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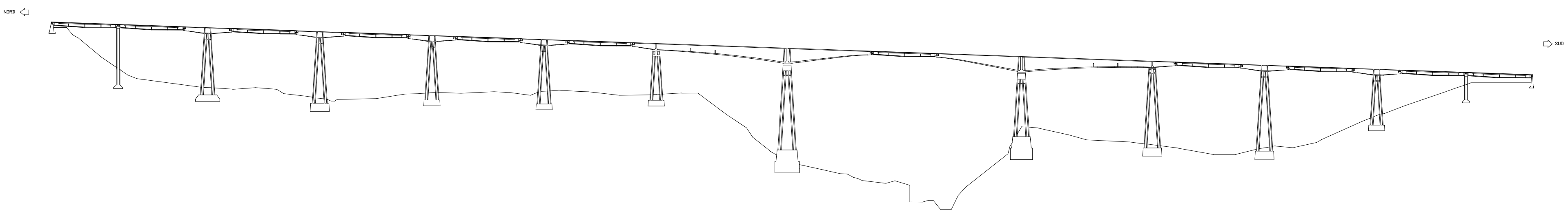
# Colle Isarco Viaduct – Structural assessment based on periodic and permanent dynamic monitoring

Dr. Andrea Mordini




Colle Isarco Viaduct:

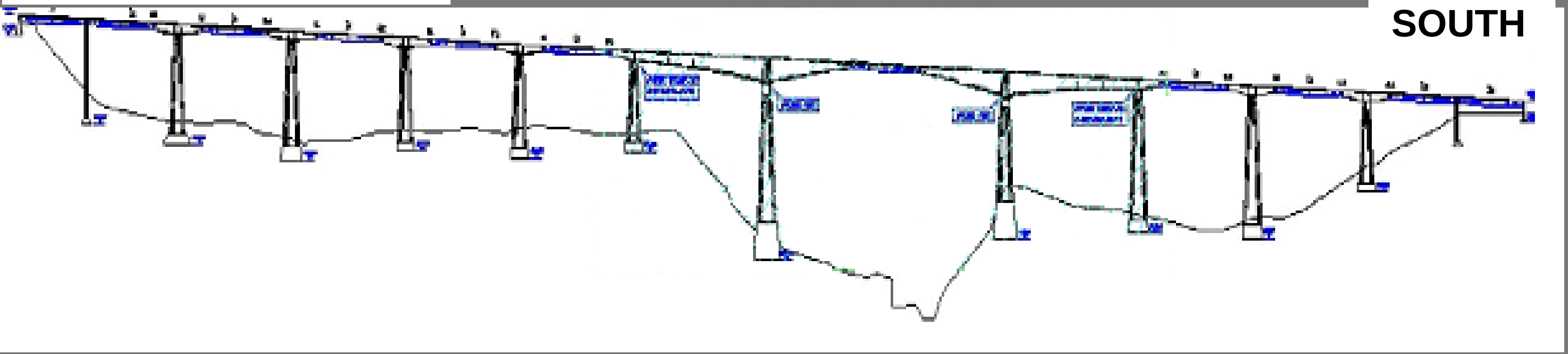
- Located on the Brennero Highway in an alpine valley in the north of Italy.
- Two parallel equal structures.
- 13 spans for a total length of 1028 m.
- Main span 163 m with a suspended beam of 45 m.
- Post-tensioned reinforced concrete box girder.
- Fully isostatic structure.


PATRICK STAUDACHER

The investigation at the Colle Isarco Viaduct included three essential parts:

- A detailed initial measurement campaign with BRIMOS® in March 2007.
- Two permanent monitoring systems – one for each carriageway, 2007-2008
- A second measurement campaign with BRIMOS® one year after the initial one in March 2008.

NORTH



SOUTH

Carriageway North

| | | |
|---|---|---|
| CW North - North | Main structure North | CW North - South |
| CW South - North | Main structure South | CW South - South |

Carriageway South

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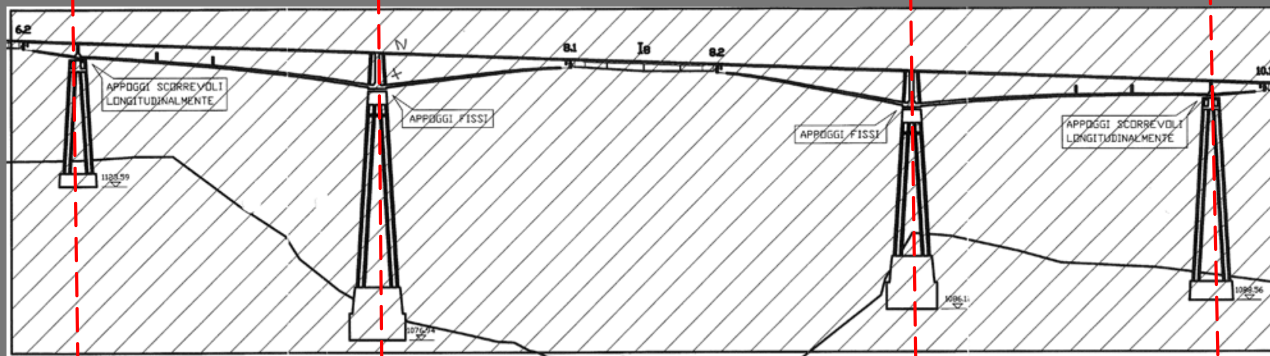
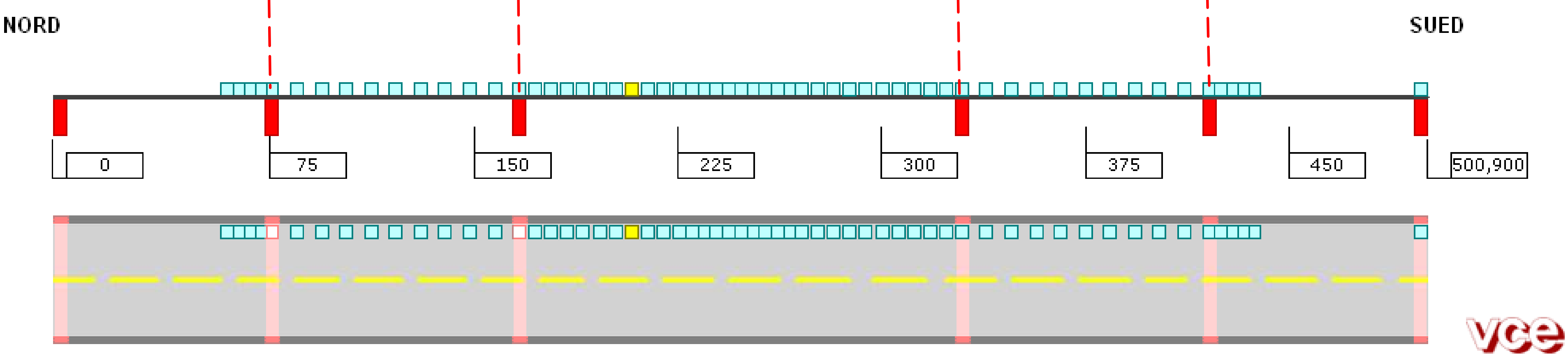
## Sensor layout for the main structures

