# hbm application story

## Keeping an eye on the effects of heavy goods traffic: Long-term monitoring on a motorway bridge

Jan Peter Liebig
Olaf Menze

Institut für Massivbau
(Institute of Concrete Construction)
Faculty of civil engineering and geodetic science
Leibniz Universität Hannover

### Introduction

In order to investigate the effects of current heavy goods traffic on the load-bearing structures of a prestressed concrete box girder bridge, the Federal Highway Research Institute (BASt) commissioned the Institut für Massivbau (Institute of Concrete Construction) of the Leibniz Universität Hannover with structural measurements of the box girder structure of a bridge on the A8 motorway. The A8 runs in three segments from the Luxembourg to the Austrian border near Salzburg and is one of the main West-East connections in southern Germany.

The following questions needed to be answered: What effects do the increasingly greater total loads of the heavy goods traffic have? What conclusions can be drawn from the determination of the actual traffic compositions on the standard loading evaluations? Must recommendations for the updating of standards be drawn up?

### The test set-up

The bridge structure under investigated was a prestressed concrete bridge across four spans with two separate, single cell box-girders. A comprehensive monitoring system was installed on one of the box-girders. The measurements are implemented in three measurement cross-sections.
Component, internal and external air temperatures, concrete strain and relative deformation are measured in the measurement cross-sections MQ-1 (mid-span) and MQ-2 (coupling joint). MQ-2 also has two strain gages (SG) applied to the prestressed steel.

