept

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Helmut **WENZEL**

Copenhagen, 4. May 2015



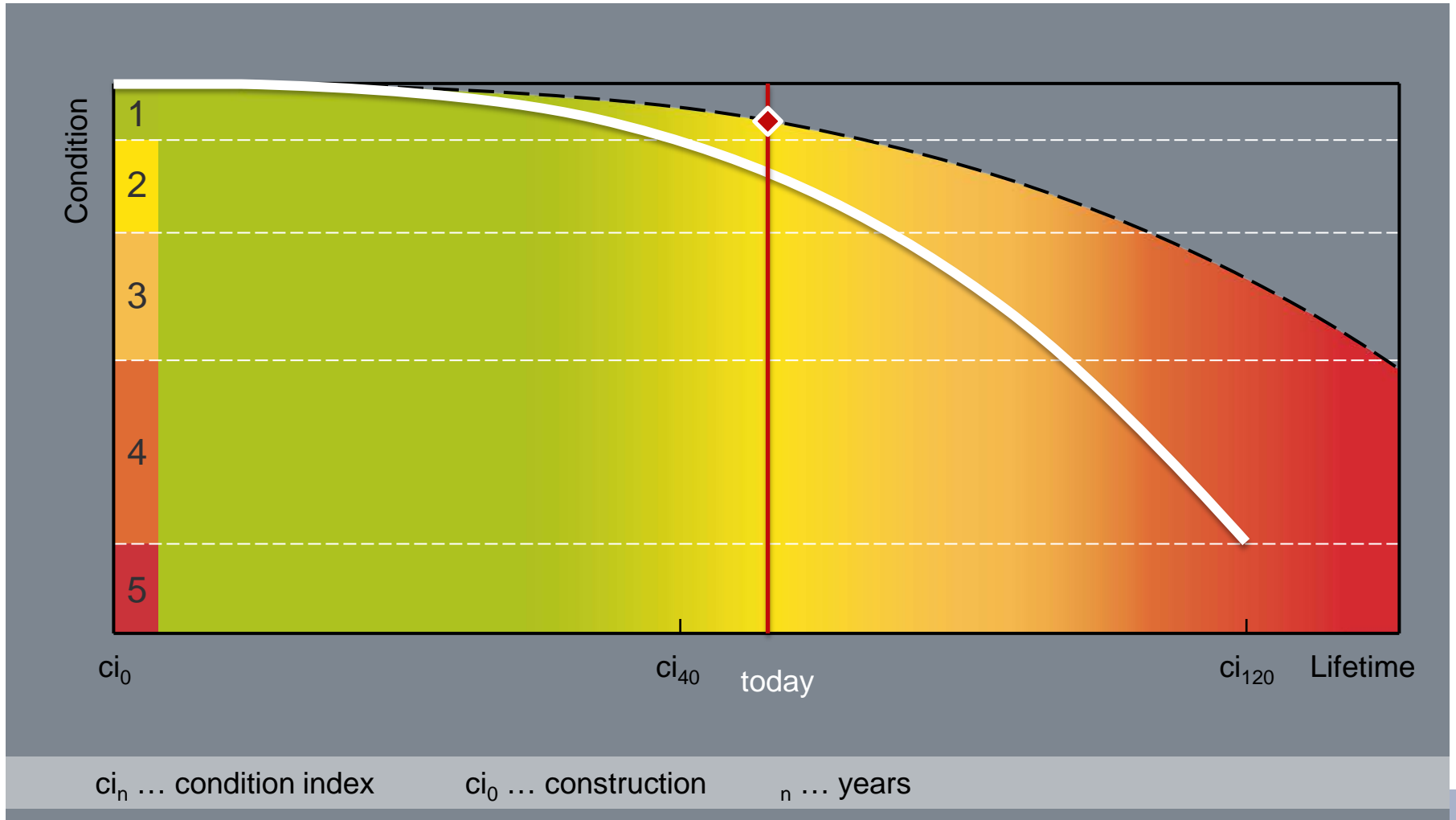
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# Information required for the cases

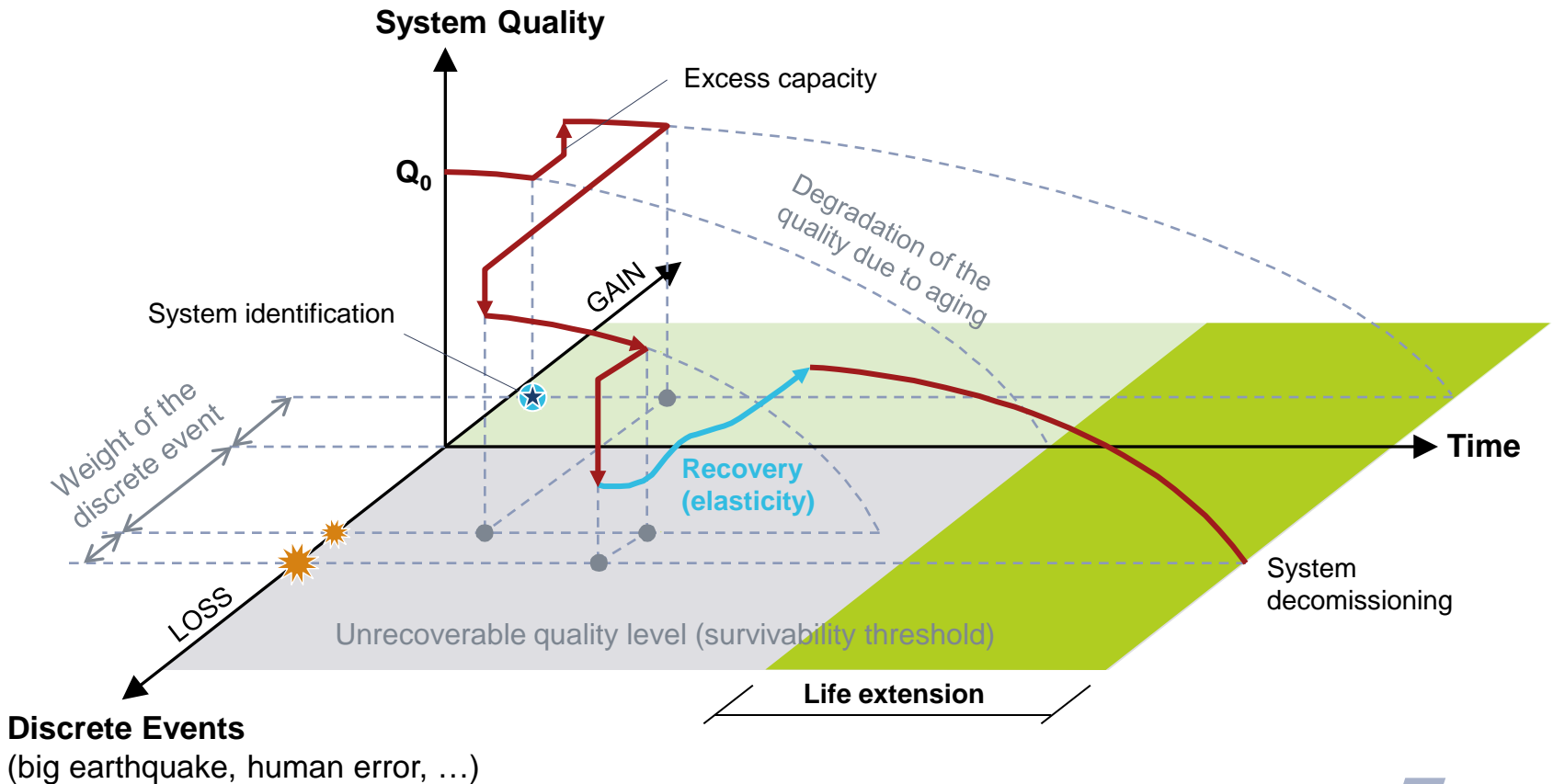
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- » Replacement value of the structure
- » Costs of SHM
- » Costs of maintenance and operation
- » Non availability costs
- » Indirect consequential costs
- » Financing information
- » Information on use of the structure, history and future changes

# The NEW Colour Scheme with Uncertainty



# Life Cycle and Event Management Concept



# Recent Monitoring Projects

Hunter Expressway // Australia 2013



# Recent Monitoring Projects

Hunter Expressway // Australia 2013



VCE

# Recent Monitoring Projects

Gold Tower, Dubai



VCE

# Recent Monitoring Projects

## Gold Tower, Dubai





# Recent Monitoring Projects

Gold Tower, Dubai



# Recent Monitoring Projects

Gold Tower, Dubai



# Happel Stadion

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# Multi functional Web-Interface

## Happel Stadion (Austria): Video based snow load monitoring

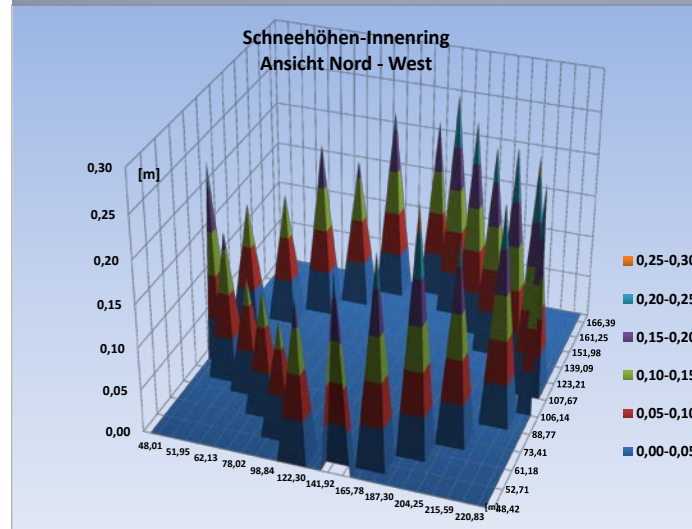
The screenshot shows a web browser window displaying a monitoring interface for Ernst Happel Stadium. The browser address bar shows the URL: [http://www.brimos.com/DMA/pages/vce/overview\\_HAPPEL/](http://www.brimos.com/DMA/pages/vce/overview_HAPPEL/). The page title is "Overview - Ernst Happel Stad...".

The interface features a navigation bar with tabs: "Timebase: local", "Filezone", "Sensoren", "Alarmer", and "Messdaten". The main content area is divided into several sections:

- Projektbeschreibung:** A section for project details, currently empty.
- Bildgalerie:** A gallery of eight images showing different views of the stadium, including the exterior, interior, and the roof structure.
- Position der Struktur:** A section providing the location of the stadium: "Ernst Happel Stadion, Wien" with coordinates "Lat: 48,207 - Long: 16,421". It includes three map thumbnails and a link "Google Maps: Hier klicken".
- Sensorenübersicht:** A section listing various sensor measurements:
  - Meteorologische Messungen:**
    - Lufttemperatur
    - Luftfeuchtigkeit
    - Wind - Maximum aus 2 Sekunden Mittel
    - Wind - 10 Minuten Mittel
  - Beschleunigung:**
    - Beschleunigung - Achse 1
    - Beschleunigung - Achse 57
    - Beschleunigung - Achse 71
    - Beschleunigung - Achse 113
  - Beschleunigung - Trendkarte Achse 71 Vertikal:**
    - Beschleunigung - Trendkarte Achse 71 Vertikal, 0 - 10 Hertz
    - Beschleunigung - Trendkarte Achse 71 Vertikal, 0 - 2 Hertz
  - Korrelation - Wind zu Achse 71 Vertikal:**
    - Korrelation - Wind zu Achse 71 Beschleunigung Vertikal
    - Korrelation - Wind zu Achse 71 Amplitude Max F1 Vertikal
  - Manuelle Messungen:**
    - Höhe - Innenring
- Live vom Stadion:** A live video feed showing the stadium roof structure. A green bounding box is overlaid on the video, indicating the area of interest for snow load monitoring.