### (the viaduct was loaded by traffic on one lane)

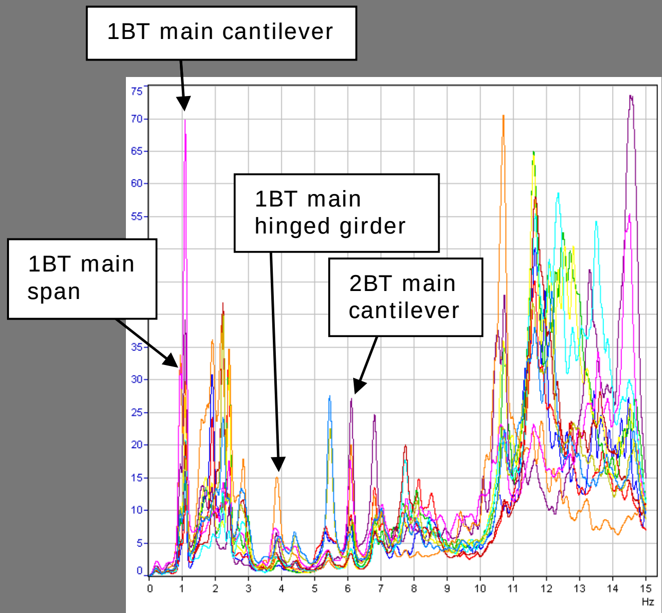


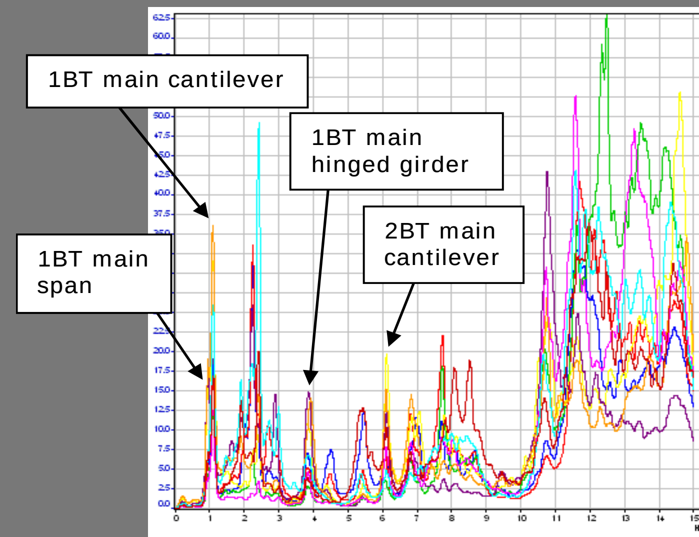




**Symbolskizze** Aufstellungsposition: linker Rand

## ANPSD (vertical direction) for all measurement files in the range 0-15 Hz.

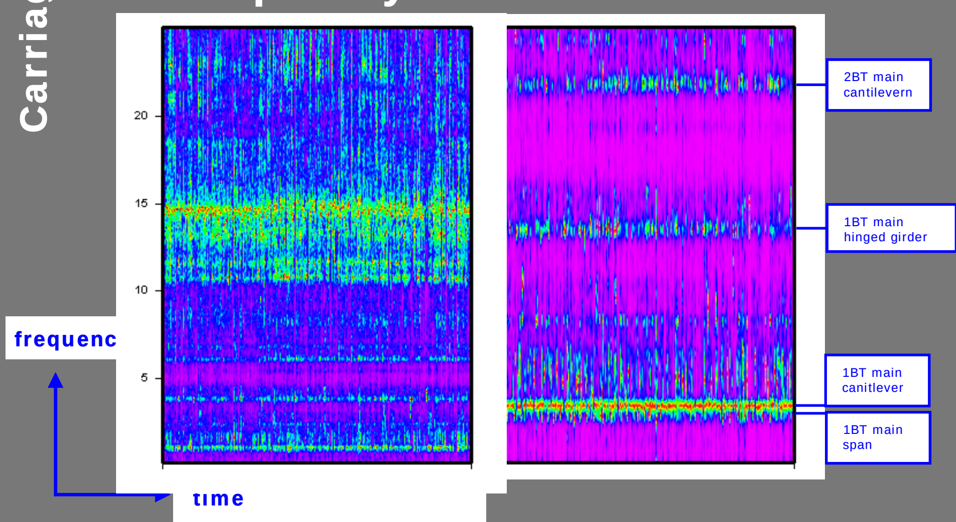
Carriageway North

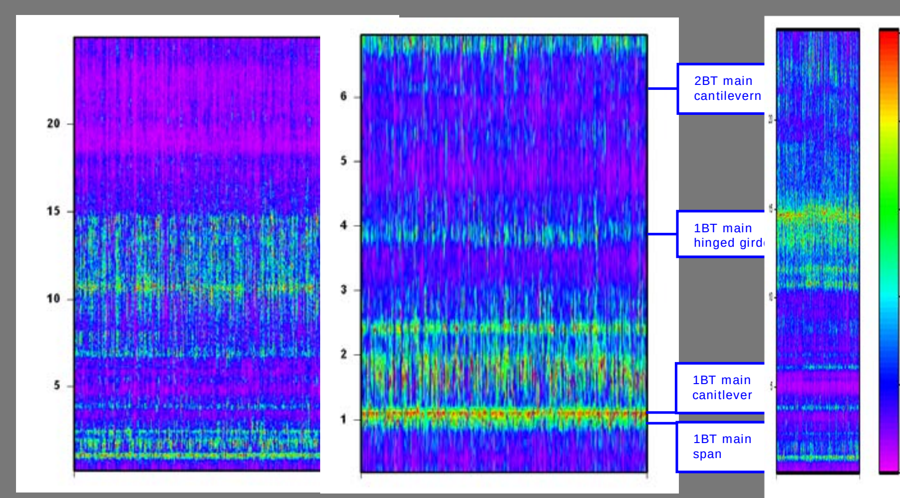



Carriageway South

## Frequency trend in time

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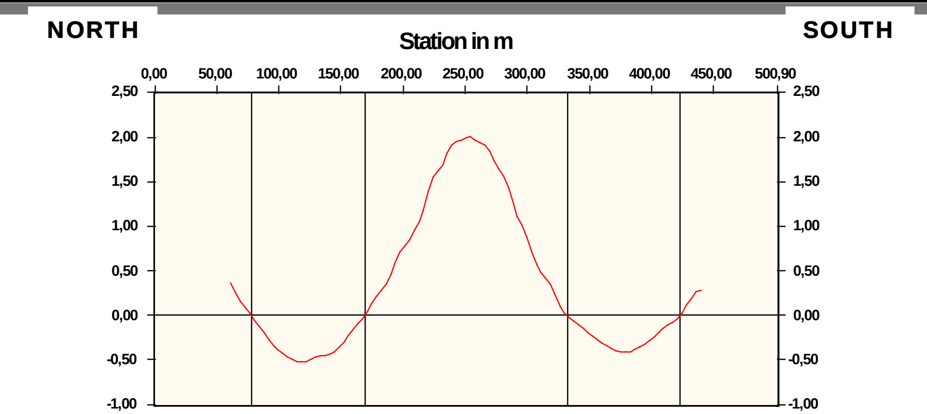
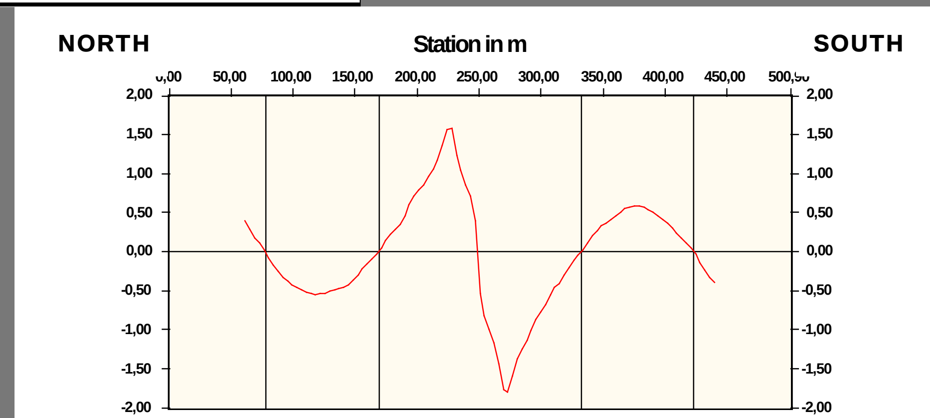
| Eigenfrequency [Hz] | Measurement campaign 2007 | | |
|---|---|---|---|
| | carriagway North | carriageway South | |
| $1^{st}$ bending mode | 0.99 | 0.96 | 1BT main span |
| $2^{nd}$ bending mode | 1.10 | 1.10 | 1BT main cantilever |
| $3^{rd}$ bending mode | 3.83 | 3.89 | 1BT main hinged girder |
| $4^{th}$ bending mode | 6.11 | 6.10 | 2BT main cantilever |

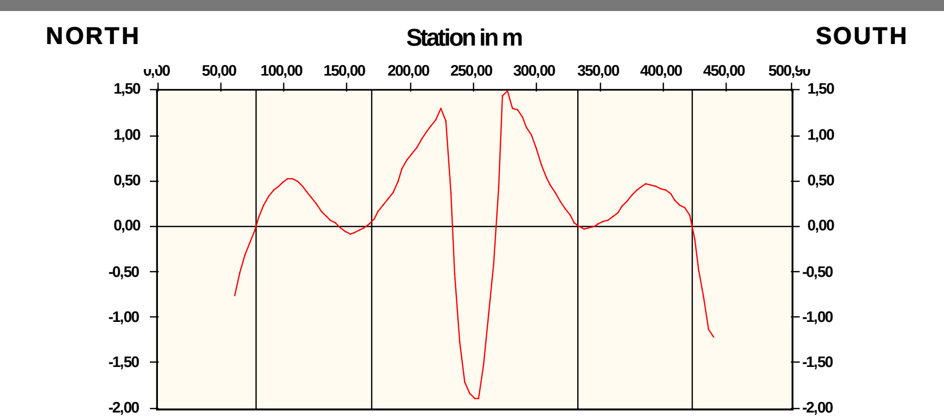
## Main structure Eigenfrequencies



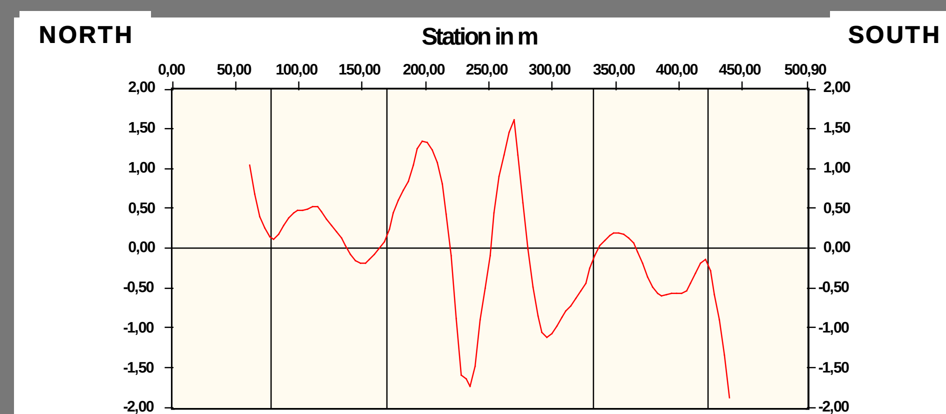

Mode shape 1 – 0.99 Hz 1BT main span




Mode shape 2 – 1.10 Hz 1BT main cantilever




Mode shape 3 – 3.83 Hz 1BT main hinged girder




Mode shape 4 – 6.11 Hz 2BT main cantilever

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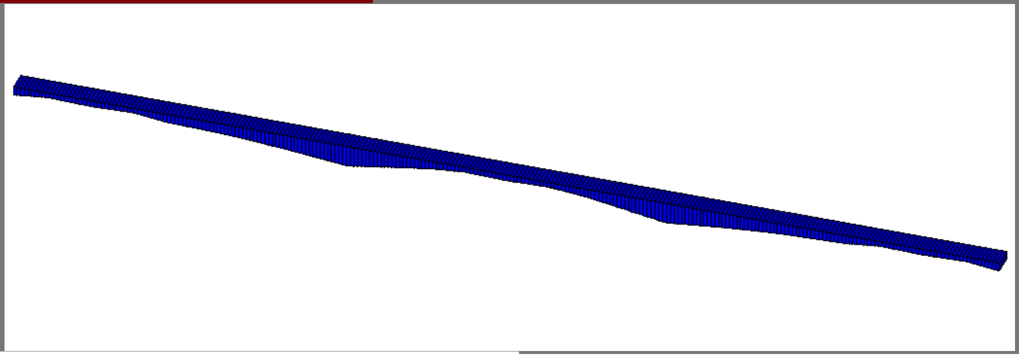
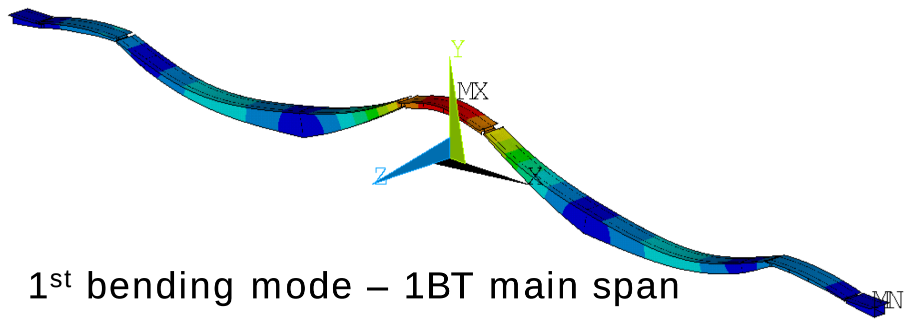
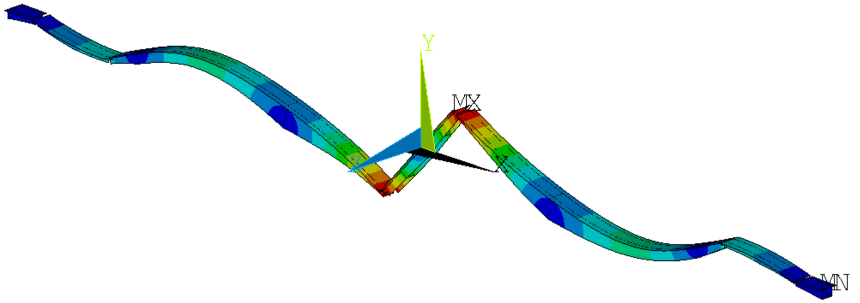
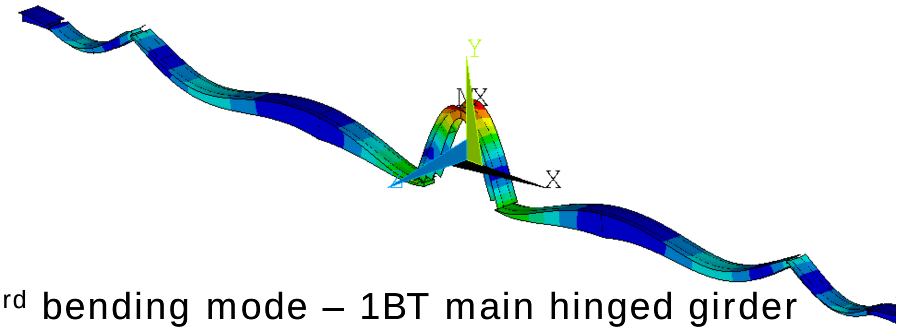