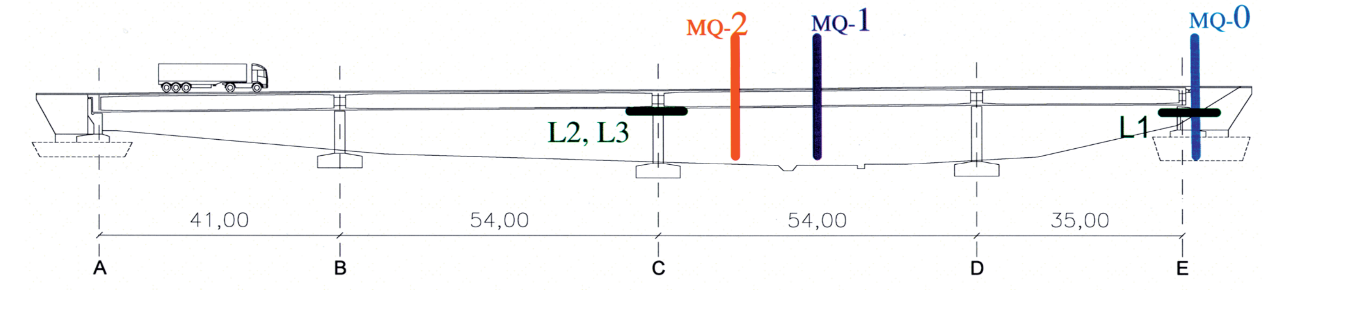


*Fig. 1: Longitudinal section with indication of measurement cross-sections*

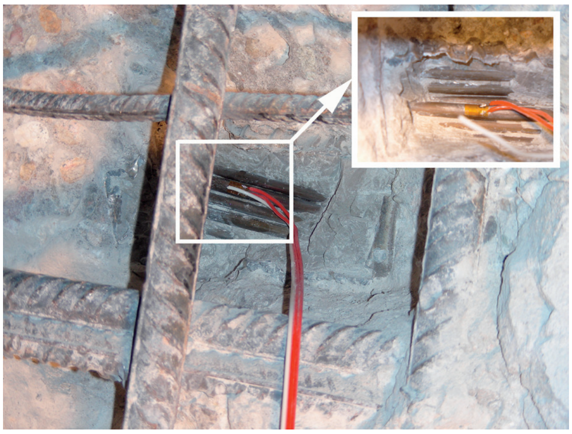

*Fig. 2: SG on the prestressed steel*

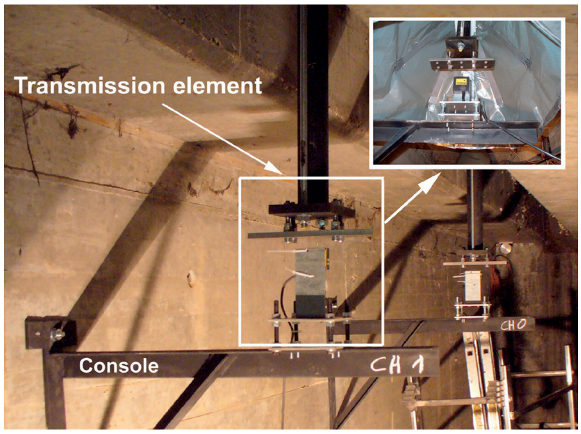


*Fig. 3: Deformation measurement in MQ-0 and weather protection*

The MQ-0 is set up for the determination of the traffic composition. The strain of the traverses and the deformation of the corresponding centre beam between the traverses were recorded at two points on the roadway joint (RJ):

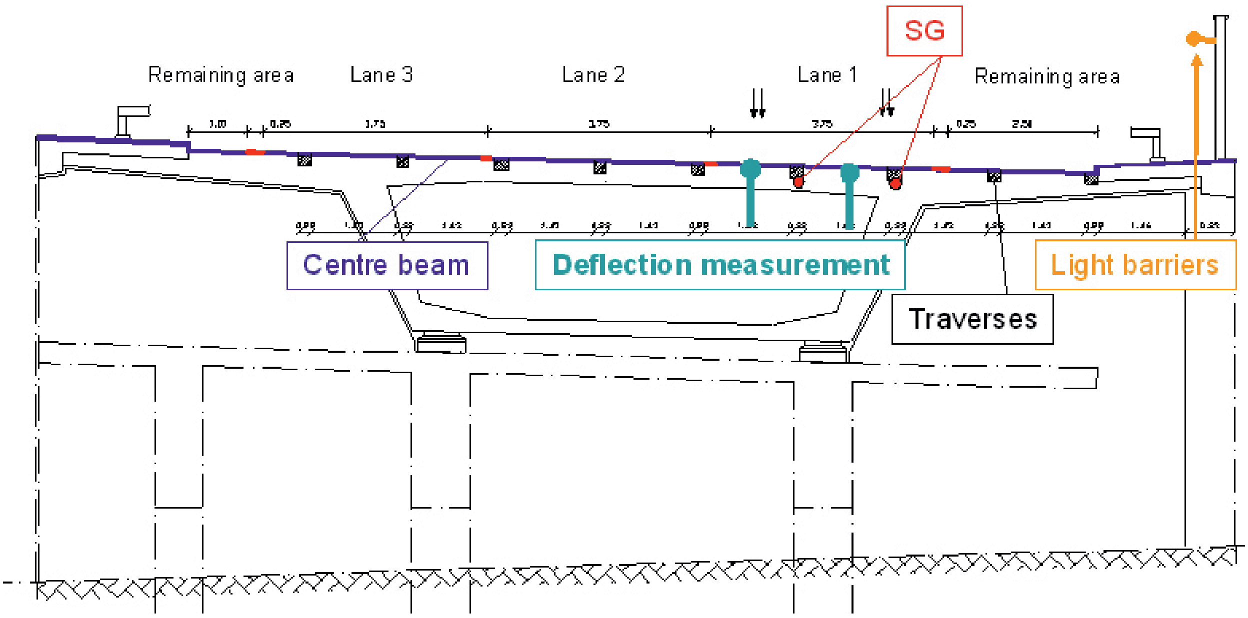


*Fig. 4: Arrangement of the sensors in MQ-0*

Due to the thermally-dependent structural deformations in the longitudinal direction and the lack of room in the area of the RJ, two transmission elements were attached to the centre beam of the RJ. This allowed the deflection to be shifted to the area of the abutments and measured there against a console on which a high resolution laser distance sensor was applied (see Fig. 3.)

The deformation and movement of pot bearings were recorded at the measurement points L1 to L3 for another project. Laser light barriers were mounted on the existing lateral noise protection walls to detect and determine the speed of heavy goods vehicles. This delivered additional measured values with which the positions of the HGV's in the lanes on the bridge could be determined.