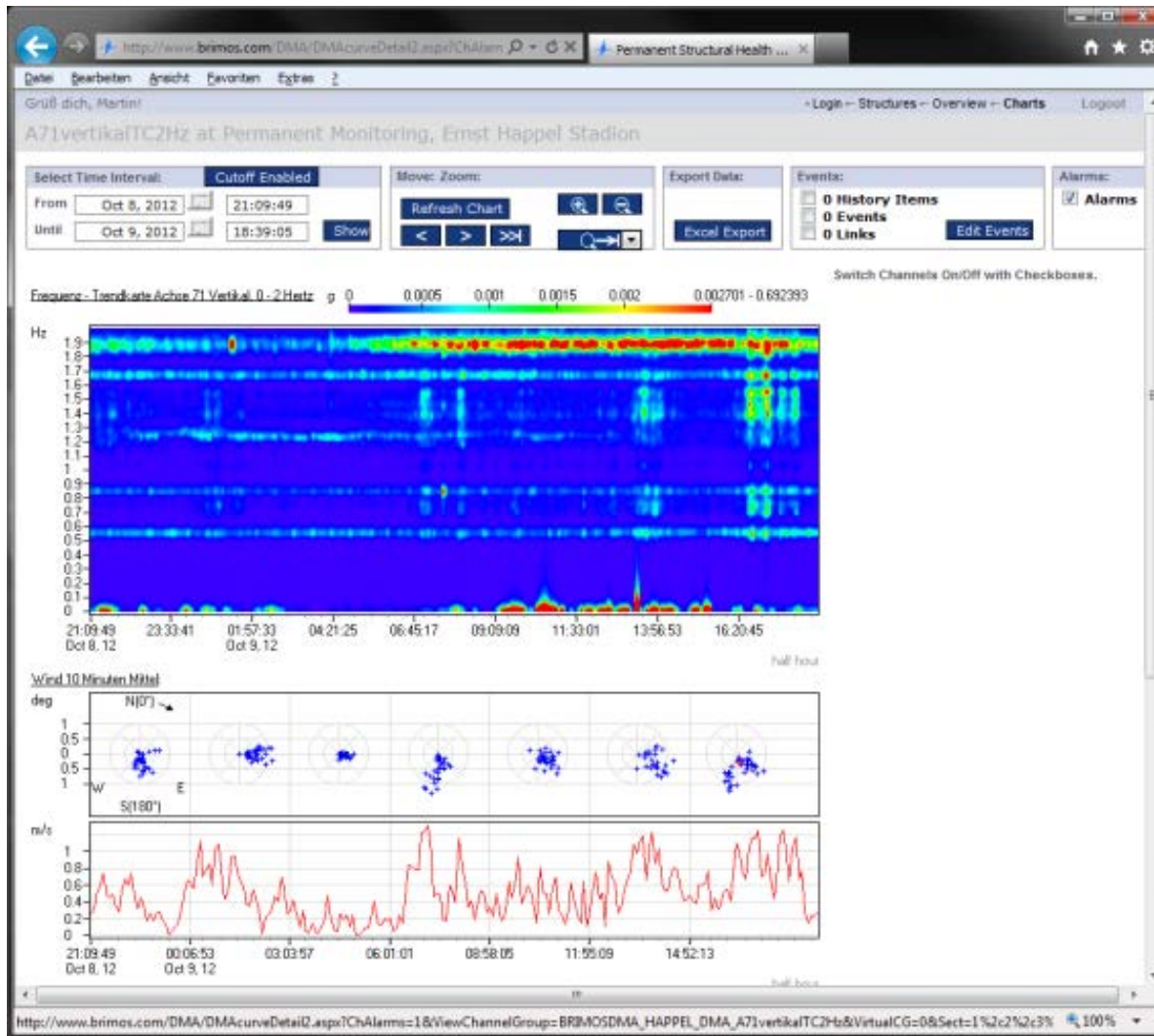
# Multi functional Web-Interface

## Happel Stadion (Austria): Video based snow load monitoring



# Multi functional Web-Interface

## Happel Stadion (Austria): Trend of Fundamental Frequencies



# Offshore Issues: Metocean? Extension of Life



Copyright: Flying Focus



Copyright Flying Focus

# Offshore Wind Industry

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Copyright: London Array



# Offshore Issue: Grouted Joints?



# Offshore Issue: Construction stages



Copyright: Flying Focus

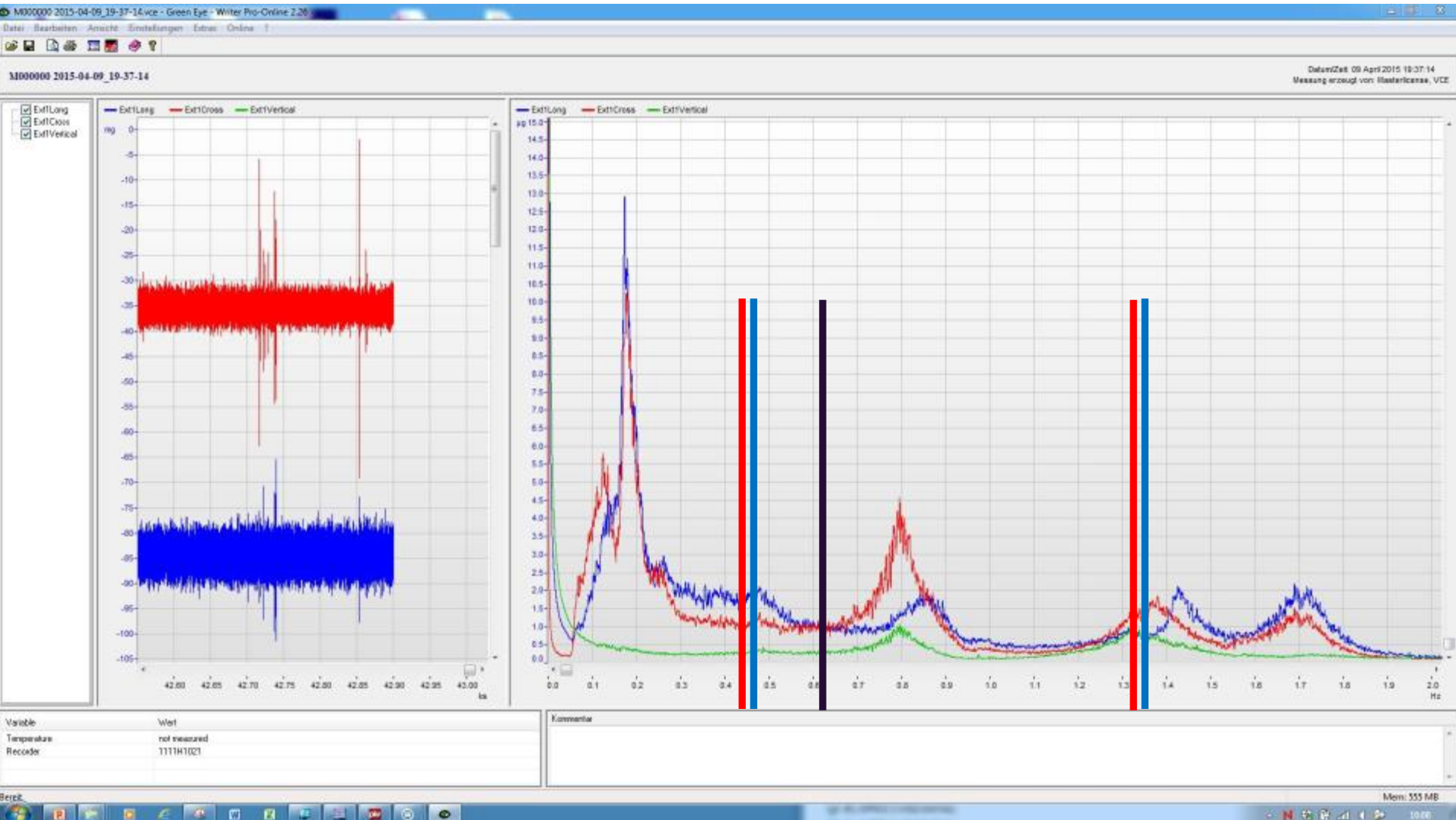
# OFFSHORE WIND INDUSTRY

## NEW CHALLENGES



Copyright: VCE

# OFFSHORE WIND INDUSTRY COMPARISON



# Amir Kabir Semi-Submersible Drilling Unit, Caspian Sea

## On-board Calibration and Adjustment of Mooring System

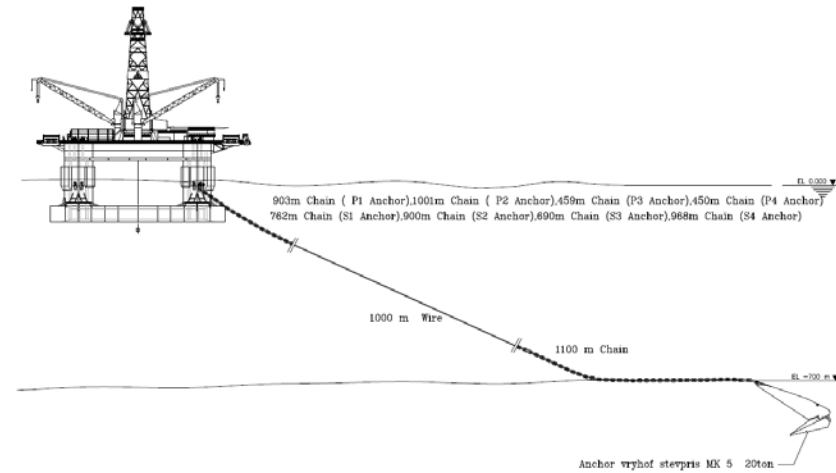


Shana/Photo: received

VCE

# Amir Kabir Semi-Submersible Drilling Unit, Caspian Sea

## On-board Calibration and Adjustment of Mooring System



VCE

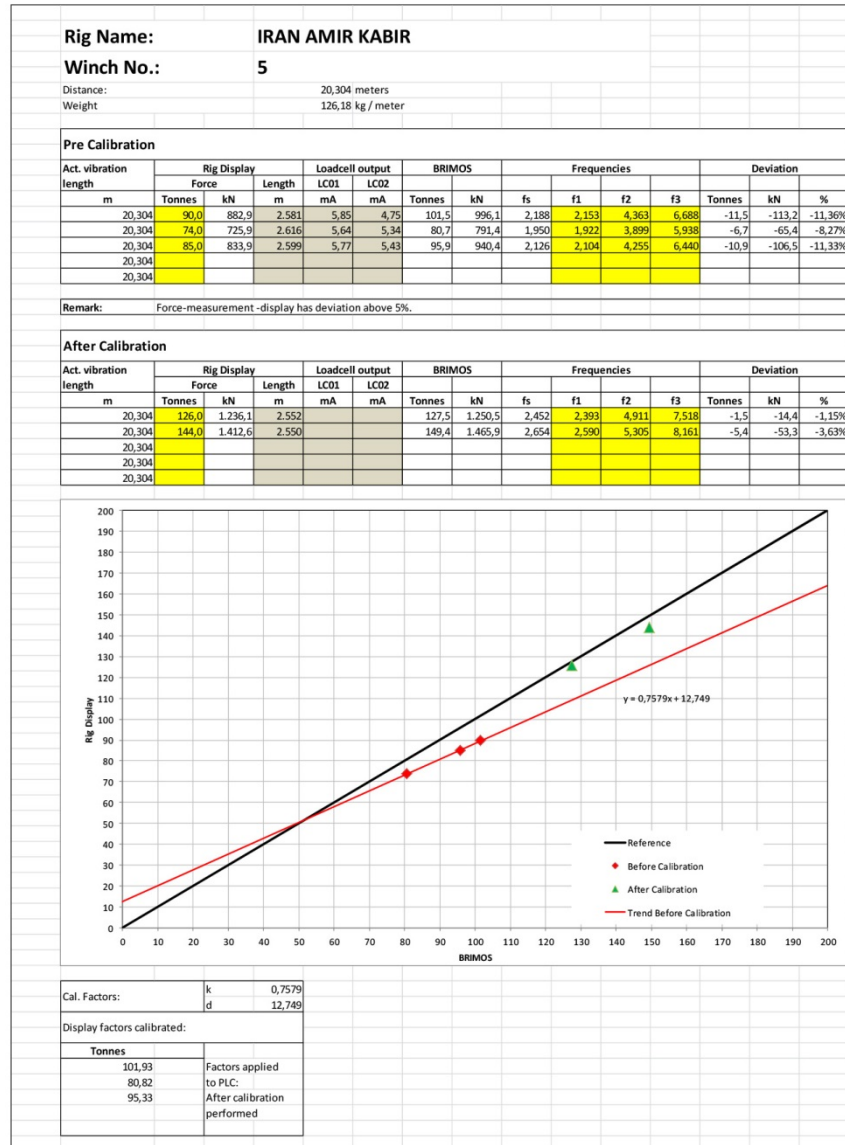
# Amir Kabir Semi-Submersible Drilling Unit, Caspian Sea