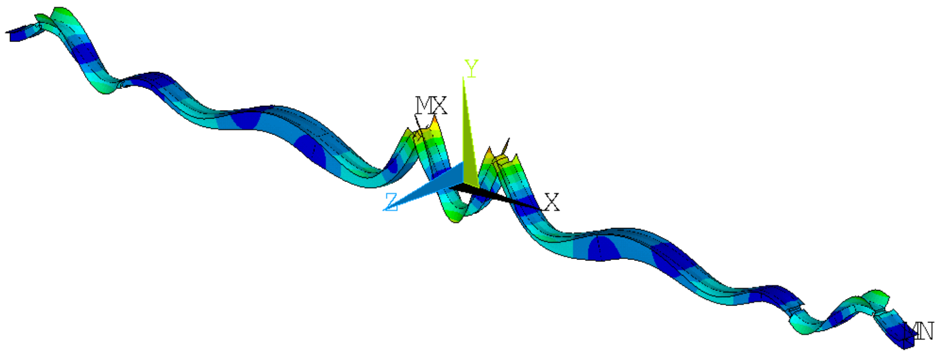

1st bending mode – 1BT main span




2nd bending mode – 1BT main cantilever




3rd bending mode – 1BT main hinged girder

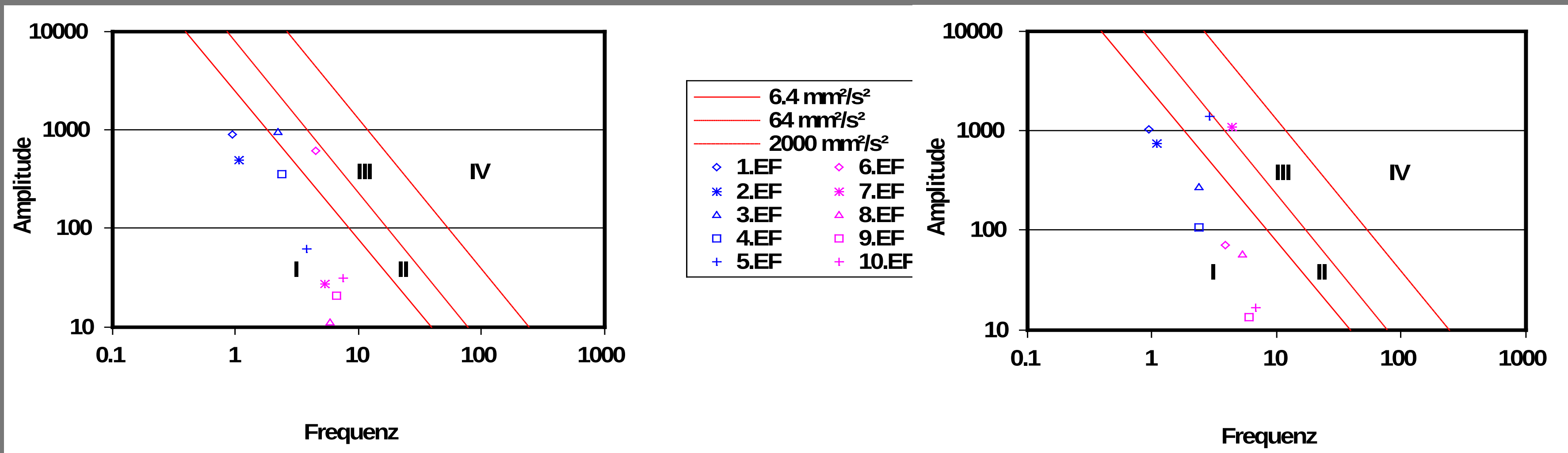



4th bending mode – 2BT main cantilever

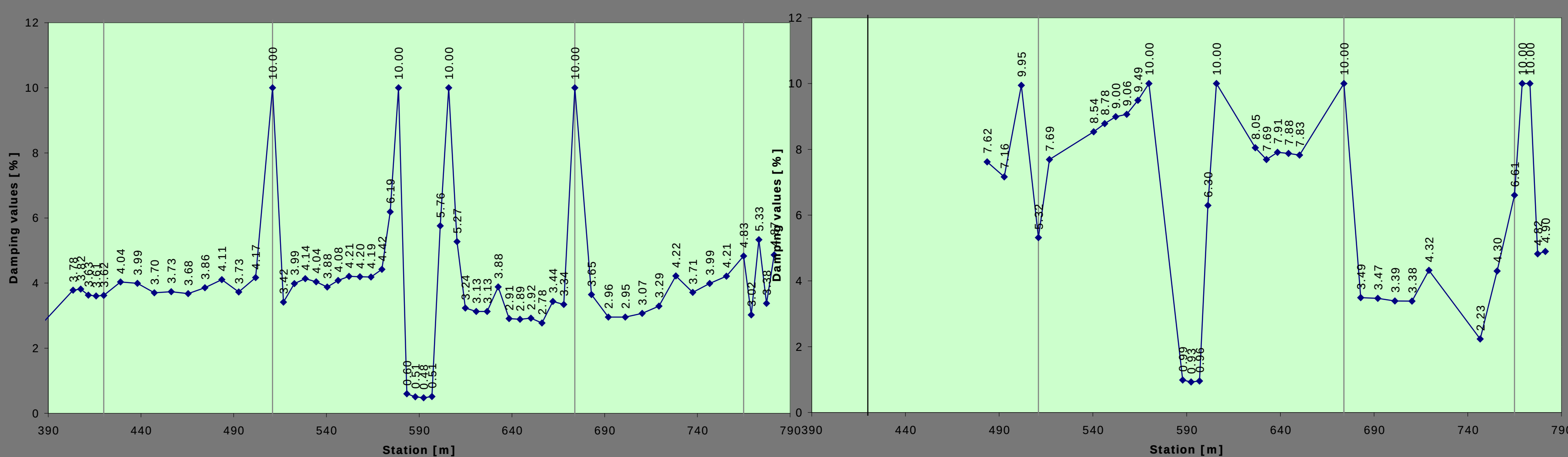
Carriageway North

Carriageway South

## Vibration Intensity




## Damping value distribution

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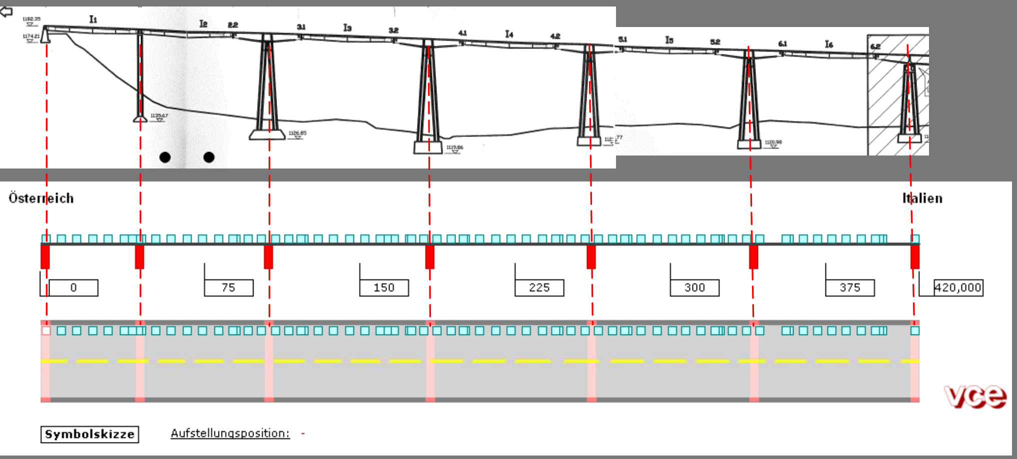
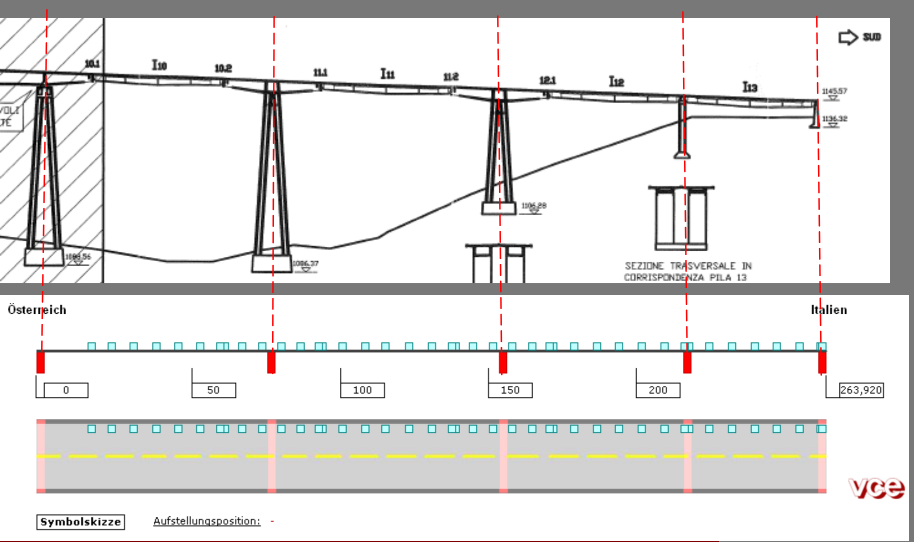
## Northern and Southern part of the bridge

