# Short-term Automated Monitoring of the Danube Bridge in Sinzing


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## Summary


The short-term use of an automated monitoring system to record the movements of the "Donaubrücke Sinzing" motorway bridge over the River Danube close to Regensburg in Germany is presented. It had recently been observed that excessive wear of the PTFE sliding discs of some bridge bearings had occurred, and it was surmised by the responsible engineers that this resulted primarily from the frequent movements of the bridge deck, which could be observed when traffic passed over the bridge. It was decided to install an automated monitoring system in order to assess the actual movements of the bridge, with particular attention to total additive sliding distance over a period of time. This information would then be used to verify the theory that excessive movements had been responsible for the wearing away of the PTFE, and to specify sliding materials for use in a refurbishment project. The short-term nature of the proposed project, combined with the standard types of measurement required, made a very elegant solution possible: a portable, stand-alone monitoring system was fitted with the required sensors, configured and installed. Two weeks later the system was de-installed and the data downloaded for assessment. The system is re-usable and therefore relatively affordable – especially when a turnkey package of system rental combined with the required expertise for its use (including configuration, installation and data analysis) is offered by the system supplier. This report describes the project to supply and install the proposed monitoring system, and the evaluation of the recorded data.



**Keywords:** Monitoring, bridges, structures, measurement, forces, movements


Fig. 1 *The "Donaubrücke Sinzing" motorway bridge near Regensburg*

# 1. Introduction

A wide range of bridge monitoring solutions are available today, using modern technology to maximise the efficiency and accuracy of data collection for whatever reason it may be required on any particular structure. One of these solutions, recently installed on the “Donaubrücke Sinzing” motorway bridge in Germany for the short-term collection of data, is presented.

The bridge carries the German Autobahn No. 3 over the River Danube near the town of Sinzing (close to Regensburg), and is thus an important transport artery. It was observed by the bridge owner that the bridge moves significantly under normal traffic loading, and that the PTFE sliding material of a number of the bridge bearings had already been worn away to the point that it required replacement, as shown in Figure 2. This condition was reached after only five years of service, although PTFE sliding material can be expected to last at least twenty years under “normal” conditions. Therefore it was surmised that the unusually large movements of the bridge had resulted in the early wearing away of the PTFE.

Fig. 2 *Damage to PTFE of bridge bearings*

Rather than simply replacing the PTFE discs of the bearings, and expect the problem to repeat throughout the life of the bridge, the bridge owner decided to gain a fuller understanding of the movements and characteristics of the bridge, so that a lasting solution could be implemented, saving the effort and expense of replacing PTFE discs in the future.

# 2. Description of the bridge

The bridge has a total length of approximately 800m and consists of nine spans, stretching from the West Abutment to the East Abutment via eight pillars, as presented schematically in Figure 3.