## On-board Calibration and Adjustment of Mooring System



# Amir Kabir Semi-Submersible Drilling Unit, Caspian Sea On-board Calibration and Adjustment of Mooring System

## Results of Winch 5





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# Amir Kabir Semi-Submersible Drilling Unit, Caspian Sea

## On-board Calibration and Adjustment of Mooring System

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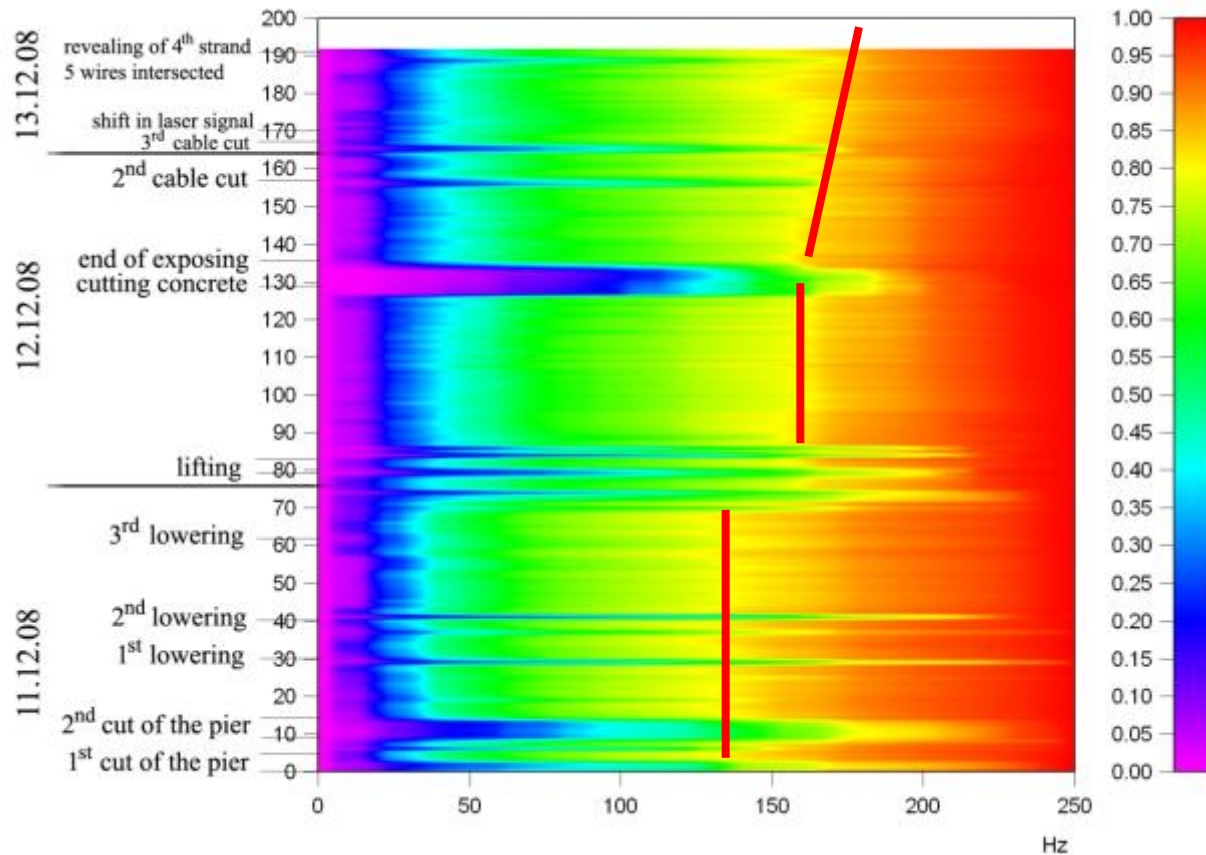
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# Bridge S101    Dezember 2008

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# ACCUMULATED ENERGY FUNCTION



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# INDUCED DAMAGE TEST REGAU

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VCE



VCE

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# CLORITE CONTENT 0,8%

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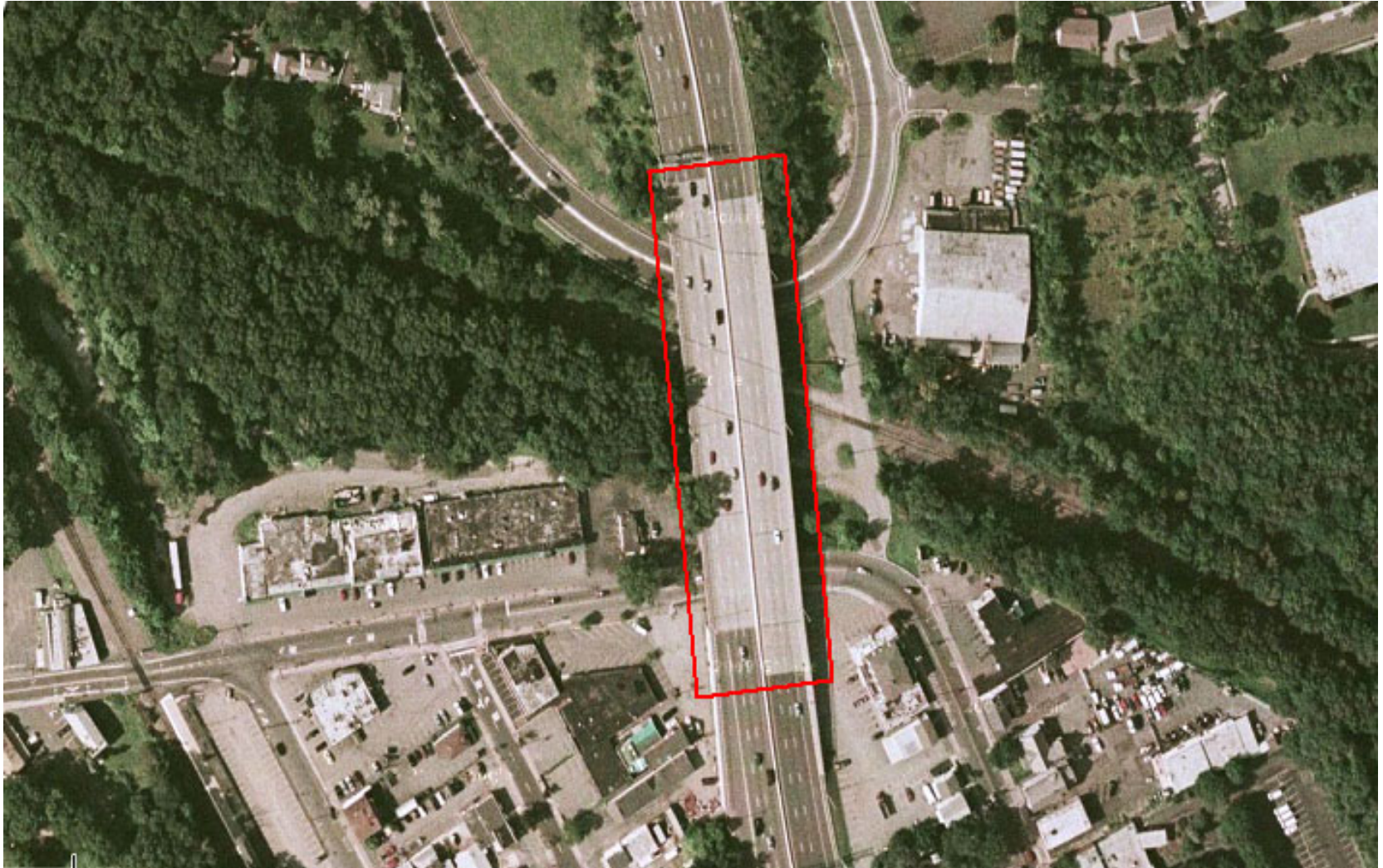