### Sensor layout for the northern part

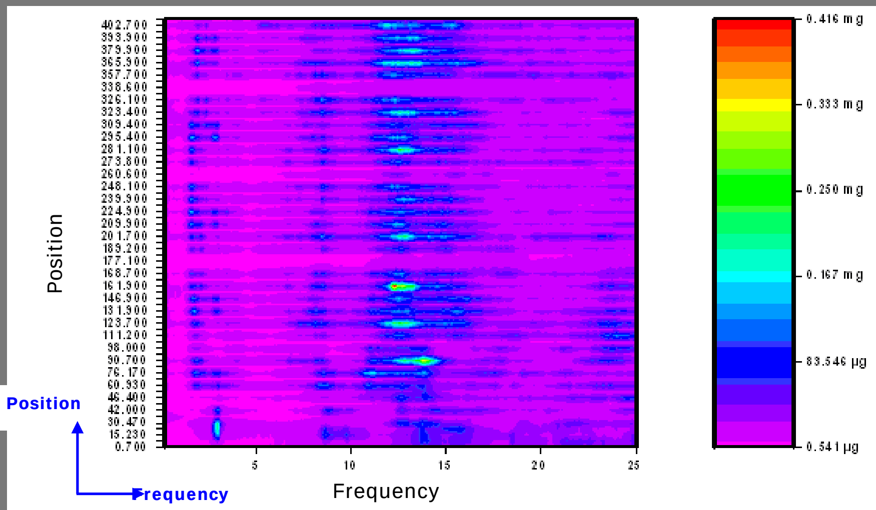



### Sensor layout for the southern part

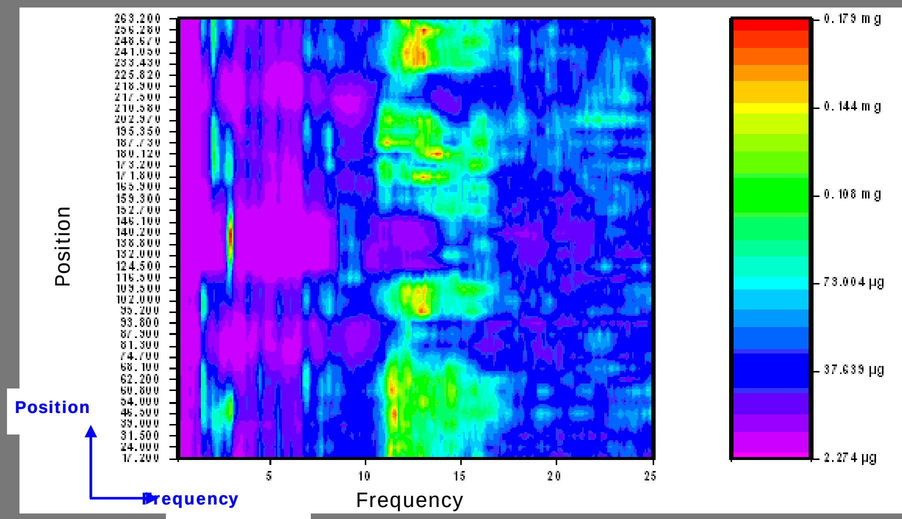



# Frequency trend in vertical direction, 0.2 – 25 Hz

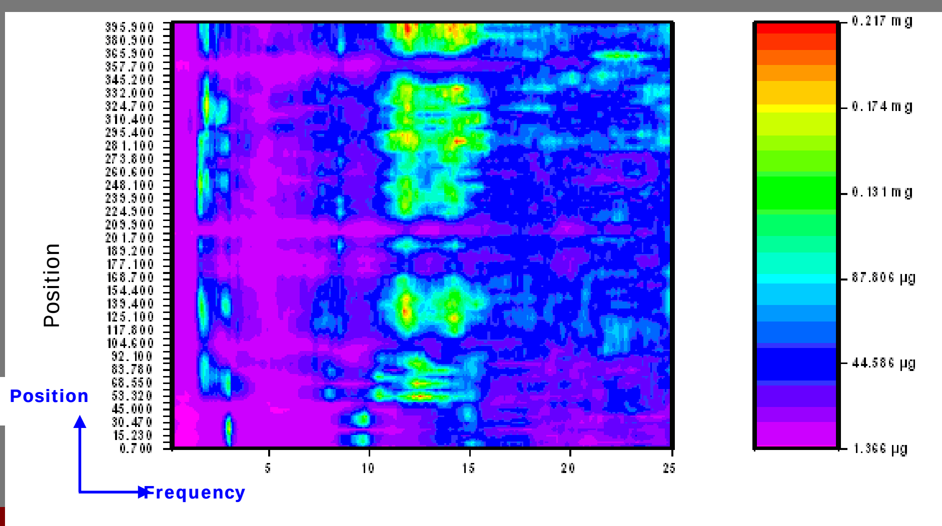
## CW North – Northern part



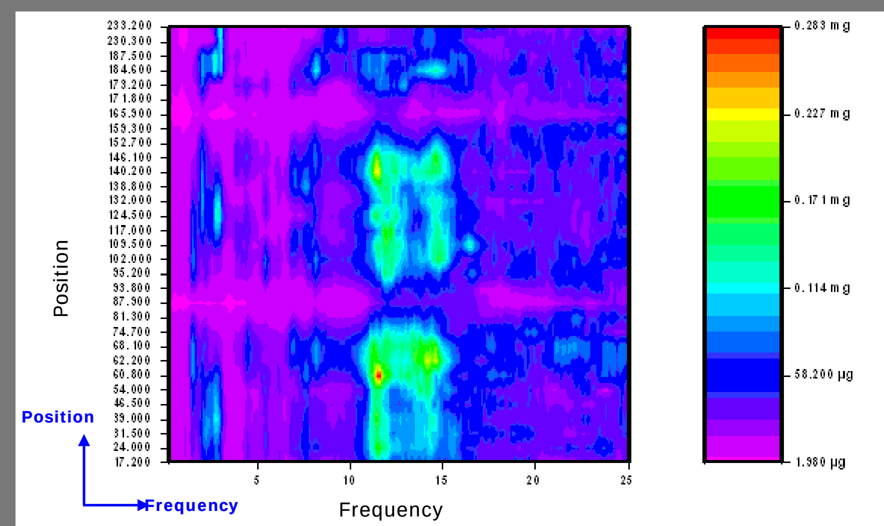

## CW North – Southern part



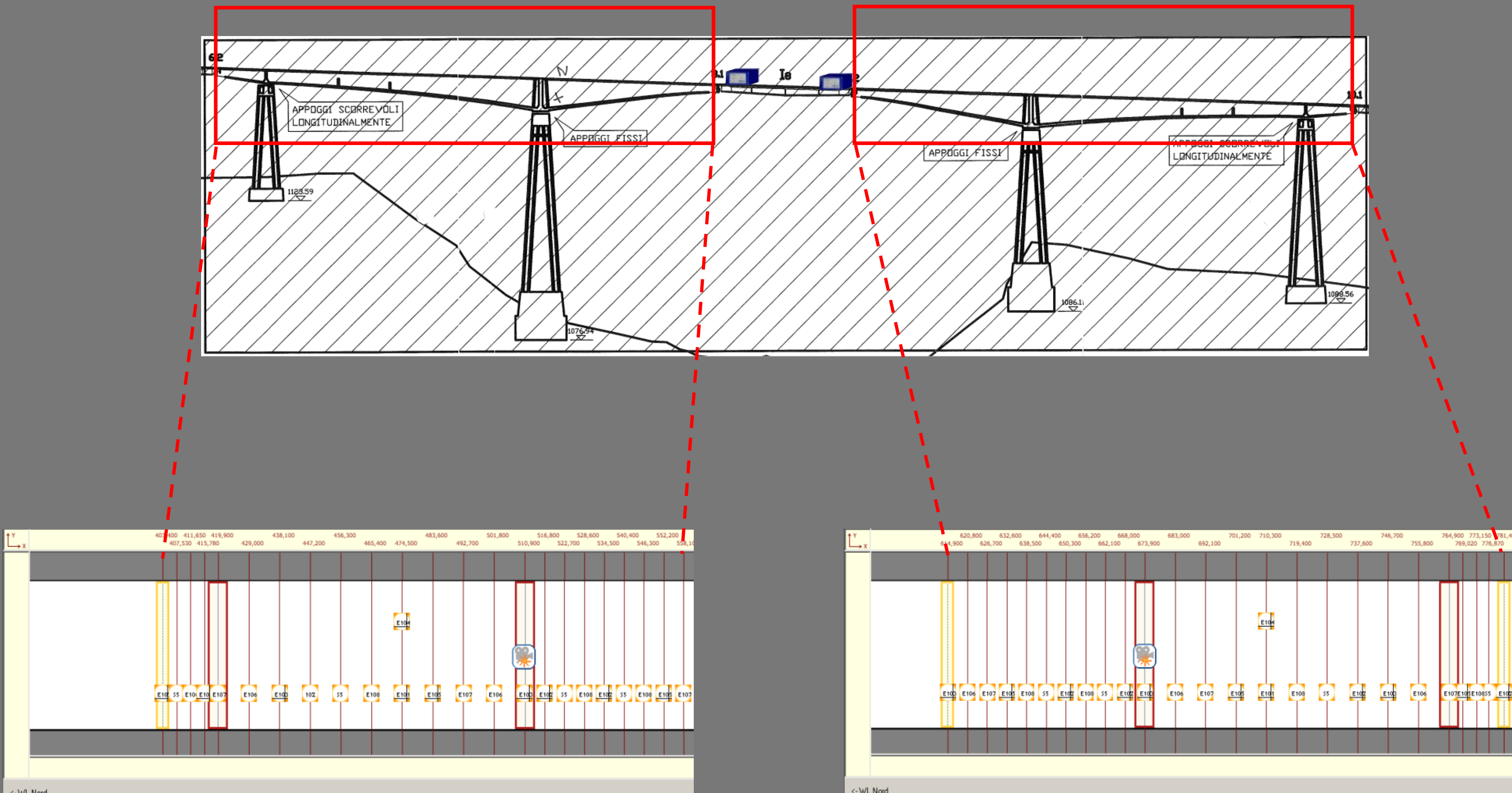

## CW South – Northern part




## CW South – Southern part



# Sensor layout for the main structures
## (the traffic was deviated)



# Main structures

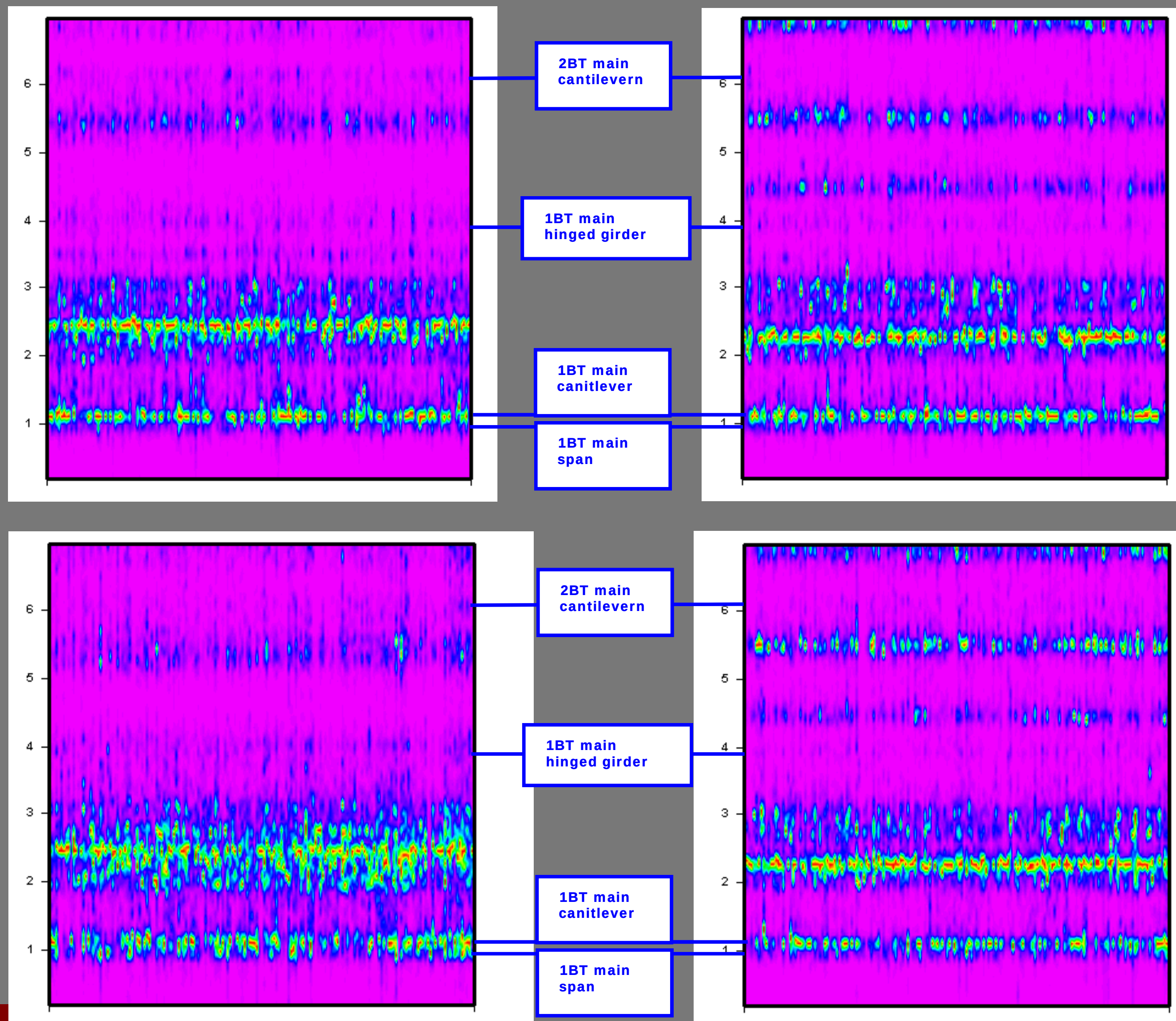