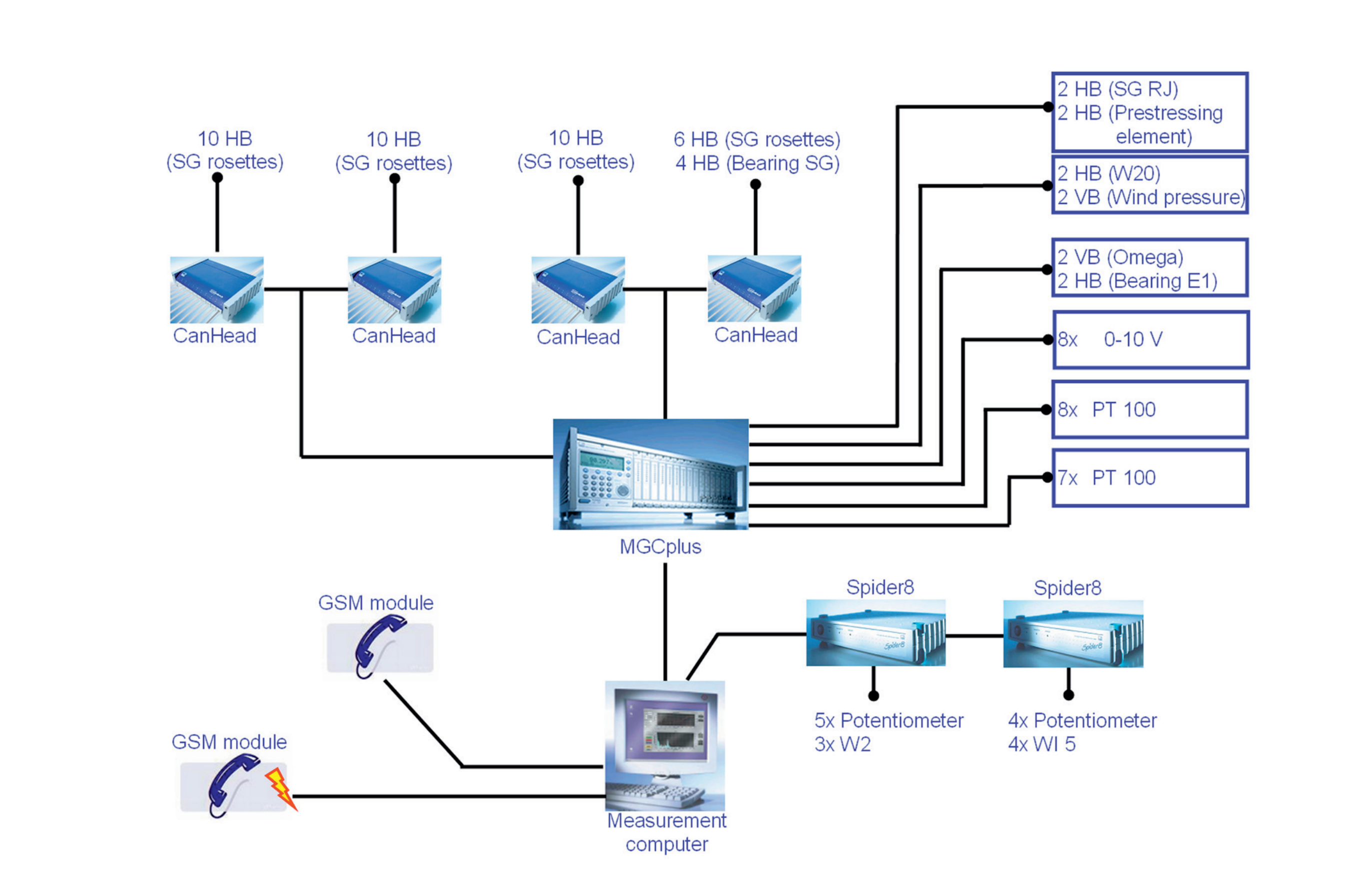


*Fig. 5:*
*Schematic layout of measurement system*

In total, the measurement system comprised 96 measurement channels. There were great distances within the structure between sensors and amplifiers. The CANbus system was used to bundle the various measuring points. Four CANHEAD modules with CB 1010 carrier-frequency amplifiers were used here. The measurement channels came together with various connection cards in the amplifier system MGCplus. DC modules, TF modules and connections for PT100 temperature transducers were combined in the MGCplus.