# International Bridge Study

## New Jersey 202 Bridge



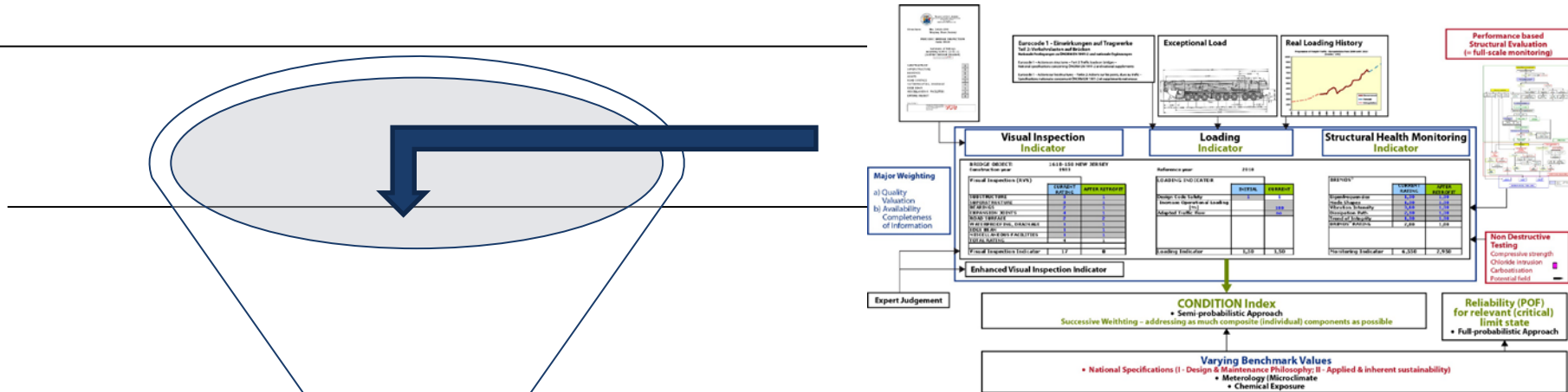
# Visual Condition, Corrosion

## Structural Condition – Fascia Bearing Deterioration

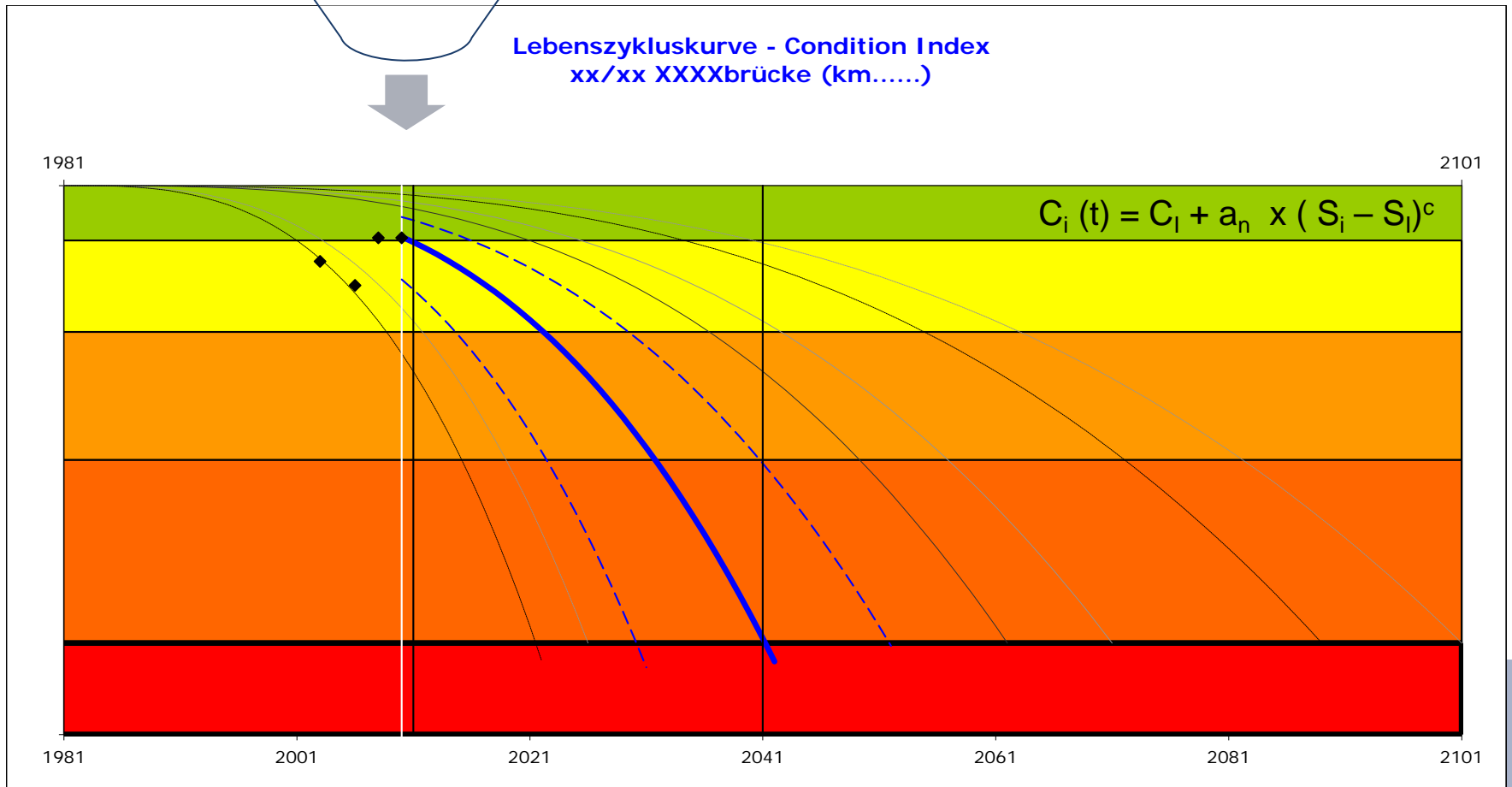


# Visual Condition, Cracks





Lebenszykluskurve - Condition Index  
xx/xx XXXXbrücke (km.....)





## RECOMMENDED RETROFIT INTERVENTIONS

### **Substructure:**

Renewal of corrosion protection,  
Repair of spallings, holes and concrete pockets,  
removal of contamination of the concrete surface,  
Deep injection of cracks



### **Dewatering:**

Establishing of an effective drainage concept

### **Expansion Joints:**

Proper detailing & design  
⇒ Full replacement (abutment area)  
⇒ Partial replacement (at least seals above the piers)

### **Superstructure:**

Renewal of corrosion protection,  
Repair of the concrete surface,  
fatigue cracks, Repair of corroded stringers,  
Replacement of wind bracings,  
proper replacement of the bearings



# LESSONS NEW JERSEY

BRIDGE OBJECT: 1618-150 NEW JERSEY  
Construction year 1983

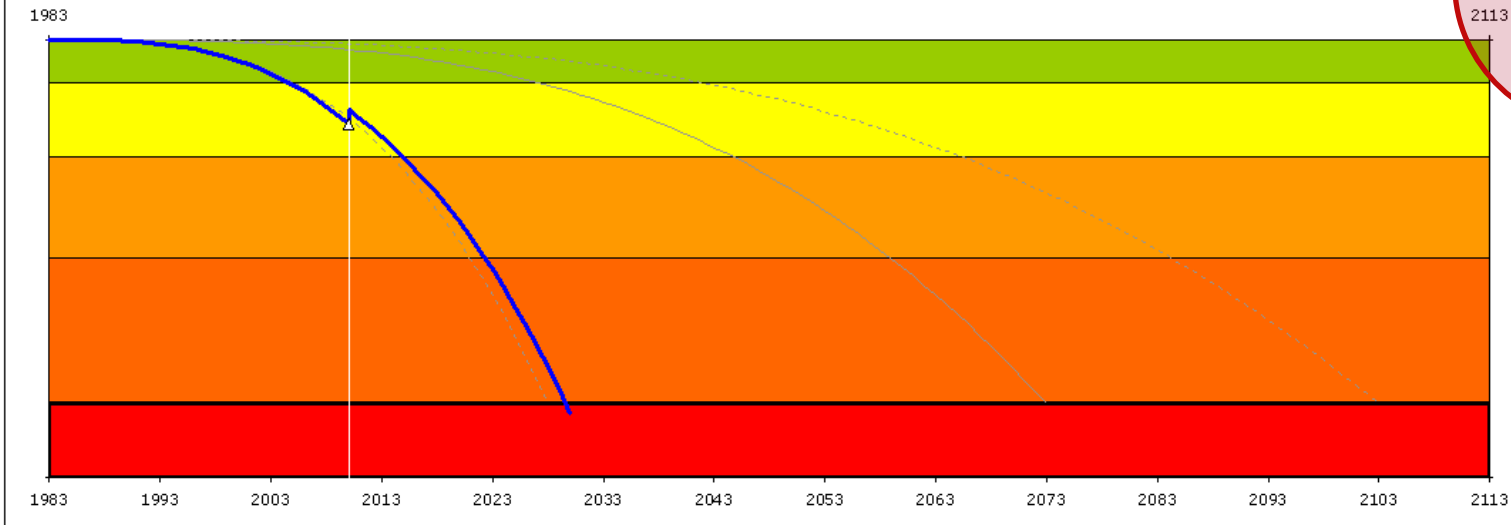
Visual Inspection (RVS)	CURRENT RATING	AFTER RETROFIT
	SUBSTRUCTURE	3
SUPERSTRUCTURE	3	3
BEARINGS	2	2
EXPANSION JOINTS	4	4
ROAD SURFACE	2	2
WATERPROOFING, DRAINAGE	4	1
EDGE BEAM	1	1
MISCELLANEOUS FACILITIES	1	1
TOTAL RATING	4	3
Visual Inspection Indicator	18	14

Reference year 2010

LOADING INDICATOR	INITIAL	CURRENT
	Design Code Safety	1
Level of operational loads [%]		100
Adapted Traffic Scenario		no
Loading Indicator	1,50	1,50

BRIMOS <sup>®</sup>	CURRENT RATING	AFTER RETROFIT
	Eigenfrequencies	1,30
Mode Shapes	1,30	1,30
Vibration Intensity	3,60	2,95
Dissipation Path	2,10	2,10
Trend of Integrity	1,30	1,30
BRIMOS <sup>®</sup> RATING	2,00	2,00
Monitoring Indicator	6,550	5,250

Bridge Object 1618-150 - Global Lifeline (Safety Level regarding ULS)



REMAINING LIFE  
**19**

COSTS [€]  
Retrofit 922.328  
Replacement 11.901.000

## RECOMMENDED RETROFIT INTERVENTIONS

### Substructure:

Renewal of corrosion protection,  
Repair of spallings, holes and concrete pockets,  
removal of contamination of the concrete surface,  
Deep injection of cracks

### Dewatering:

Establishing of an effective drainage concept

### Expansion Joints:

Proper detailing & design  
⇒ Full replacement (abutment area)  
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Replacement of wind bracings,  
proper replacement of the bearings





# LESSONS NEW JERSEY

BRIDGE OBJECT: 1618-150 NEW JERSEY  
Construction year 1983

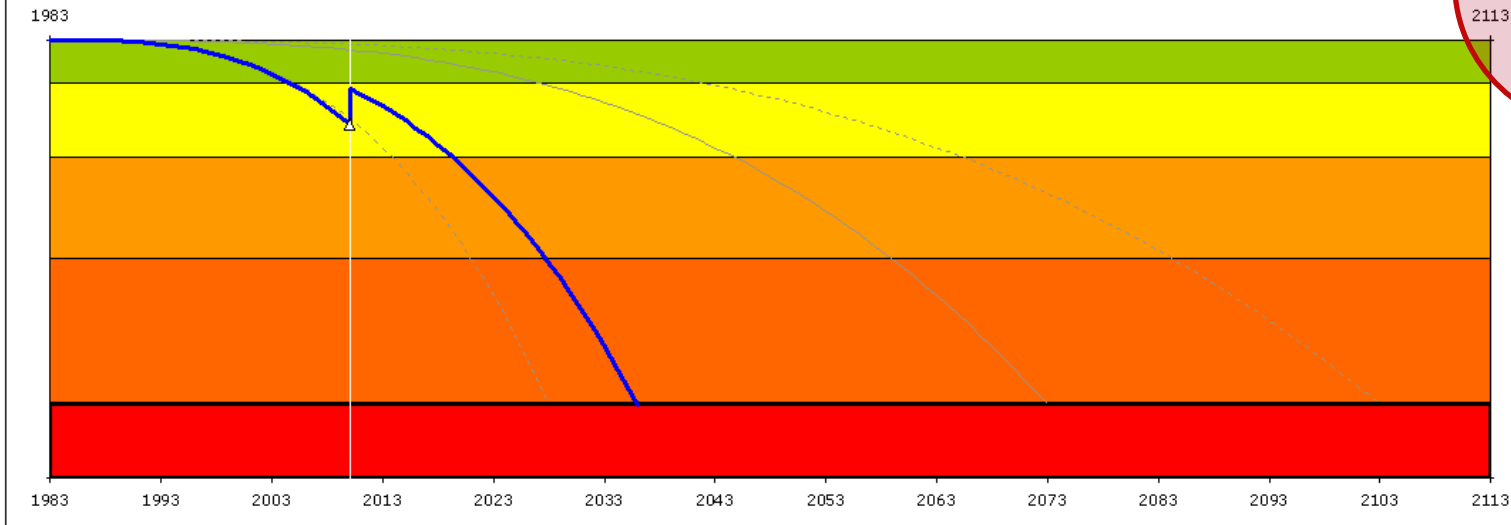
Visual Inspection (RVS)	CURRENT RATING	AFTER RETROFIT
	SUBSTRUCTURE	3
SUPERSTRUCTURE	3	3
BEARINGS	2	2
EXPANSION JOINTS	4	1
ROAD SURFACE	2	2
WATERPROOFING, DRAINAGE	4	1
EDGE BEAM	1	1
MISCELLANEOUS FACILITIES	1	1
TOTAL RATING	4	3
Visual Inspection Indicator	18	9

Reference year 2010

LOADING INDICATOR	INITIAL	CURRENT
	Design Code Safety	1
Level of operational loads [%]		100
Adapted Traffic Scenario		no
Loading Indicator	1,50	1,50

BRIMOS <sup>®</sup>	CURRENT RATING	AFTER RETROFIT
	Eigenfrequencies	1,30
Mode Shapes	1,30	1,30
Vibration Intensity	3,60	1,70
Dissipation Path	2,10	1,80
Trend of Integrity	1,30	1,30
BRIMOS <sup>®</sup> RATING	2,00	1,00
Monitoring Indicator	6,550	2,950

Bridge Object 1618-150 - Global Lifeline (Safety Level regarding ULS)



REMAINING LIFE  
**25**

COSTS [€]  
Retrofit 1.160.348  
Replacement 11.901.000

## RECOMMENDED RETROFIT INTERVENTIONS

### Substructure:

Renewal of corrosion protection,  
Repair of spallings, holes and concrete pockets,  
removal of contamination of the concrete surface,  
Deep injection of cracks

### Dewatering:

Establishing of an effective drainage concept

### Expansion Joints:

Proper detailing & design  
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### Superstructure:

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Replacement of wind bracings  
proper replacement of the bearings