## Structurs´relevant stiffness-pattern in the vertical direction over the measurements´entire time period, for the reference sensor

CW North
Northern part

CW North
Southern part

CW South
Northern part

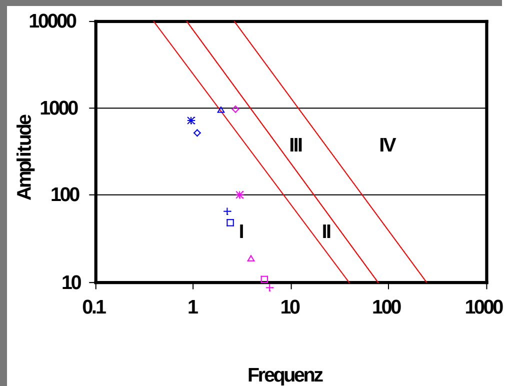
CW South
Southern part

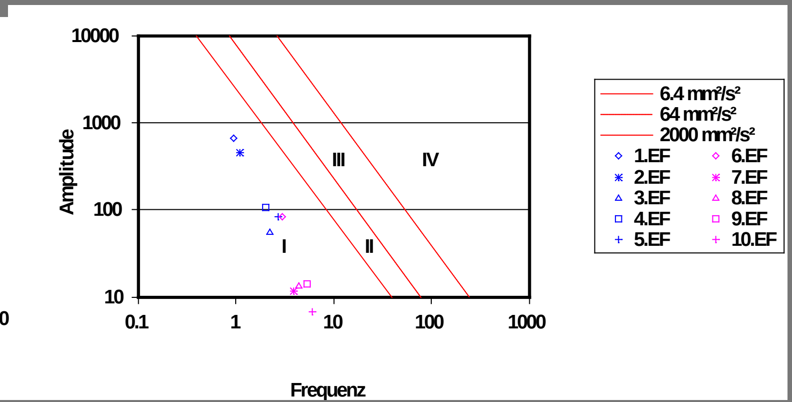


## Vibration Intensity Analysis - Main structures

CW North

Northern part

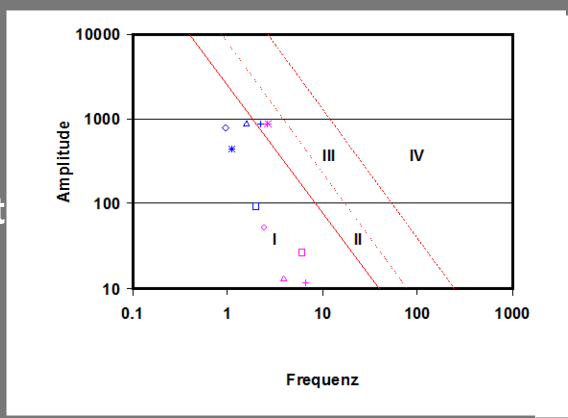


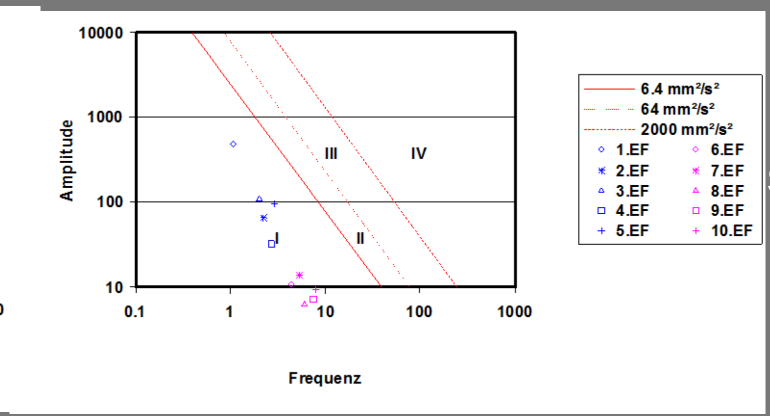




Southern part

CW South

Northern part




Southern part

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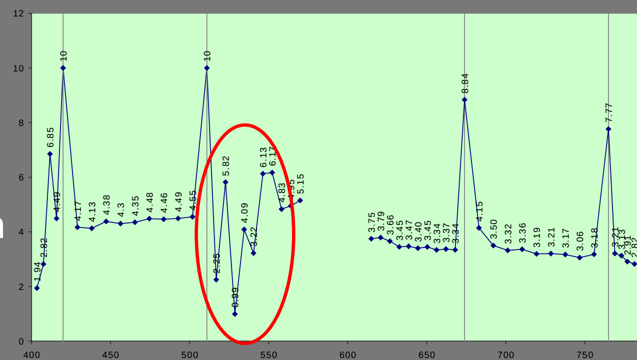
# Damping Analysis - Main structures