In addition to the MGCplus, two Spider8 amplifiers, connected in series to the measurement computer, were connected via the parallel port of the measurement computer. These carried out the deformation and movement measurements for the bearing bodies.

The measurement period was set for one year. As the measurement object is not in the vicinity of the Leibniz University of Hannover, it needed to be possible to monitor the measurements remotely and, where necessary, to influence them. Two GSM modules were integrated in the measurement system for this purpose. One module is used here for separate control of the power supply for the measurement computer and amplifier, the other for the online-monitoring of the measurements.

The measurement sensor signals are recorded in three measurement rate groups. A measurement frequency of min. 1200 Hz is required for the very short-term actuation of the RJ. Strains and deformations are recorded with 50 Hz and temperatures with 1 Hz.

The measurement data with a channel depth of around 100 million measured values runs to around 1.4 GB per day, so that regular monitoring of the system is necessary.

## Requirements for a long-term test

The measurement period of one year posed high requirements for the equipment and the settings of the measurement sensors. The measurement system was adjusted during a calibration process. The measurement ranges could therefore not be set too small, taking into account the necessary measured value resolution in order to avoid a drift in measurement sensor signals over the measurement range. In addition, great value was placed on the protection of the measurement equipment against weather influences. The sensors on the RJ needed to be protected against penetration of water and de-icing salts in particular as the RJ had become leaky in some areas during the time the structure has been in use. It was necessary to lay the prestressing steels bare at two points to measure the prestressing steel strains. These measurement points were then resealed once installation was complete. The applied SG's therefore also needed to be protected from moisture coming from the filler material. Overall, the measurement system had to be designed so that the individual sensors were not only protected against the weather but also appropriately protected against the vagaries of on-site measurements.

## MGCplus in use with CANHEAD modules

The decision to use the MGCplus was based on the number of measurement channels required. The MGCplus system made it possible, from the start, with the use of CANHEAD modules, to bundle numerous measurement channels and transmit data across greater distances. This measurement system also made it possible to bring together various sensor signals into an amplifier system due to the flexible use of plug-in cards. The combination of MGCplus and Spider8 was seen as most practical because the catman® software provides the possibility of combining various amplifiers.

## Installation characterized by weather conditions

The installation of the measurement system was particularly affected by the weather conditions. The test measurements carried out simultaneously with the installation led to continuous adaptation of the system to the local conditions. During the set-up of the measurement system, it became clear that the use of different amplifiers in mixed operation was possible but needed extreme attention and experience, which was helped by the technical support of HBM.

## Calibration of the measurement system

Following completion of all installation work and once all measurement procedures were running smoothly, the measurement system on the bridge was calibrated. Various heavy goods vehicle combinations with different total weights were driven over the bridge at different speeds for this purpose. The measurements during the calibration program were used to draw conclusions about the stress based on continuous traffic. Support was provided during this calibration program by Daimler AG in the form of a 25t flatbed truck, a 40t articulated lorry and a 60t vehicle combination based on modular commercial vehicle concept. The motorway bridge was closed to continuous traffic during calibration so that comprehensive measurement drives were possible.

## Initial test results

In parallel to the structural measurements, numerical investigations of the support structure were also implemented. Using the experience gained from prior investigations on other bridge support structures [3], the support structure was depicted in a complex finite element model.