# LESSONS NEW JERSEY

BRIDGE OBJECT: 1618-150 NEW JERSEY  
Construction year 1983

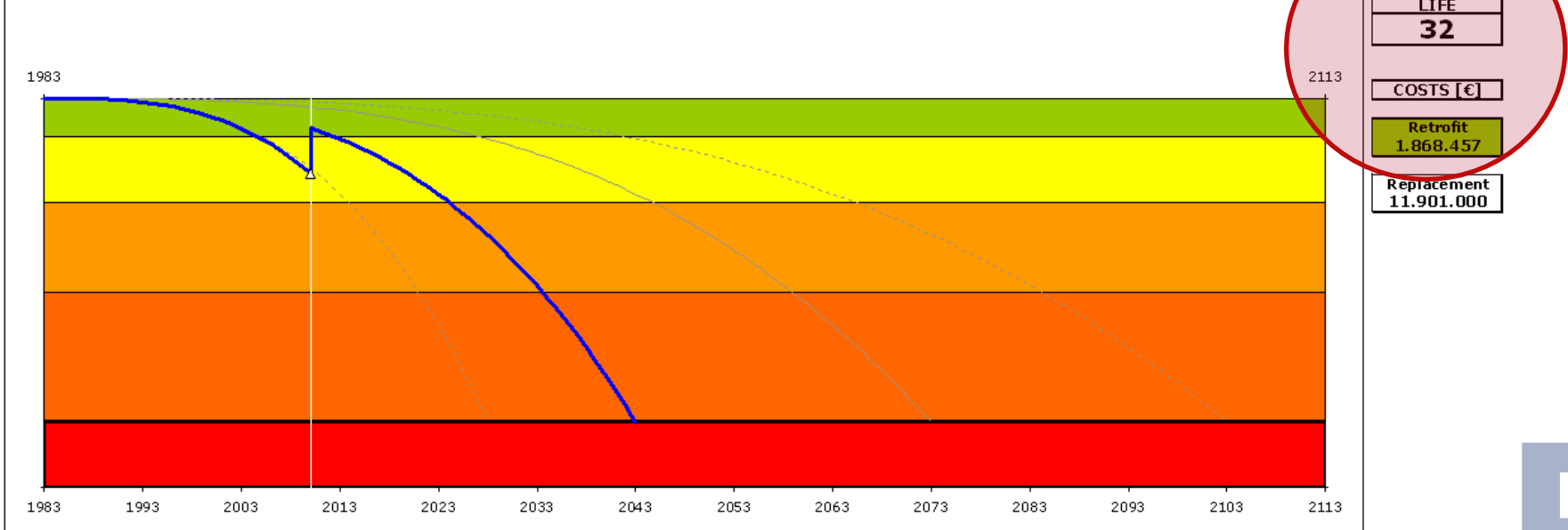
Reference year 2010

Visual Inspection (RV5)	CURRENT RATING	AFTER RETROFIT
	SUBSTRUCTURE	3
SUPERSTRUCTURE	3	1
BEARINGS	2	2
EXPANSION JOINTS	4	1
ROAD SURFACE	2	2
WATERPROOFING, DRAINAGE	4	1
EDGE BEAM	1	1
MISCELLANEOUS FACILITIES	1	1
TOTAL RATING	4	1
Visual Inspection Indicator	18	2

LOADING INDICATOR	INITIAL	CURRENT
	Design Code Safety	1
Level of operational loads [%]		100
Adapted Traffic Scenario		no
Loading Indicator	1,50	1,50

BRIMOS <sup>®</sup>	CURRENT RATING	AFTER RETROFIT
	Eigenfrequencies	1,30
Mode Shapes	1,30	1,30
Vibration Intensity	3,60	1,40
Dissipation Path	2,10	1,80
Trend of Integrity	1,30	1,30
BRIMOS <sup>®</sup> RATING	2,00	1,00
Monitoring Indicator	6,550	2,950

Bridge Object 1618-150 - Global Lifeline (Safety Level regarding ULS)



## RECOMMENDED RETROFIT INTERVENTIONS

### **Substructure:**

Renewal of corrosion protection,  
Repair of spallings, holes and concrete pockets,  
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### **Dewatering:**

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# LESSONS NEW JERSEY

BRIDGE OBJECT: 1618-150 NEW JERSEY  
Construction year 1983

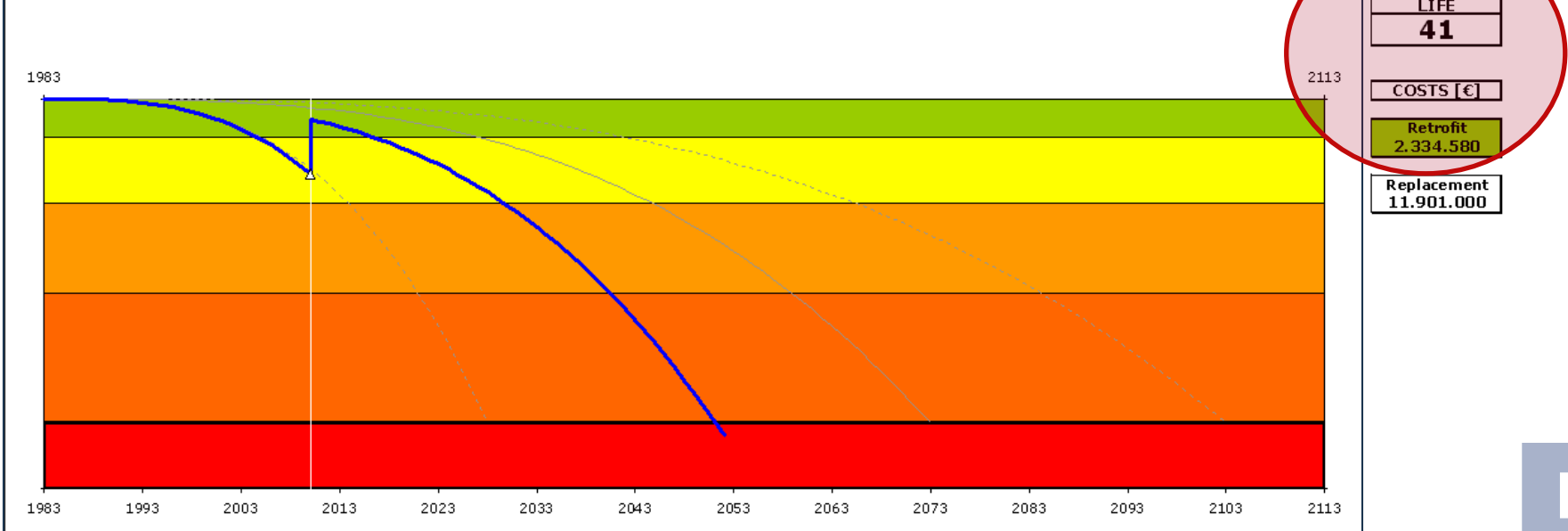
Reference year 2010

Visual Inspection (RVS)	CURRENT RATING	AFTER RETROFIT
	SUBSTRUCTURE	3
SUPERSTRUCTURE	3	1
BEARINGS	2	1
EXPANSION JOINTS	4	1
ROAD SURFACE	2	2
WATERPROOFING, DRAINAGE	4	1
EDGE BEAM	1	1
MISCELLANEOUS FACILITIES	1	1
TOTAL RATING	4	1
Visual Inspection Indicator	18	0

LOADING INDICATOR	INITIAL	CURRENT
	Design Code Safety	1
Level of operational loads [%]		100
Adapted Traffic Scenario		no
Loading Indicator	1,50	1,50

BRIMOS <sup>o</sup>	CURRENT RATING	AFTER RETROFIT
	Eigenfrequencies	1,30
Mode Shapes	1,30	1,30
Vibration Intensity	3,60	1,30
Dissipation Path	2,10	1,30
Trend of Integrity	1,30	1,30
BRIMOS <sup>o</sup> RATING	2,00	1,00
Monitoring Indicator	6,550	2,950

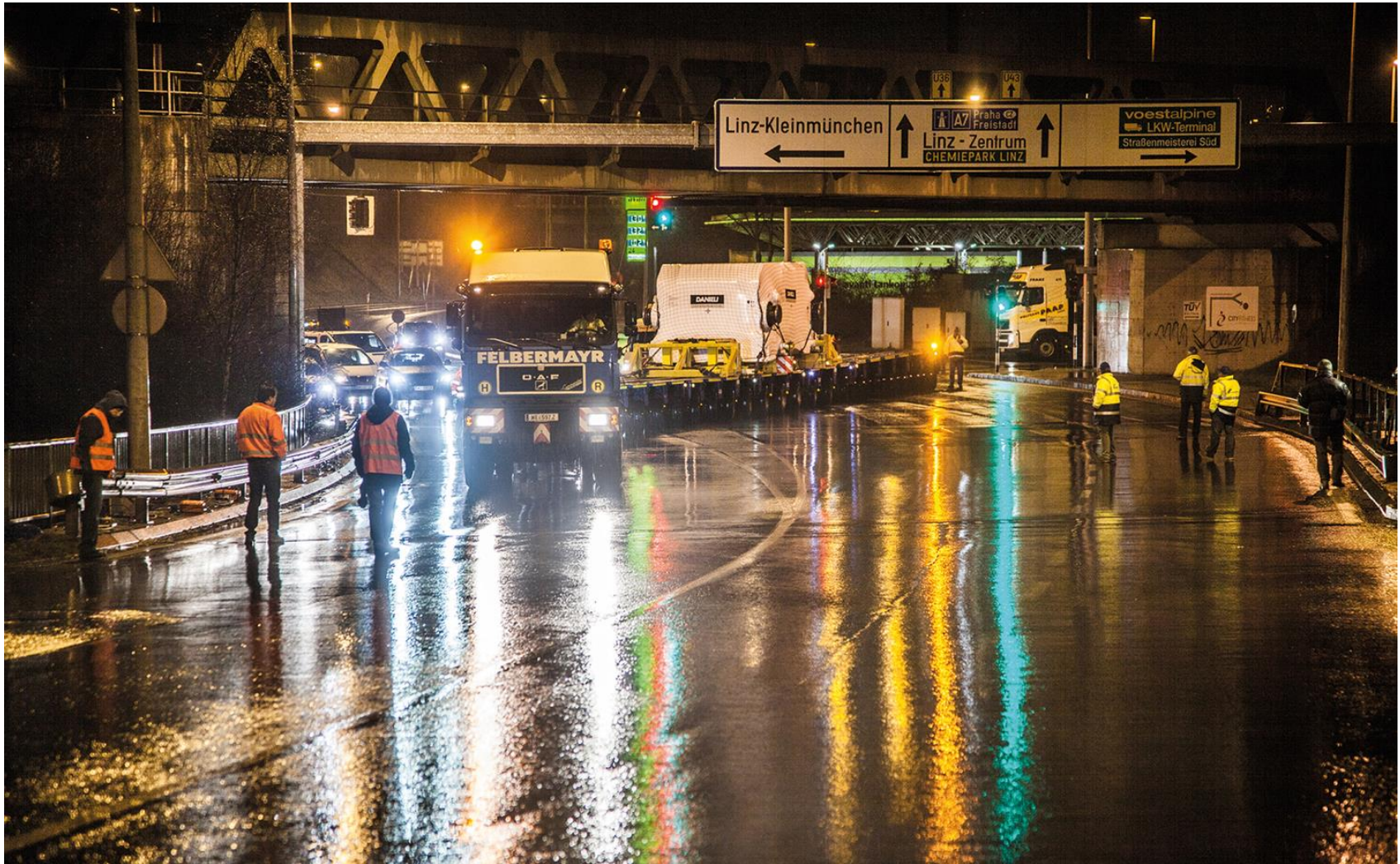
Bridge Object 1618-150 - Global Lifeline (Safety Level regarding ULS)



# Heavy transport impact on bridges



# Real-time Assessment



# Umfahrungsstraße Ebelsberg – Objekt 307

1.Überfahrtsserie



	1. Überfahrtsserie 16.12.2013	
	Überfahrt 1	Überfahrt 2
Tonnage	305	305
Achszahl Tieflader	20	20
Gewichtverteilung	Achse 7-15	Achse 7-15

2.Überfahrtsserie



	2. Überfahrtsserie 21.01.2014	
	Überfahrt 1	Überfahrt 2
Tonnage	260	286
Achszahl Tieflader	20	20
Gewichtverteilung	Achse 9-11	Achse 9-11

3.Überfahrtsserie

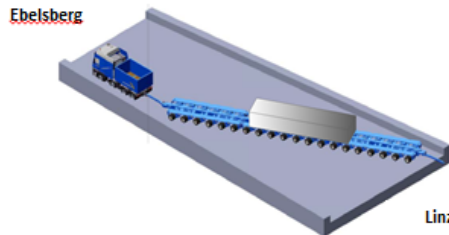


	3. Überfahrtsserie 17.02.2014	
	Überfahrt 1	Überfahrt 2
Tonnage	295	295
Achszahl Tieflader	20	20
Gewichtverteilung	Achse 8-17	Achse 8-17