**CW North**

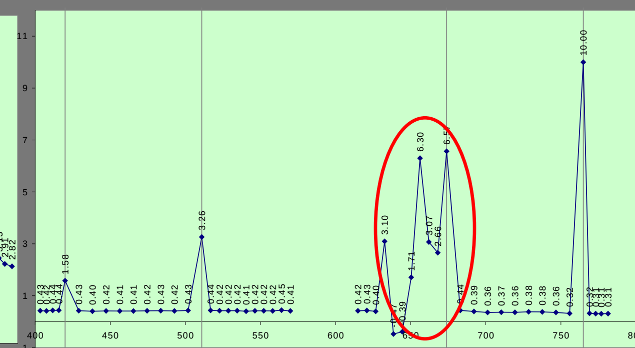
**Northern part**

**1BT main span**




**Southern part**

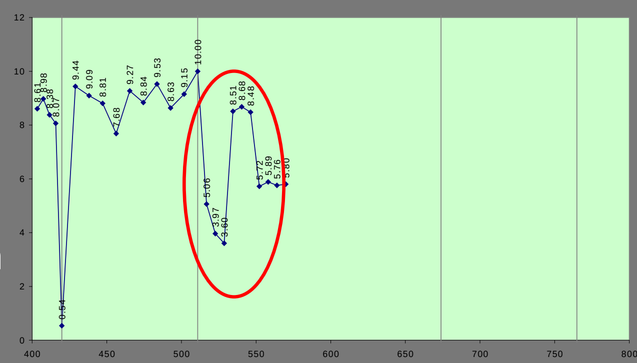
**1BT main cantilever**




**CW South**

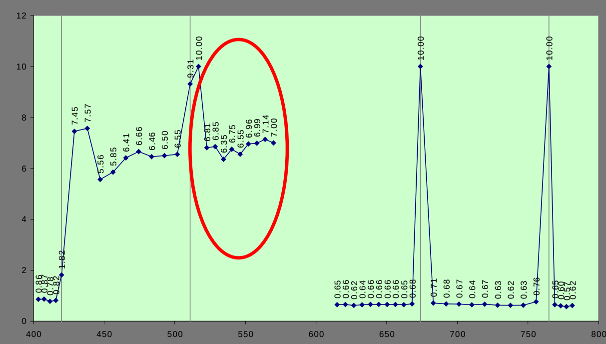
**Northern part**

**1BT main span**




**Southern part**

**1BT main cantilever**

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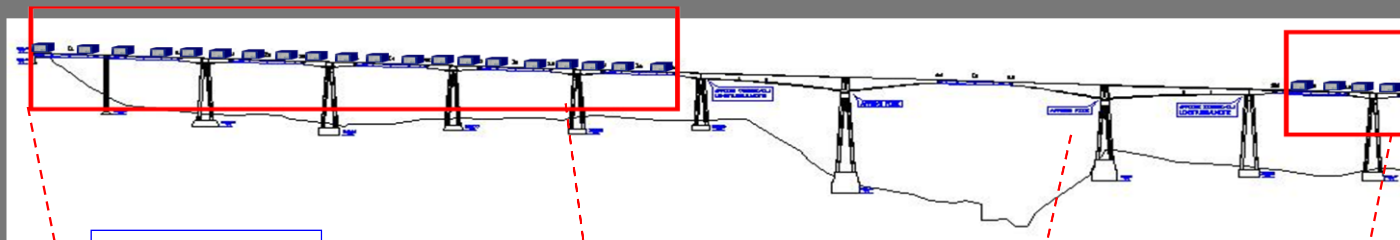
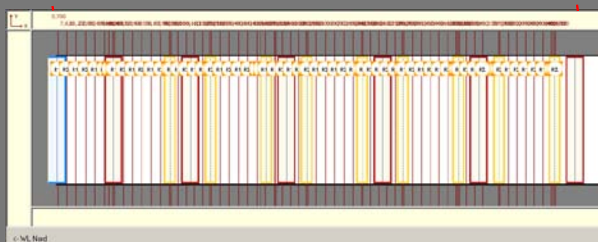
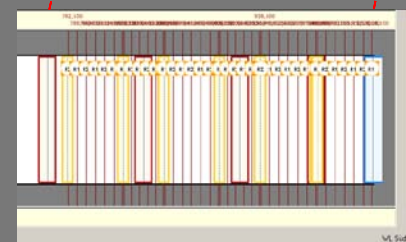
# Northern and Southern part of the bridge

Sensor layout 2008



Sensor layout 2007

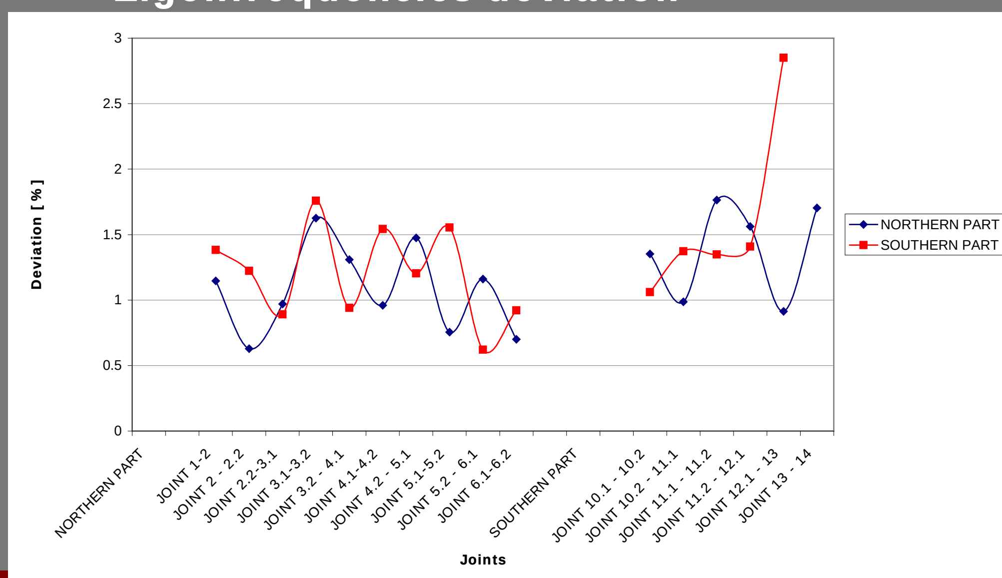




| CW North - North | Deviation of the Eigenfrequencies 2007 vs. 2008 [ % ] |
|---|---|
| Joint 1-2 | 1.1 |
| Joint 2 - 2.2 | 0.6 |
| Joint 2.2-3.1 | 1.0 |
| Joint 3.1-3.2 | 1.6 |
| Joint 3.2 - 4.1 | 1.3 |
| Joint 4.1-4.2 | 1.0 |
| Joint 4.2 - 5.1 | 1.5 |
| Joint 5.1-5.2 | 0.8 |
| Joint 5.2 - 6.1 | 1.2 |
| Joint 6.1-6.2 | 0.7 |
| on average | 1.1 |

| CW South - North | Deviation of the Eigenfrequencies 2007 vs. 2008 [ % ] |
|---|---|
| Joint 1-2 | 1.4 |
| Joint 2 - 2.2 | 1.2 |
| Joint 2.2-3.1 | 0.9 |
| Joint 3.1-3.2 | 1.8 |
| Joint 3.2 - 4.1 | 0.9 |
| Joint 4.1-4.2 | 1.5 |
| Joint 4.2 - 5.1 | 1.2 |
| Joint 5.1-5.2 | 1.6 |
| Joint 5.2 - 6.1 | 0.6 |
| Joint 6.1-6.2 | 0.9 |
| on average | 1.2 |

## Eigenfrequencies deviation



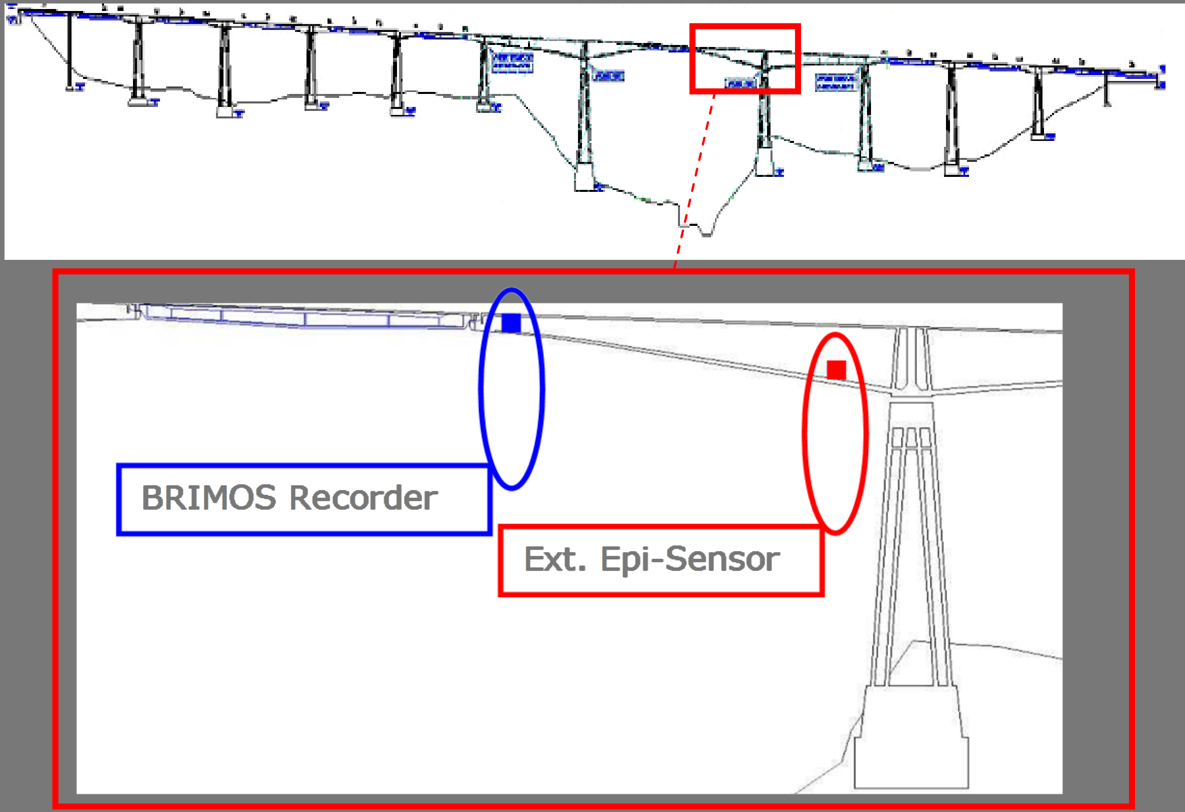

| CW North - South | Deviation of the Eigenfrequencies 2007 vs. 2008 [ % ] |
|---|---|
| Joint 10.1 - 10.2 | 1.4 |
| Joint 10.2 - 11.1 | 1.0 |
| Joint 11.1 - 11.2 | 1.8 |
| Joint 11.2 - 12.1 | 1.6 |
| Joint 12.1 - 13 | 0.9 |
| Joint 13 - 14 | 1.7 |
| on average | 1.4 |

| CW South - South | Deviation of the Eigenfrequencies 2007 vs. 2008 [ % ] |
|---|---|
| Joint 10.1 - 10.2 | 1.1 |
| Joint 10.2 - 11.1 | 1.4 |
| Joint 11.1 - 11.2 | 1.3 |
| Joint 11.2 - 12.1 | 1.4 |
| Joint 12.1 - 13 | 2.9 |
| Joint 13 - 14 | --- |
| on average | 1.6 |