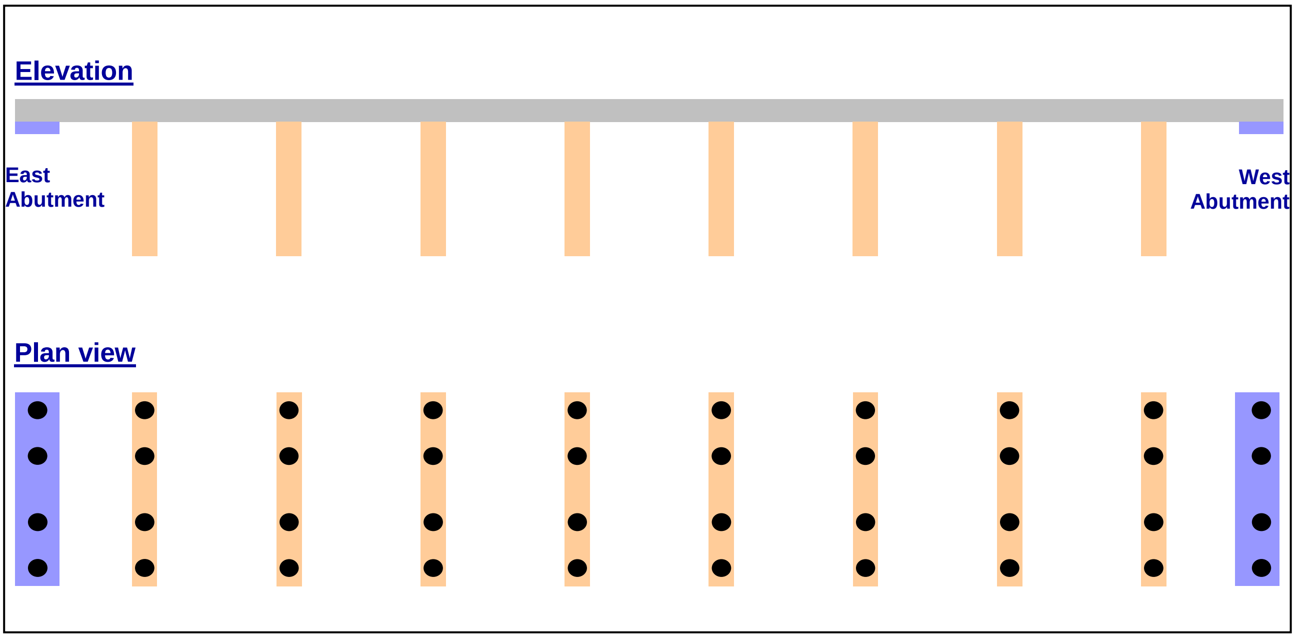


Fig. 3 *Schematic layout of the bridge*

The steel bridge deck is composed of two separate constructions, one for each carriageway of the motorway. Each of these consists of two large steel girders which span the gaps between the the abutments and pillars, and smaller transverse members between the girders. This construction is shown in Figures 4 and 5, which present views of the West Abutment from below.

Fig. 4 & Fig. 5 *Views of West Abutment*

Each girder is supported by a pot bearing at each abutment or pillar. These bearings are represented by large dots in Figure 2.

## 3. Problem statement

It had been observed during bridge inspections that the PTFE sliding material of a number of the bridge bearings had already suffered significant wear after only 5 years of service. However PTFE sliding material can normally be expected to last much longer. An attempt had already been made to solve this problem by replacing the sliding material with new PTFE discs, however the problem repeated itself within a few years.

It was also observed that the bridge moves significantly under normal traffic loading. Therefore it was surmised that the large movements of the bridge were responsible for the problem with the PTFE. A new sliding material, known as RoboSlide, a special high-grade polyethylene material which has been tested over a sliding distance of 60 km with no signs of abrasion, had newly become available, and it was anticipated that this would be a suitable sliding material, even giving the extreme movements of the bridge. However it could not be concluded that this change alone would result in a lasting solution. If the accumulated sliding distance of a bearing would significantly exceed 60 km over the life of the bearing, then an alternative solution such as the addition of dampers or strengthening members to reduce the bridge movements might also be considered. A monitoring system was proposed to gather information on the actual movements of the bridge and determine if the movements of the bridge were within the sliding distances that could be supported by the new sliding material. A similar solution has been concluded for a similar problem at the Ponte 25 de Abril in Lisbon [1].

## 4. Implementation of the proposed solution

### 4.1 Data requirements to be fulfilled by the proposed system

The following data requirements were identified, to assist in evaluating the movement characteristics of the bridge deck:

- Movement of the bridge deck - measured to an accuracy of 0.1mm
- Strain of the bridge deck girders
- Acceleration of the bridge deck – in all three principle directions
- Rotation of the bridge deck
- Temperature – both of the structure itself and ambient temperature

### 4.2 Layout of the proposed system

A system configuration as presented in Figure 6 was proposed.