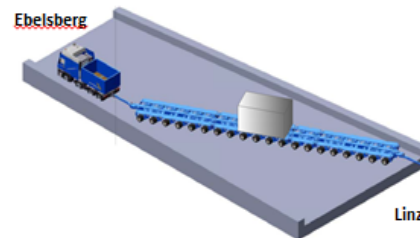
4.Überfahrtsserie



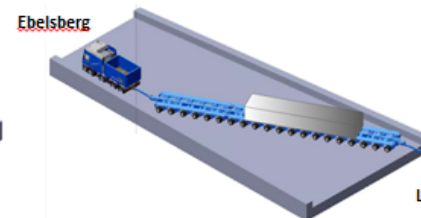
	4. Überfahrtsserie 20.03.2014	
	Überfahrt 1	Überfahrt 2
Tonnage	295	280
Achszahl Tieflader	20	20
Gewichtverteilung	Achse 9-13	Achse 8-13



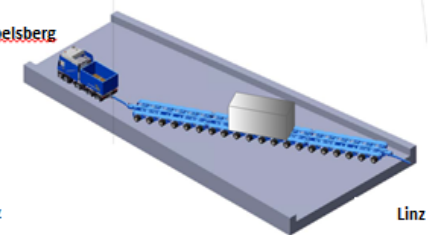
Linz



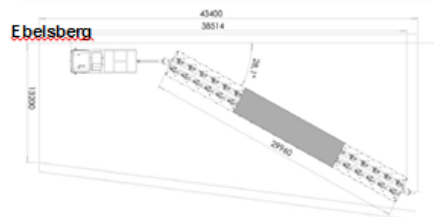
Linz



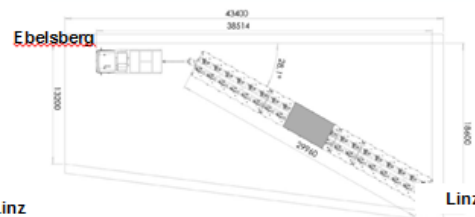
Linz



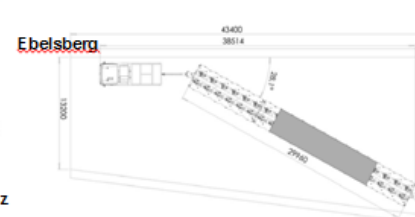
Linz



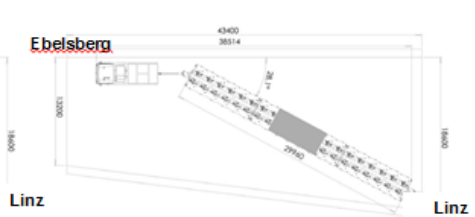
Linz



Linz



Linz



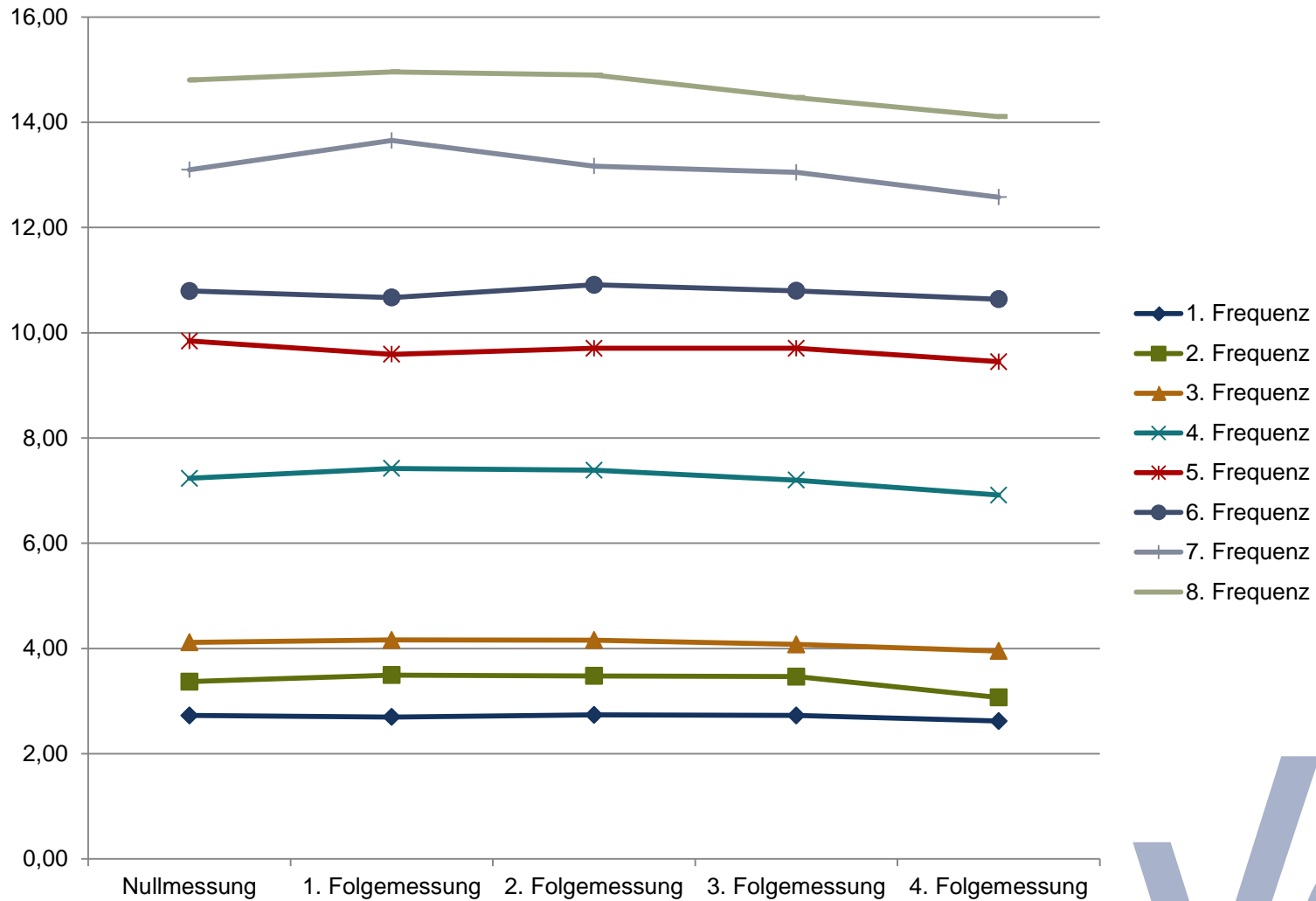
Linz