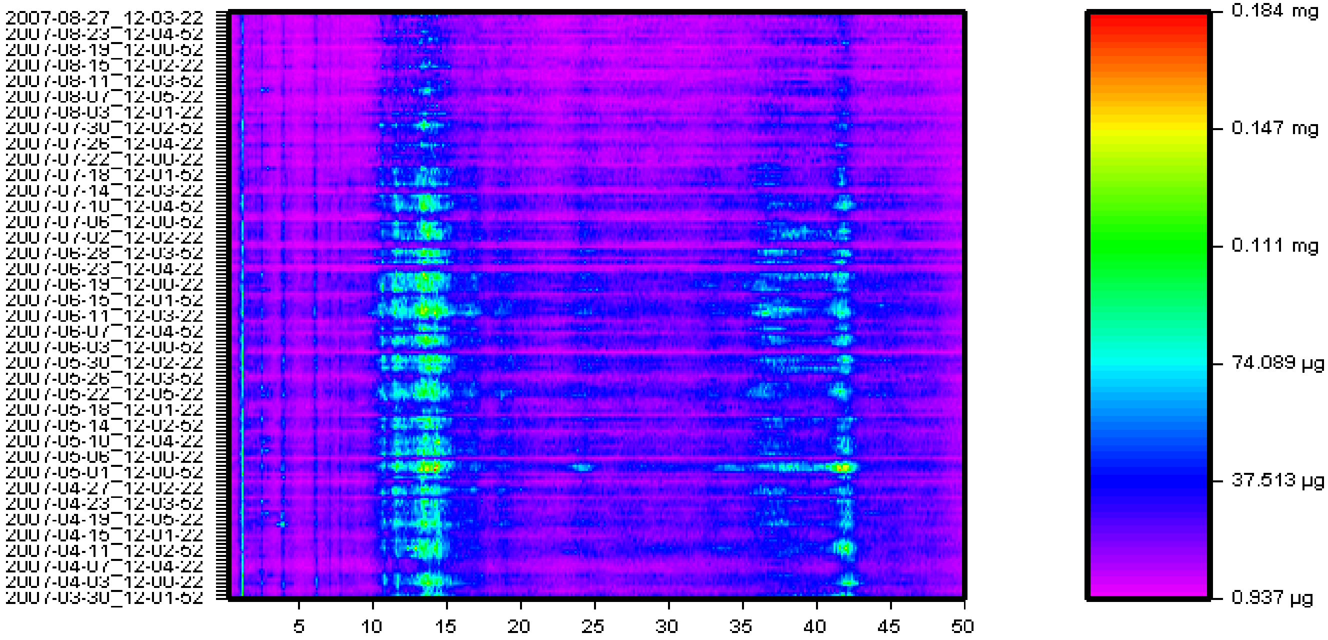
# Permanent Monitoring

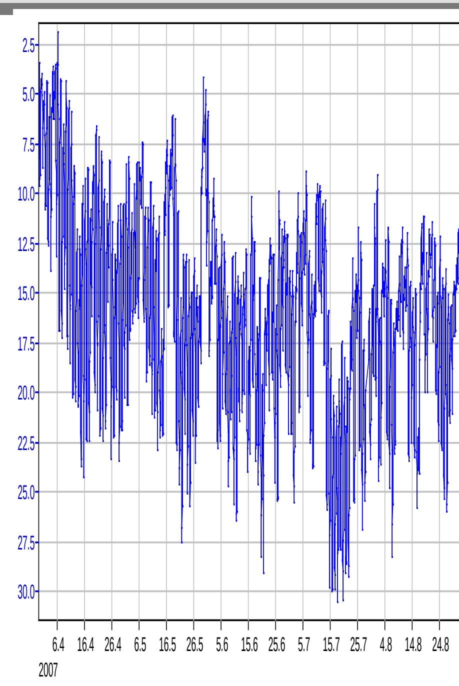


## Sensor layout

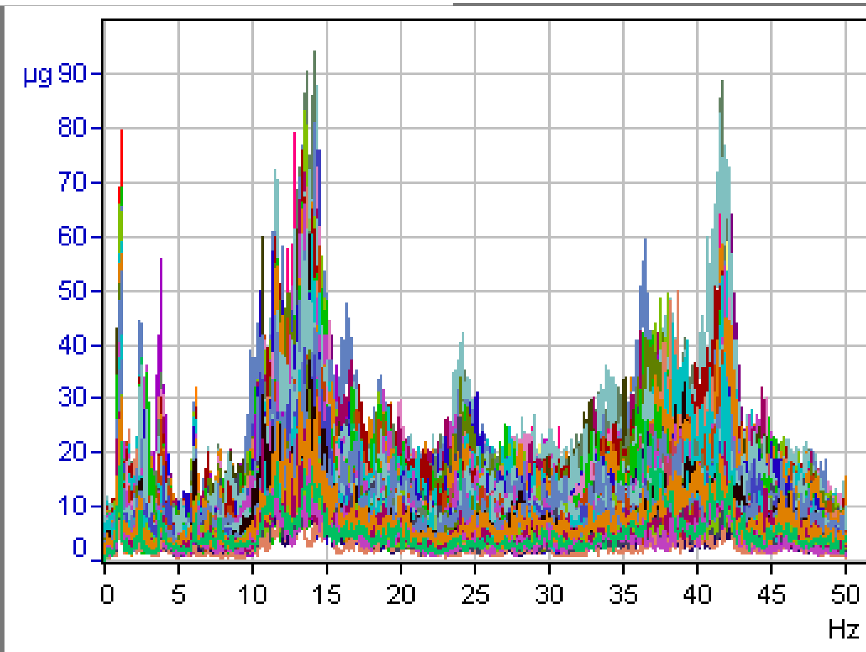



F C P




**Frequency trend (0.2-50 Hz), spectra and temperature over the whole measurement period in the vertical direction (CW South)**

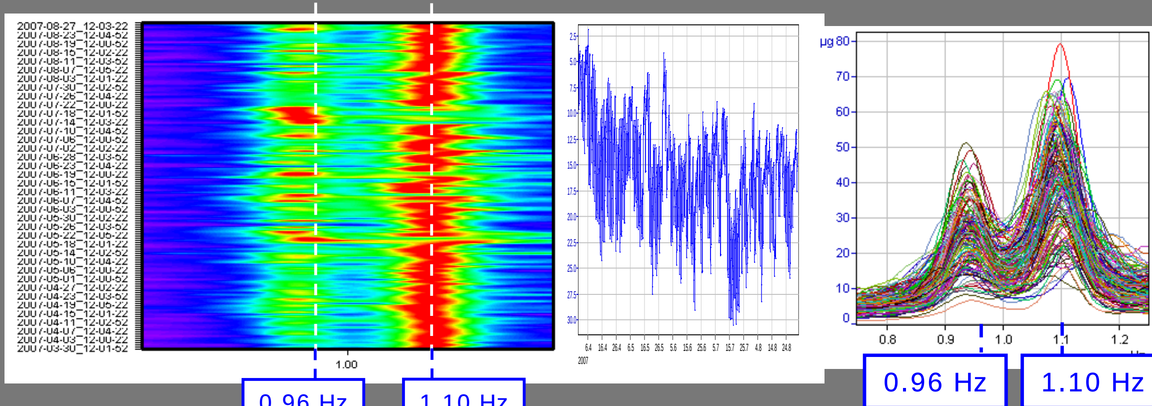


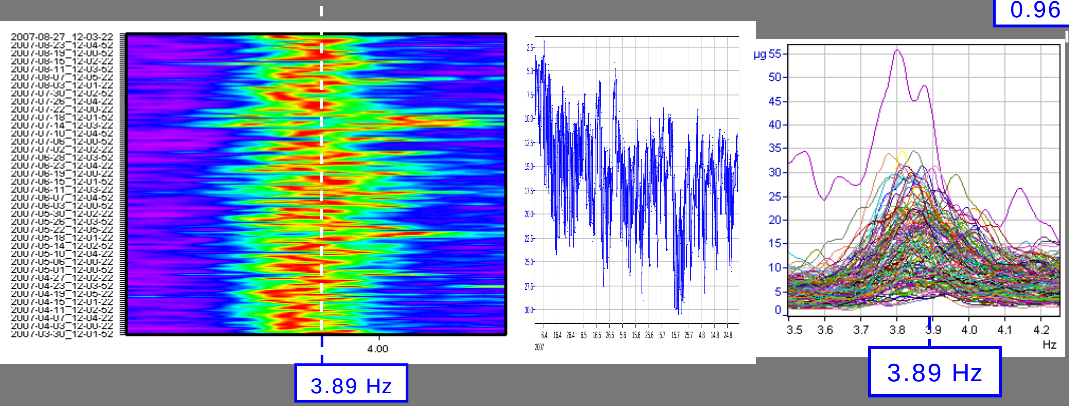
## Frequency trend, spectra and temperature sequence over the whole measurement period in vertical direction (CW South)