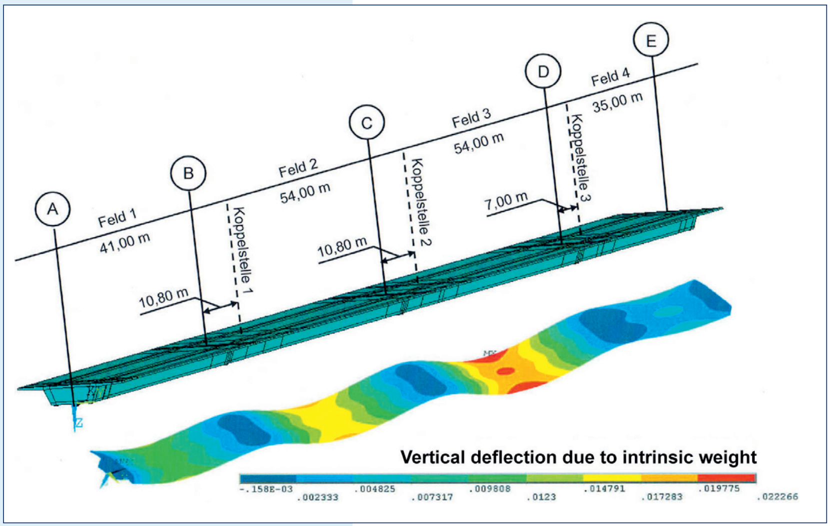


*Fig. 6:*
*FE model of box support structure*

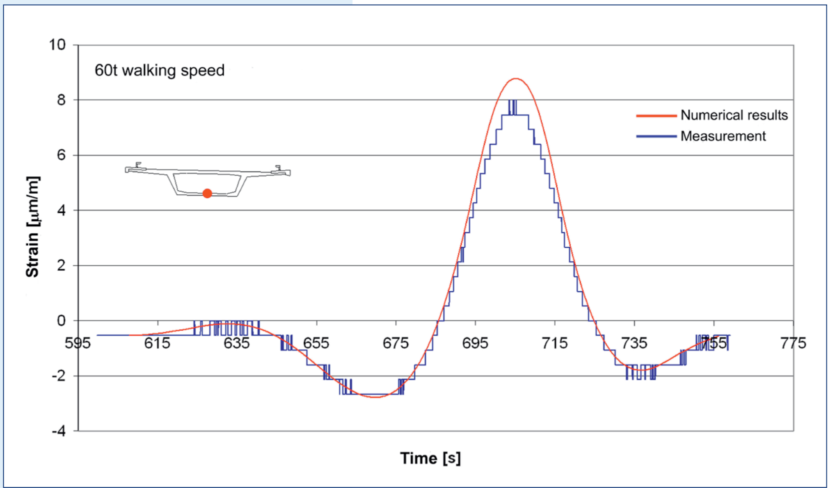


*Fig. 7:*
*Comparison of measured longitudinal strain in the base plate in MQ-1 with the results of the FE calculation*

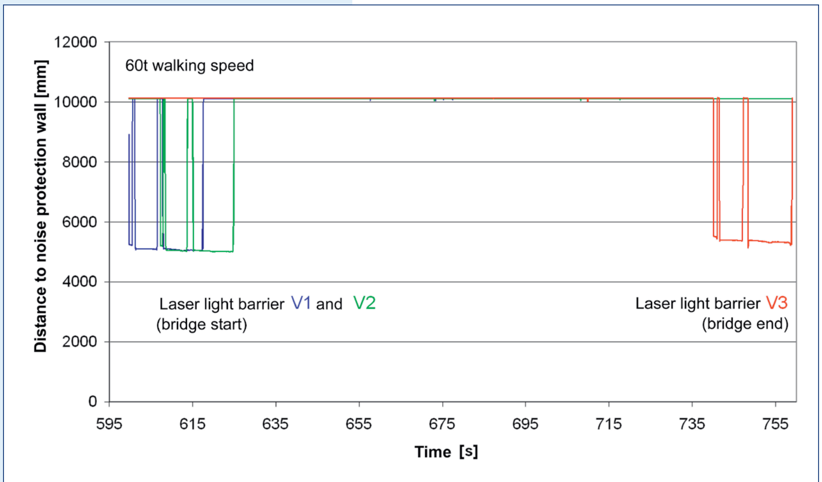


*Fig. 8:*
*Measurement signals of the laser light barriers*

This model takes into account all geometric relationships of the support structure which are also reflected in the measured values via the support structure rigidity. Comparison calculations for individual calibration drives were implemented with this model.
As an example, the measured values from the calibration drives are shown here for the passage of the 60t vehicle combination based on modular commercial vehicle concept at walking speed and compared with the corresponding results of the FE calculation.

Figure 7 shows the curves for the measured and calculated base plate longitudinal strains in MQ-1. The recorded measured values confirm the results of the numerical calculations. The HGV itself was recognized by the measurement signals of the laser light barrier.