# Umfahrungsstraße Ebelsberg – Objekt 307



# Bridge Location

## Istanbul – Golden Horn





# Halic Metro Bridge

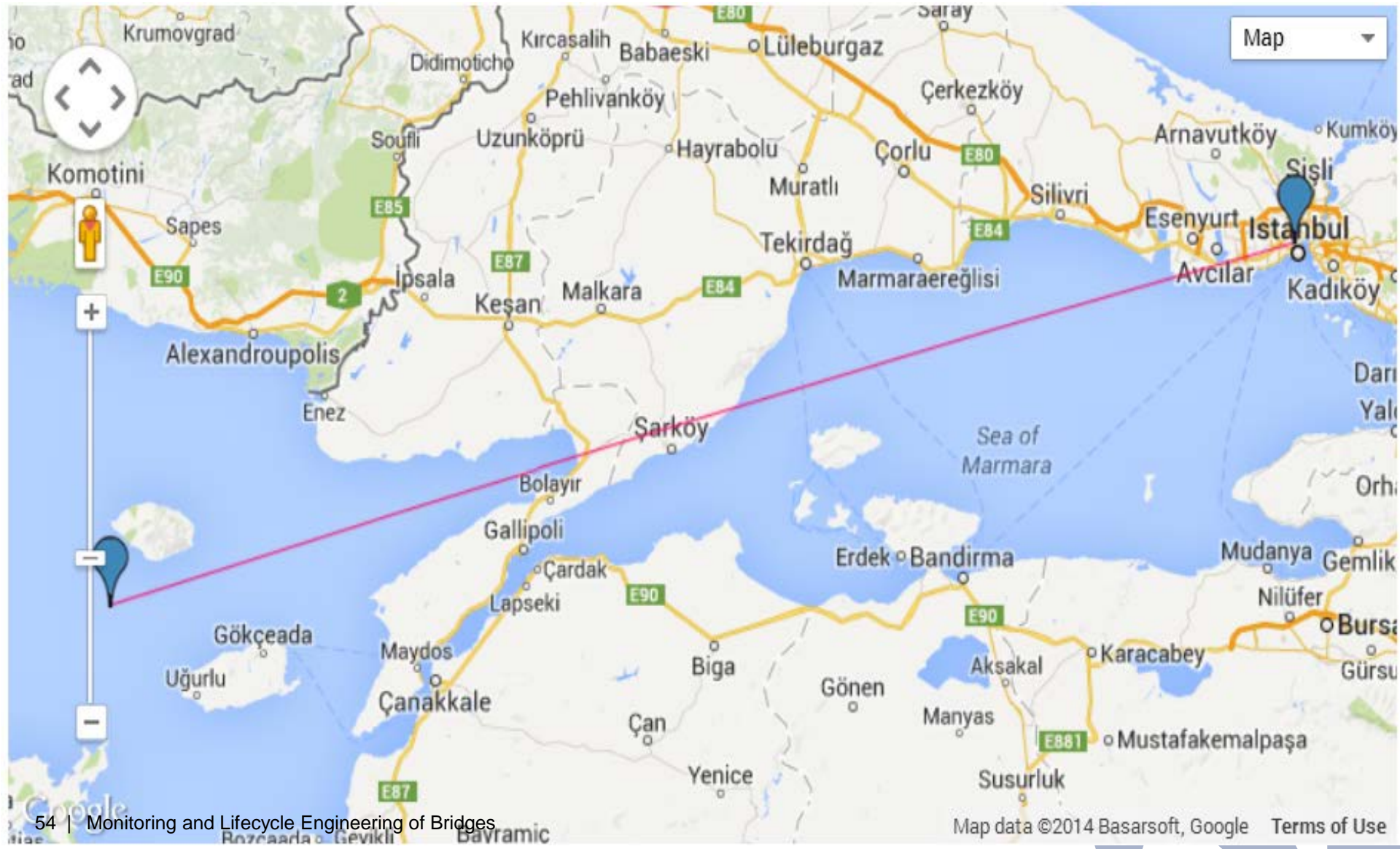
## Operation and Rotation Tests

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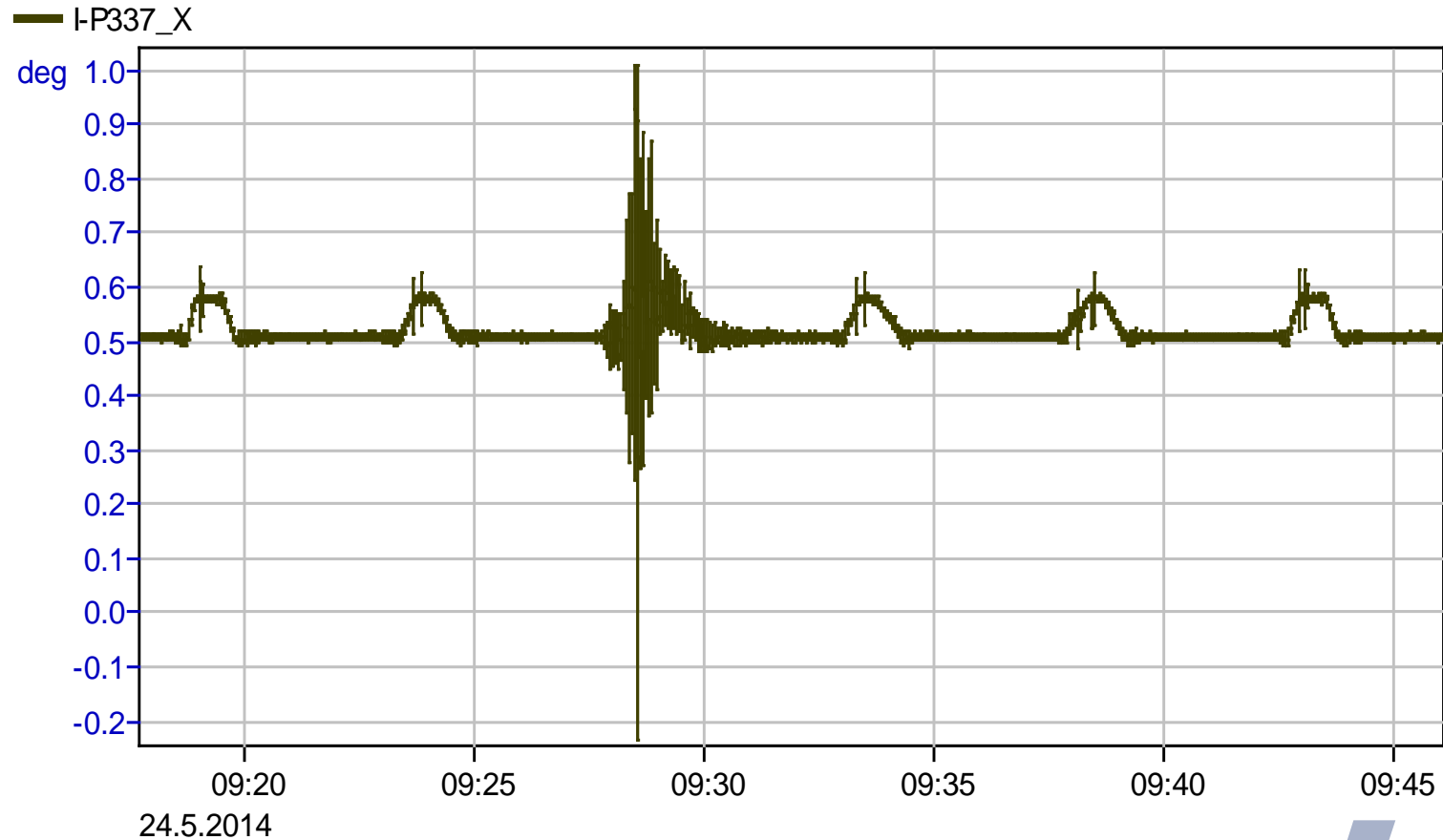
# Halic Metro Bridge

## Monitoring Facts and Figures



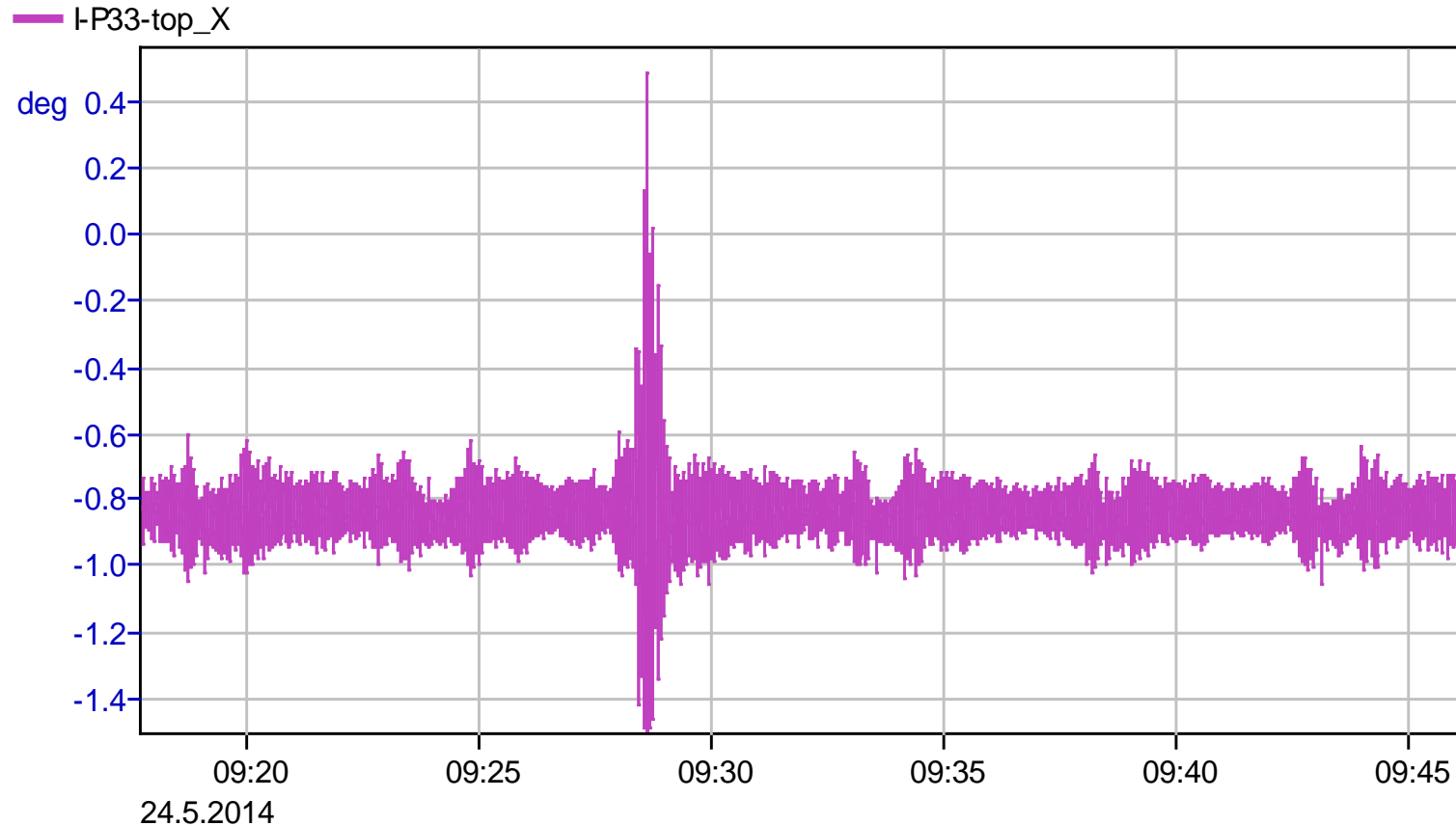
# Halic Metro Bridge

## Monitoring Facts and Figures



# Halic Metro Bridge

## Monitoring Facts and Figures





# 3. Bosphorus Bridge Monitoring

## European Side



# 3. Bosphorus Bridge Monitoring

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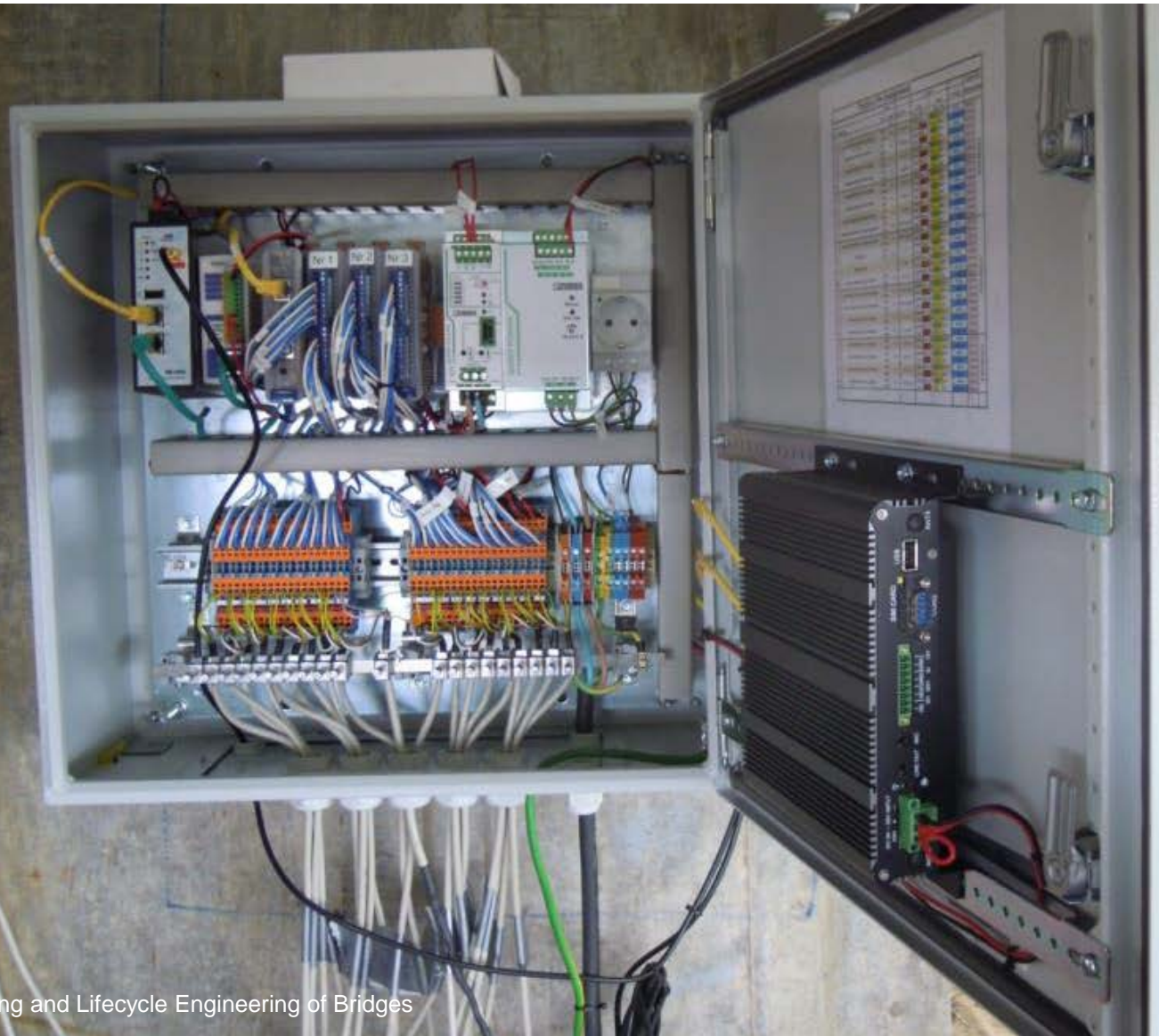