**0.75 – 1.25 Hz**

**1BT main span**

**1BT main cantilever**



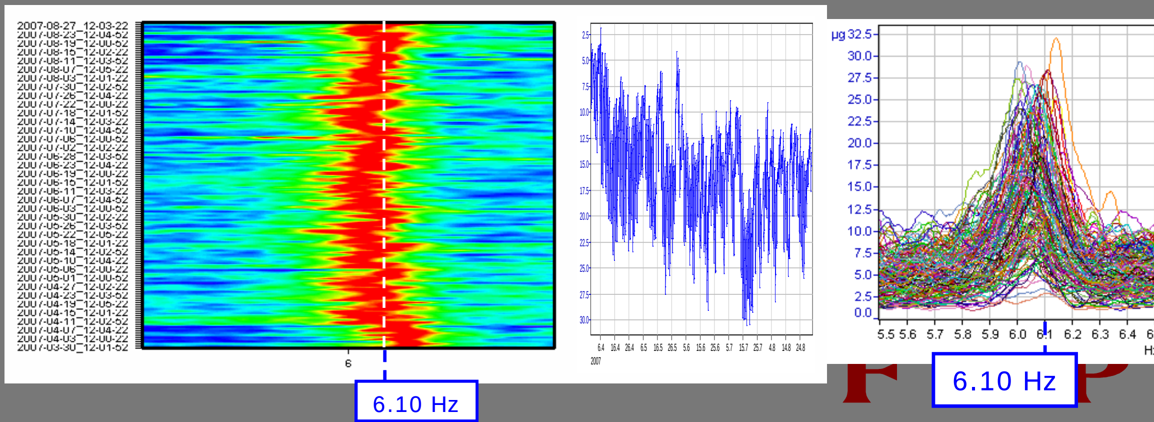




**3.5 – 4.25 Hz**

**1BT main hinged girder**

**5.5 – 6.5 Hz**

**2BT main cantilever**

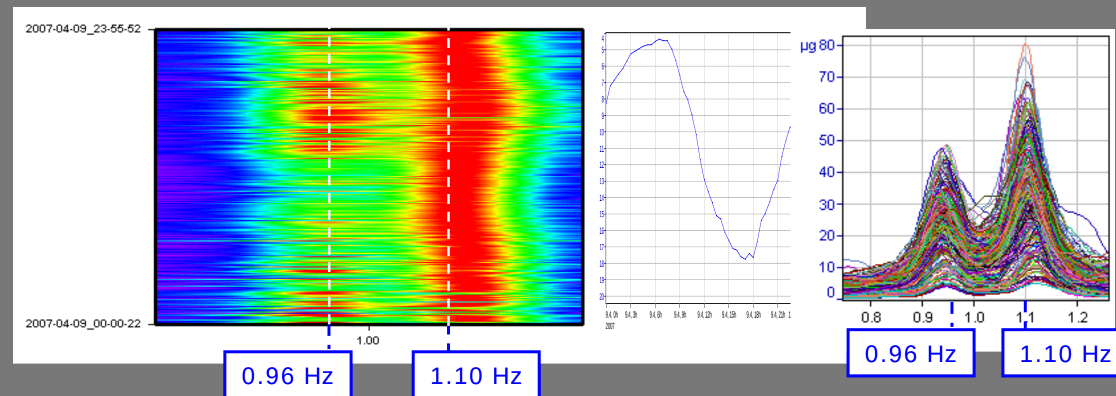


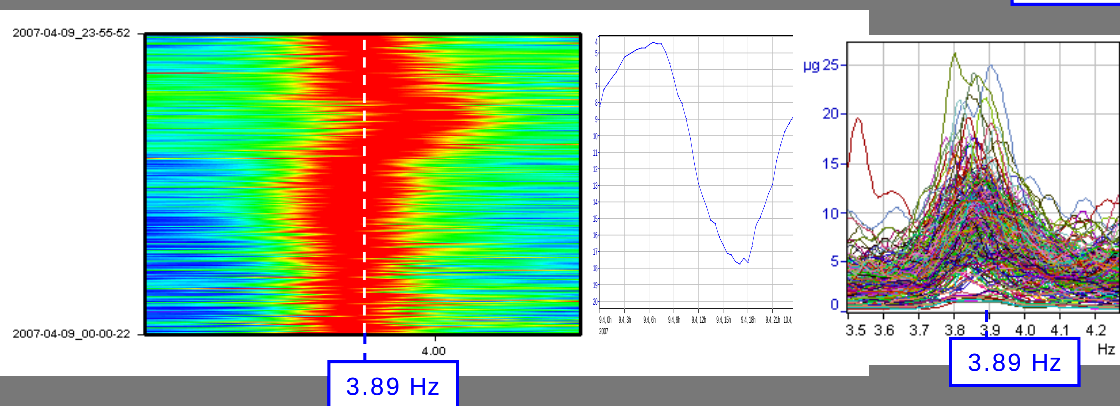
## Frequency trend, spectra and temperature sequence over one day in vertical direction (CW South)

**0.75 – 1.25 Hz**

**1BT main span**

**1BT main cantilever**



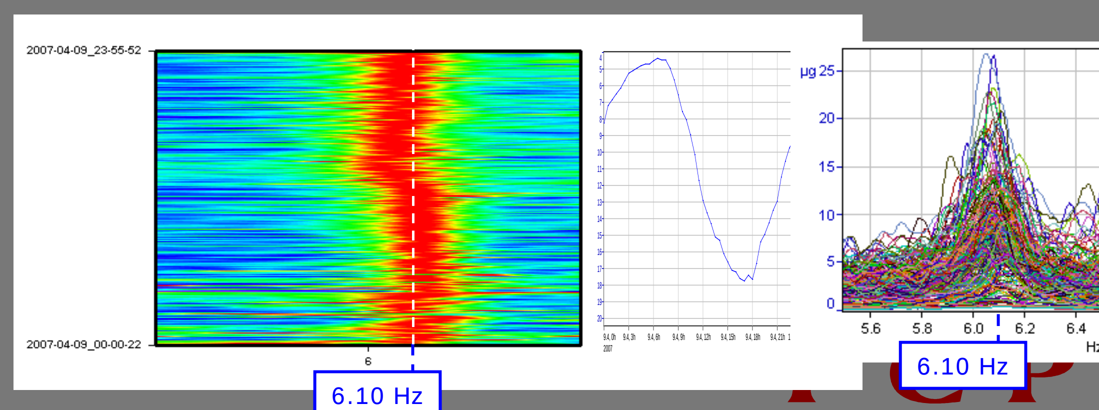




**3.5 – 4.25 Hz**

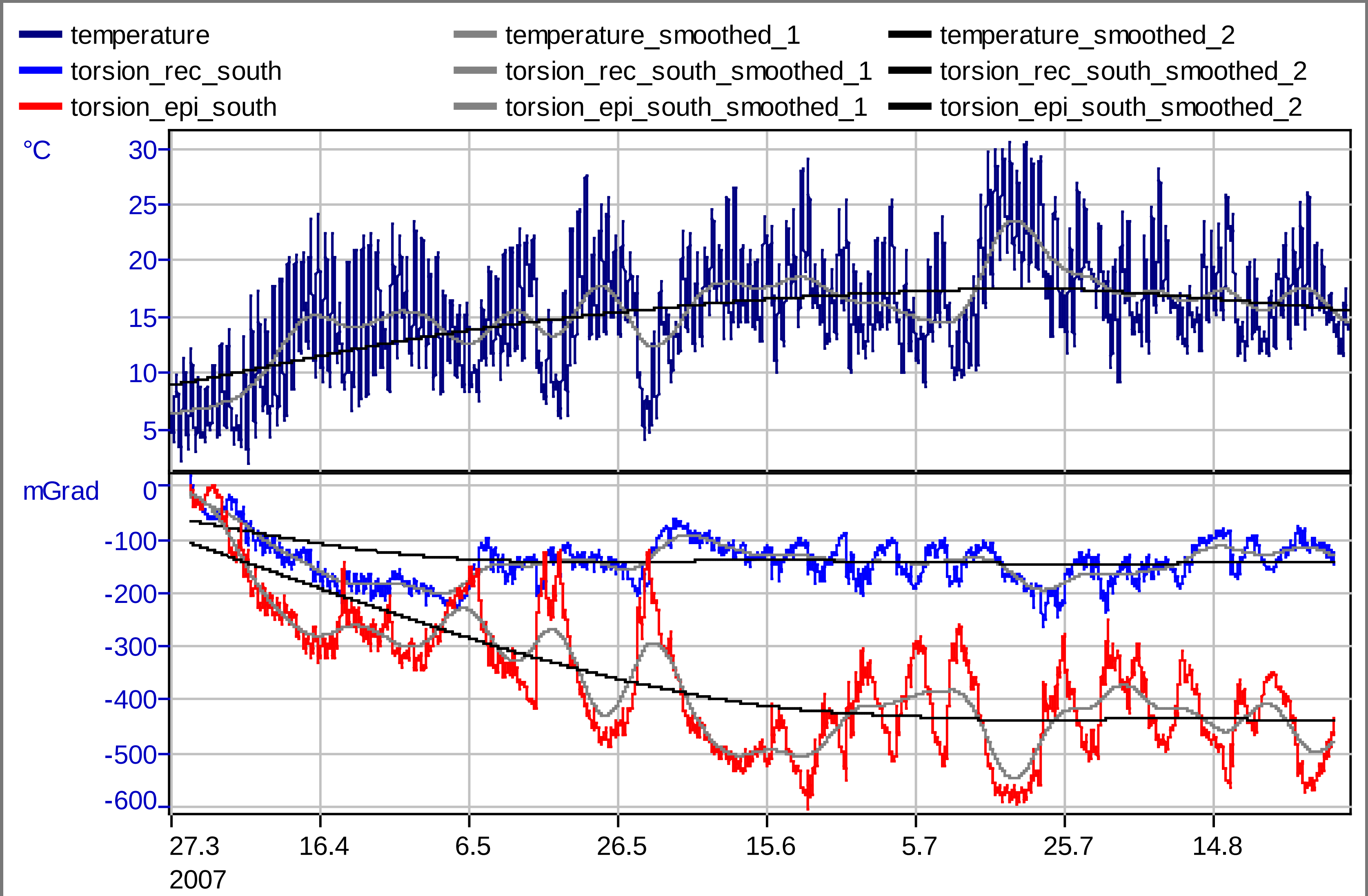
**1BT main hinged girder**

**5.5 – 6.5 Hz**

**2BT main cantilever**



## Analysis of long-term torsion (environmental condition)




**Trend of torsion – recorder (blue) and epi-sensor (red) – versus trend of temperature (CW South)**

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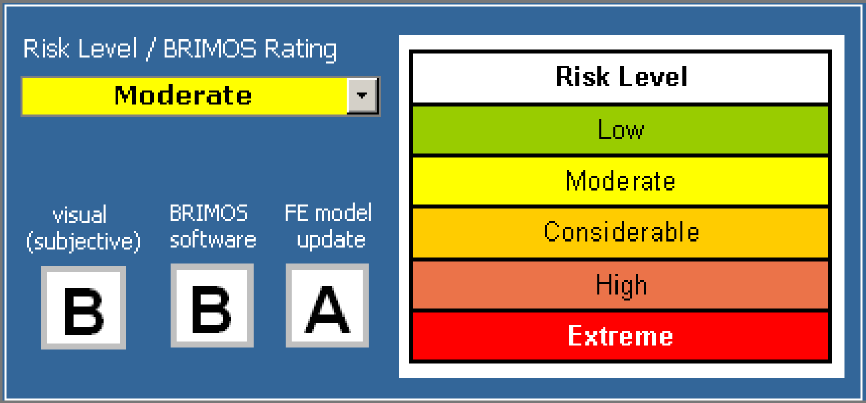
- The structural dynamic response reveals the bridge to be in good conditions.
- Due to the design choices a high sensitivity to dynamic vibrations is present.
- The area of the main hinged girder and cantilevers will demand special attention.
  - In the trend cards of the CW South the eigenfrequencies of the main hinged girder show a wide variance.
  - Increased damping values are recorder. In 2007 in the CW South, in 2008 in the CW North.
- The vibration intensity analysis reveals values in the field II and III in the CW North and South respectively. Because of the fact that the traffic was restricted during the measurement this indicates a high dynamic sensitivity of the structure.
- These conditions could lead an accelerated decrease of the structural service life in the long term.
- To this respect, the static system without redundancy could be problematic.
- In these conditions, damages to load bearing parts can cause a sudden collapse of the system

According to BRIMOS® classification the structure is rated as category B: „structures in good condition with local damages“.




**Cat. A:** good condition

**Cat. B:** good condition with local damage

**Cat. C:** problematic condition

- Immediate actions: NONE
- Short-term actions: NONE
- Mid-term actions: NONE
- Long-term actions: Permanent monitoring with real-time data analysis and automatic alarming in the case of changes in the behaviour
  Monitoring of the overall structural condition by periodic measurements with BRIMOS® every six years.

This approach assures the determination of slowly progressing processes in the structure leading to the deterioration of the operational integrity.

Thanks for your kind attention

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