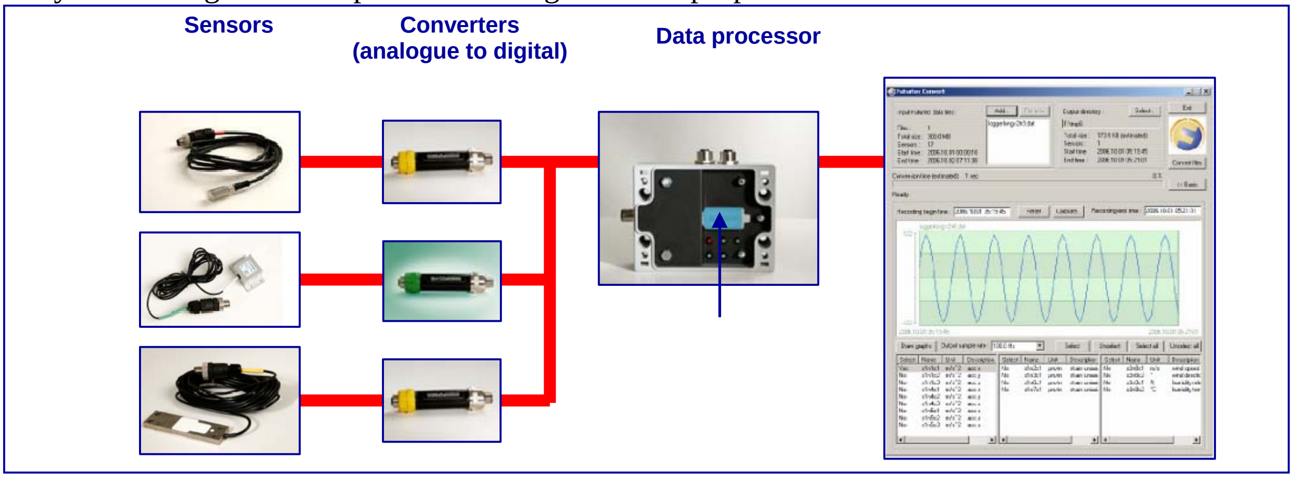


Fig. 6 *Configuration of proposed system*

The conversion of analogue data to digital format was recommended for the following reasons:

1. Digital data exhibits high resistance to electromagnetic fields (for example due to mobile telephones)
2. Information in digital format is secure in spite of changes in the resistance of the copper wire (for example due to variations in temperature)
3. Digital signals remain strong even over long cable lengths

The positioning on the bridge of sensors and other equipment to fulfil the data requirements described above was agreed upon, with consideration of local circumstances such as convenience of access, security, and length of cable runs, as well as suitability for desired results.

### 4.3 Equipment selected for use

Data logger

A 20 channel data logger as shown in the adjacent photograph was selected for use.

Memory

A 4-Gigabyte USB memory was provided to store the large amount of data which would be collected during the course of the work.

Analogue-to-digital converters

Analogue-to-digital T-node converters were selected to enhance security of data.
Sensors were then selected, with consideration of the required accuracy and range, as presented below.

Movement sensors

- Measurement unit: mm
- Accuracy: 0.01 mm
- Range: ± 300 mm

Strain gauges

- Measurement unit: µm/m
- Accuracy: 0.08 µm/m
- Range: 500 µm/m

Acceleration sensors

- ➢ Measurement unit: $mm/s^2$
- ➢ Accuracy: $1.5\ mm/s^2$
- ➢ Range: $\pm 39280\ mm/s^2$

Rotation sensors

- ➢ Measurement unit: milli-degrees
- ➢ Accuracy: 10 milli-degrees
- ➢ Range: ± 20000 milli-degrees

Temperature sensors

- ➢ Measurement unit: °C
- ➢ Accuracy: ± 0.1 °C
- ➢ Range: -55 - +125 °C

### 4.4 Installation of system and collection of data

The system, complete with battery power supply, was installed to collect data over a short period of time. Data was collected during three periods:

- From 04-09-2007 (15:09) to 05-09-2007 (13:20)
- From 20-09-2007 (15:20) to 21-09-2007 (12:59)
- From 23-09-2007 (15:10) to 24-09-2007 (13:40)

The system was removed after all required data had been collected.

This data is presented in Section 5 below.

## 5. Monitoring results

Sample graphs showing typical data from certain measurement periods are presented below with comments.

Figure 7 shows the measured longitudinal movement at three sensors (named N6, N11 and N12) during the first measurement period of 4th September to 5th September. The expansion due to daytime warming can be clearly recognised.