# Halifax – Joint Performance

## Two Suspension Bridges



# Typical Monitoring Cabinet



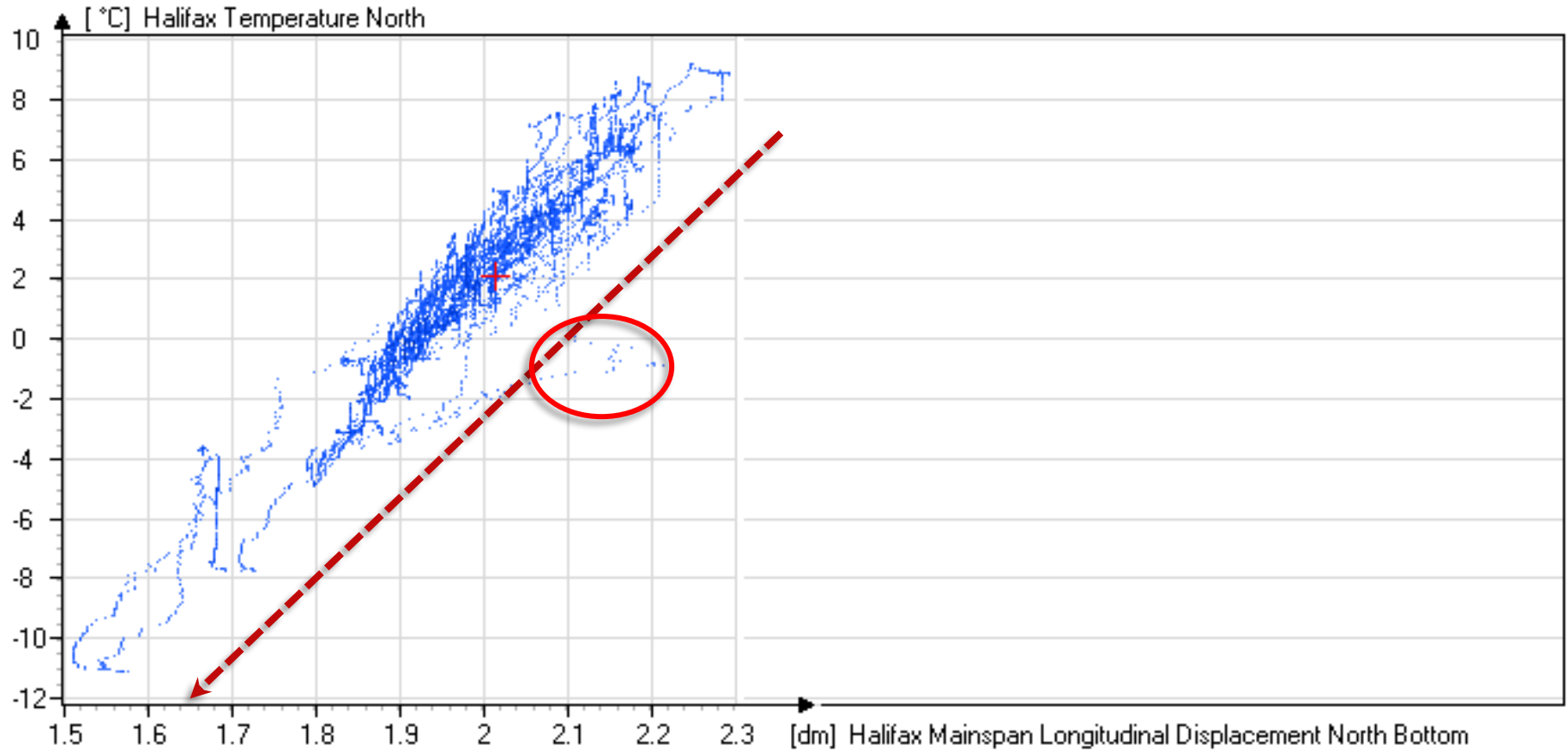
# Un-typical Monitoring Conditions

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# Alarm from outliers in correlation functions

Correlation Temperature - Displacement:



# Incheon Monitoring of Critical Joints

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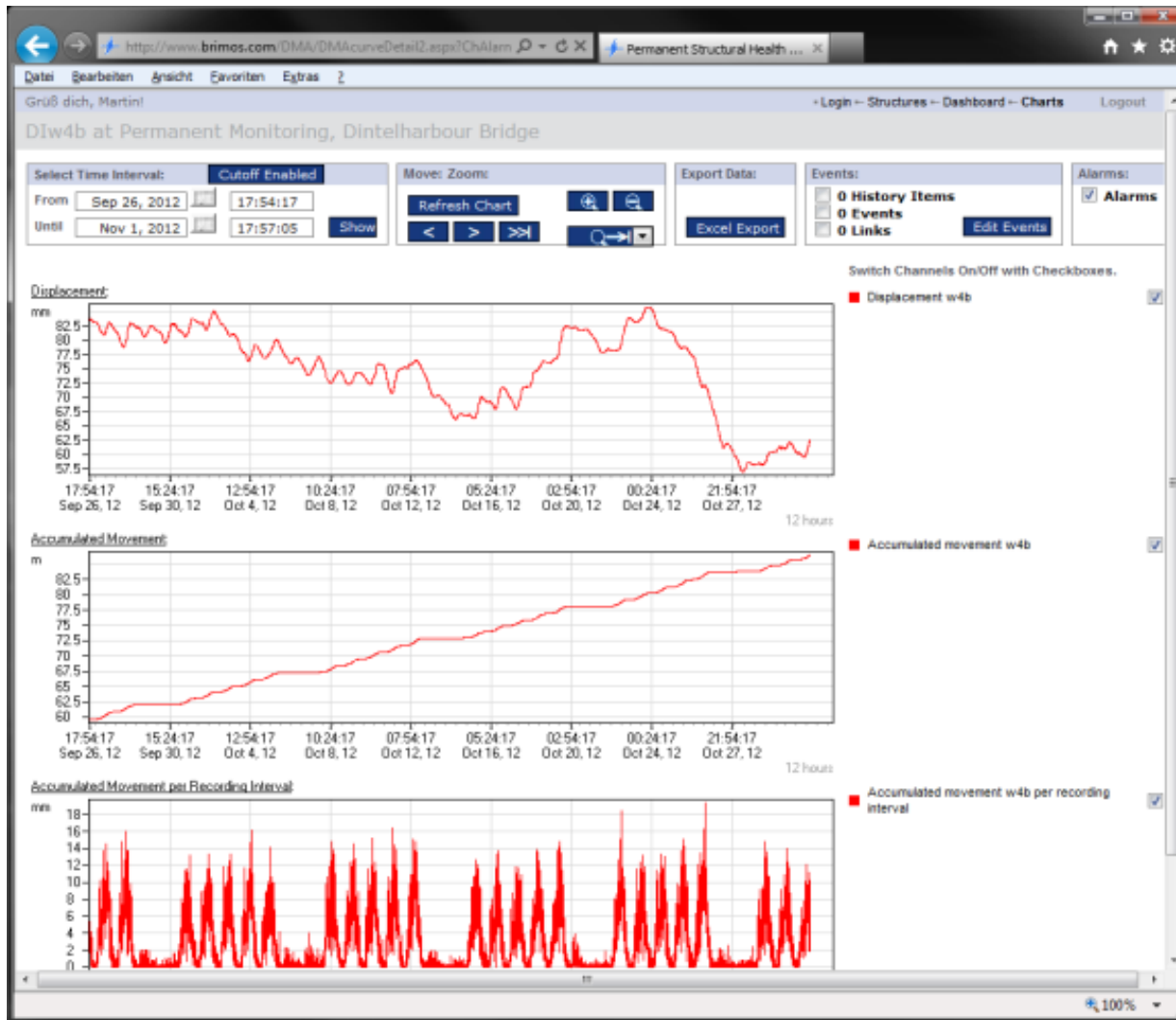
# Multi functional Web-Interface

## Inchon Bridge (Korea): Life Cycle counting and performance





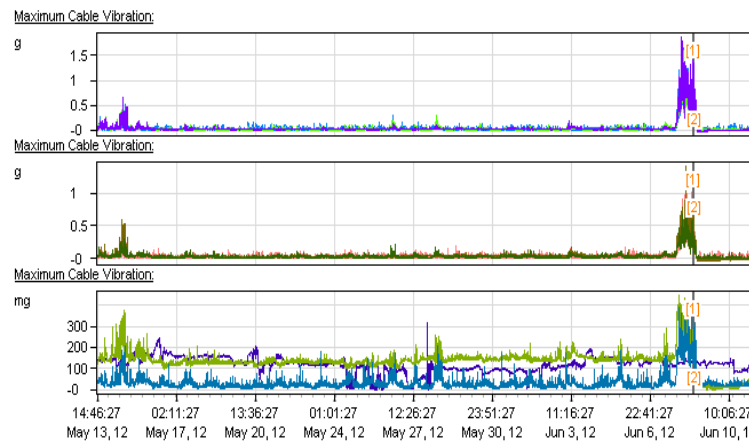
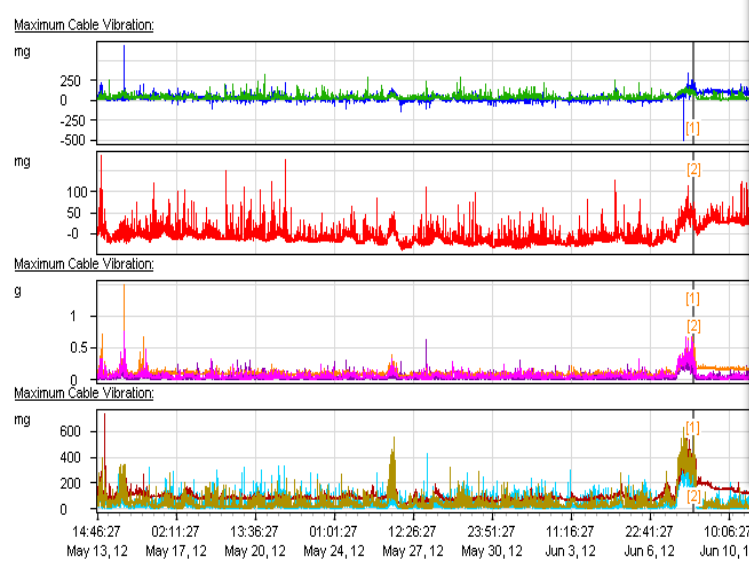
# Inchon (KR) Monitoring Displacement Collectives



Guten Tag Peter Furtner  
All Data at Permanent Monitoring, Waterford

Select Time Interval: From May 13, 2012 14:46:27 Until Jun 13, 2012 14:42:50 Show

Move: Refresh Chart Zoom: Excel Export



Air Temperature:

7-Zip Dateimanager

C:\Users\Furtner\AppData\Local\Temp\brimosdata\_20120613\_144423.zip\

Name	Größe	Gepackte Größe	Geändert am	Erstellt am	Letzter Zugriff	Attr
brimosdata_20120613_144423.WATERFORD-CV.csv	1 624 850	482 990	2012-06-13 14:44			
brimosdata_20120613_144423.WATERFORD-STAT.csv	2 901 977	806 984	2012-06-13 14:44			
brimosdata_20120613_144423.WATERFORD-STRAIN.csv	1 415 673	475 274	2012-06-13 14:44			

brimosdata\_20120613\_144423.WATERFORD-CV.csv - Microsoft Excel

A1	# section: header									
A	B	C	D	E	F	G	H	I	J	MS
1	# section: header									
2	# filetype: CSV-File									
3	# creator: db2image V2.0beta35a 18.Mai.2012									
4	# object: WATERFORD									
5	# project: DMA									
6	#									
7	#									
8	# section: measurements									
9	# channelgroup: WATERFORD-CV									
10	# units: s	g	g	g	g	g	g	g	g	g
11	# columns: timeIndex	BS_11_max	BS_11_max	BS_11_max	BS_16_max	BS_16_max	BS_16_max	BS_18_max	BS_18_max	BS_18_max
12	# data:									
13	13.05.2012 14:46	0,044115	0,125661	0,042098	0,005927	0,120198	0,040066	0,041735	-0,000968	0,013298
14	13.05.2012 14:51	0,061635	0,171083	0,031067	0,004629	0,103165	0,022546	0,063399	0,013794	0,010865
15	13.05.2012 14:57	0,024486	0,112683	0,021171	0,041454	0,108032	0,037146	0,044123	0,000168	0,018327
16	13.05.2012 15:02	0,082399	0,126797	0,065296	0,011605	0,105923	0,025953	0,053028	0,011686	0,031792
17	13.05.2012 15:12	0,081588	0,11609	0,046316	0,0653	0,146154	0,092788	0,039186	0,002439	0,013623
18	13.05.2012 15:18	0,027082	0,143181	0,071623	0,0215	0,117116	0,084191	0,055426	0,017363	0,026601
19	13.05.2012 15:23	0,044277	0,136043	0,130996	0,071789	0,108032	0,028062	0,053866	0,008441	0,013461
20	13.05.2012 15:29	0,065204	0,147561	0,038691	0,134731	0,226454	0,13383	0,071158	0,029854	0,013461
21	13.05.2012 15:34	0,014753	0,09565	0,04226	0,065138	0,219802	0,179902	0,06163	0,011037	0,052394
22	13.05.2012 15:40	0,110951	0,20807	0,123047	0,070491	0,119063	0,060831	0,067659	0,011361	0,018976
23	13.05.2012 15:45	0,076722	0,145452	0,091089	0,007711	0,102678	0,041364	0,075533	0,016877	0,013947
24	13.05.2012 15:51	0,121008	0,177734	0,283485	0,026367	0,123929	0,072024	0,065008	0,011037	0,022707
25	13.05.2012 15:56	0,083535	0,142208	0,104716	0,092229	0,206014	0,124259	0,07174	0,013308	0,027898

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# Summary

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- » Monitoring is part of integrated Asset Management
- » We need figures to demonstrate the Impact
- » Cases will help to proof the concept
- » BIM
- » Availability and Performance Costs gain importance

Thank You !

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