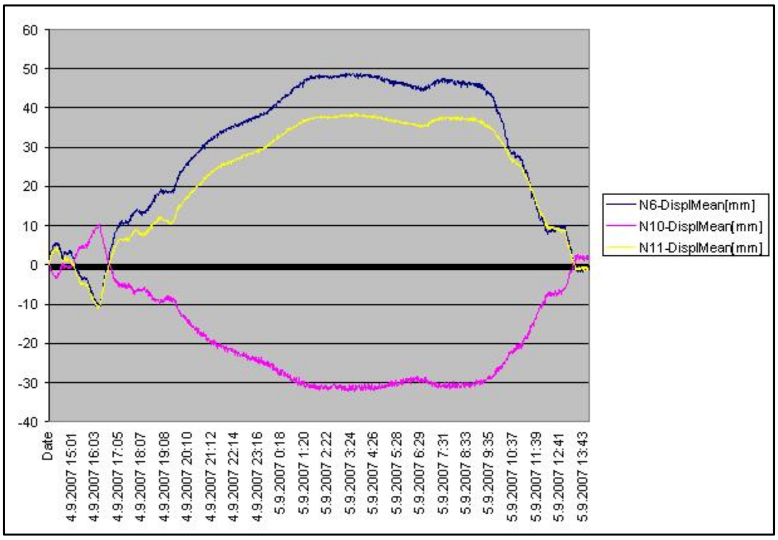


Fig. 7 *Longitudinal displacement at three sensor locations*

The total accumulated longitudinal movement on the bearings during this period was:

- Sensor N6: 5,226 mm
- Sensor N10: 5,000mm
- Sensor N11: 2,400 mm

Figure 8 shows the lateral movement at Sensor N7 during the same period.

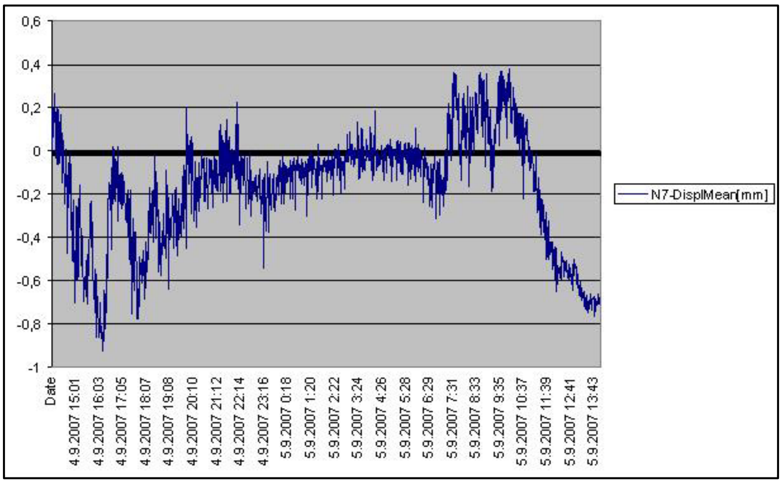


Fig. 8 *Transverse displacement at one sensor location*

The total accumulated lateral movement during this period was calculated from this data to be 1,485mm.

Figure 9 shows vibrations in the directions of the three principle axes (X, Y and Z) at one sensor location during the same first measurement period.

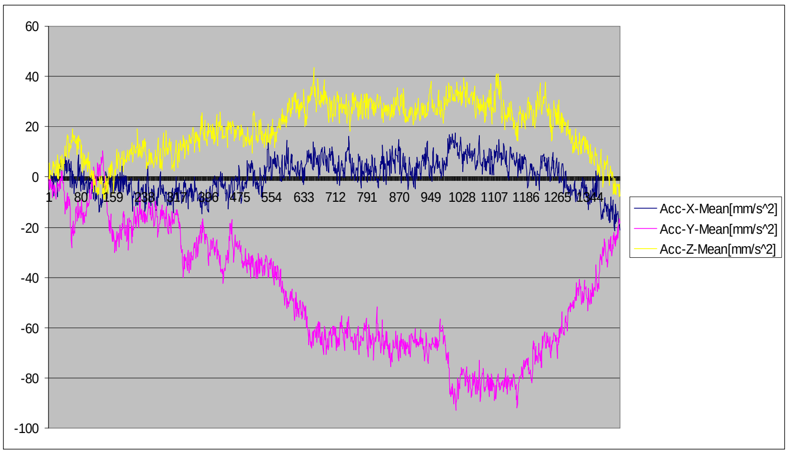


Fig. 9 *Vibrations in three directions at one sensor location*

Figure 10 shows inclination in milli-degrees at one sensor location period.

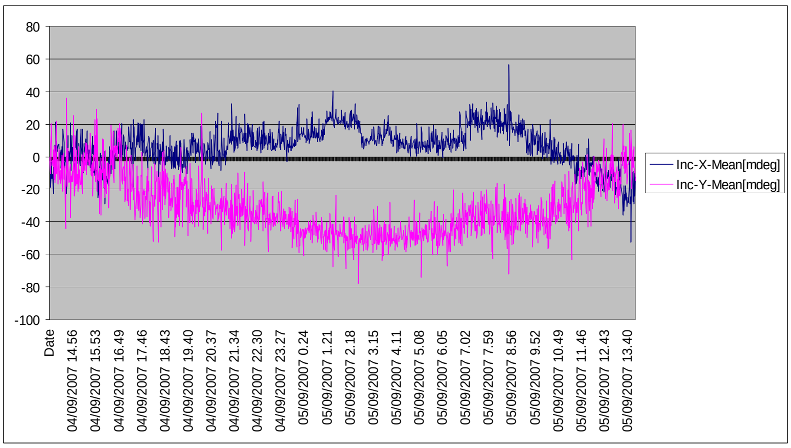


Fig. 10 *Inclination (used to measure rotation in two directions at one sensor location*

Figure 11 shows the correlation between longitudinal displacement and temperature at one location.

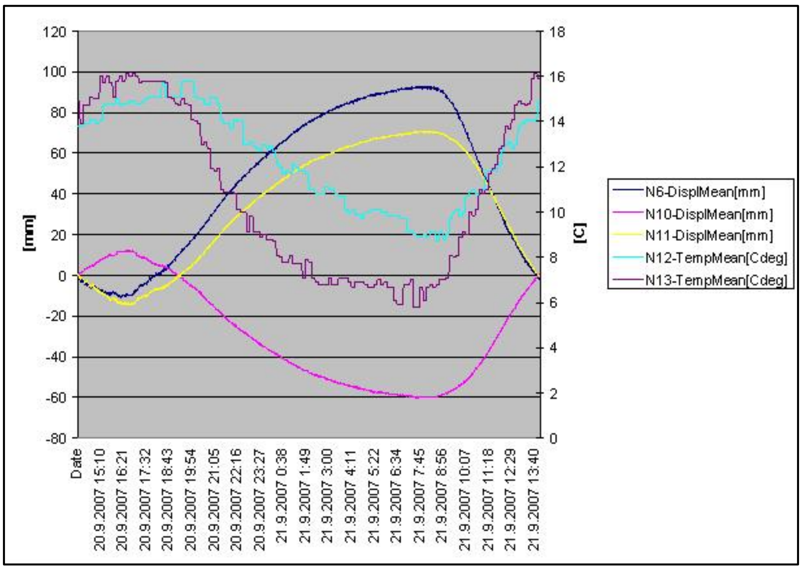


Fig. 11 *Correlation between longitudinal displacement and temperature at one location*

A clear correlation can be seen between longitudinal displacement and temperature during the measurement period.

Total accumulated movements during this period were as follows:

- Sensor N6: 6,350mm
- Sensor N10: 2,806 mm
- Sensor N11: 3,951 mm

## 6. Interpretation of results

The data recorded using this temporary automated monitoring system enabled the total longitudinal movement of the bridge deck over the bearings during the measurement periods to be calculated. It can be seen that longitudinal movements at one sensor of 6,350mm during a period of 22.5 hours were measured, which can be extrapolated to a total accumulated longitudinal sliding distance of 2,472m in a year. This means that total sliding movements of up to 12km had likely already occurred during the life of the bearings to date.

It is known that PTFE sliding material is susceptible to deterioration already after 10,000m, and no further exceptional conditions were observed at the bridge which could explain such early deterioration of the sliding surface material. Therefore it was concluded that the excessive movements of the bridge were indeed the primary cause of the wearing away of the PTFE discs.

Based on the results from the monitoring project it was decided to replace the sliding discs of the bearings with the new RoboSlide material, which not only exhibits far higher resistance to wear than PTFE, but also offers lower friction values. It can thus now be expected that the new sliding discs will perform well for the remaining life of the bearings.

## 7. Conclusions

A detailed understanding of the behaviour of the bridge, including the correlation between movements and temperature was obtained from this temporary and therefore relatively affordable monitoring system. A solution to the problem of excessive wear of the sliding materials of the bearings could be proposed based on this information, allowing the bridge owner to have confidence that the bearings will continue to function well for the foreseeable future.

## 8. References

[1] HOFFMANN S., BERGMEISTER K., „Long-term monitoring the bearings of the Ponte 25 de Abril in Lisbon", IABSE Congress in Weimar, Germany, 2007