The light barriers V1 and V2 are mounted at the start of the bridge and serve mainly to determine the speed. Light barrier V3 is installed directly before the RJ and indicates the position of the HGV in its lane via distance measurement. This is necessary to estimate the measured deformation of the RJ from the acting axle loads at a later point. At the same time, the silhouette of the vehicle can be determined, dependent on the speed, from the measurement curve. In the case shown in Figure 8, the passage of the 60t vehicle combination, the flatbed truck (with driver's cabin) and semi-trailer can be clearly recognized.

An excerpt of the measurement curve for the deformation measurements on the RJ, related to the passage of an articulated lorry, is shown in 9.

Based on the significant deflections, conclusions can already be drawn about the type of vehicle and the approximate loading condition in the initial evaluation.
In total, this is a comprehensive measurement system whose measurement results confirm the numerical comparison calculations. The number of measurement channels enables an intensive and comprehensive investigation of the support structure.

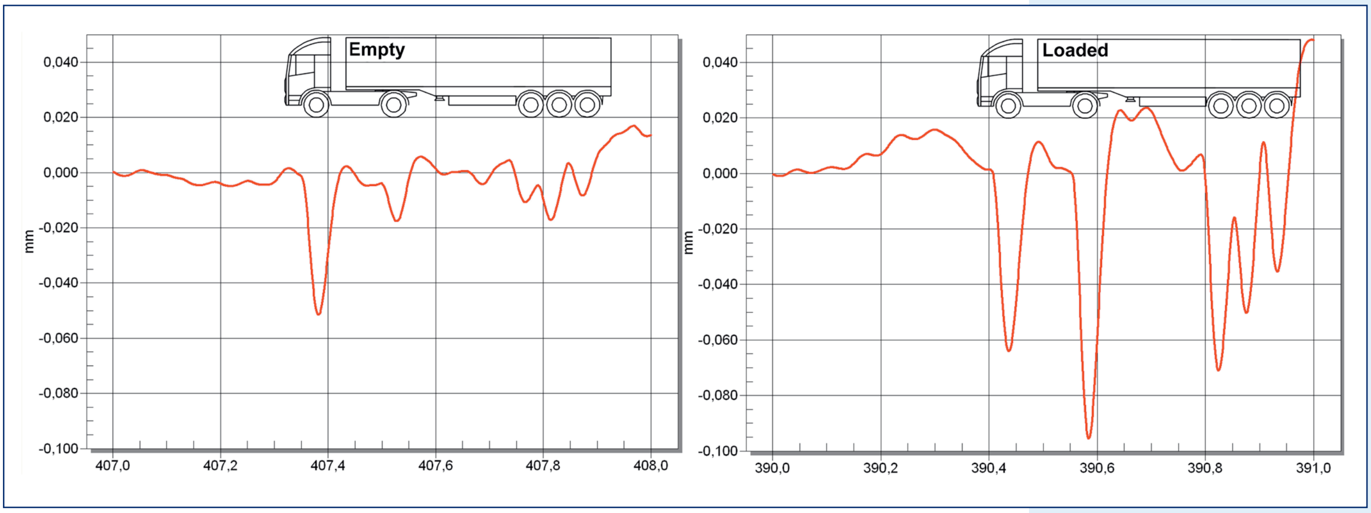


*Fig. 9:*
*Deformation measurement on RJ, depiction of measured value curves for HGV with various loads*

Literature

[1] Grünberg, J.; Hansen, M.; Liebig, J. P.: Auswirkung des Schwerverkehrs auf Brückenbauwerke, BASt FE-Nr. 15.395/2004/HRB, Leibniz University Hannover, Intermediate report 1, October 2008.

[2] Liebig, J. P.; Grünberg, J.; Hansen, M.: Monitoring von Spannbetonbrücken - Auswirkungen zunehmenden Schwerverkehrs, Beton- und Stahlbetonbau 104, Issue 6, Ernst & Sohn Verlag, Berlin 2009.

[3] Grünberg, J.; Hansen, M.; Liebig, J. P.: Ermüdungsbeanspruchungen von Betonbrücken unter zunehmenden Schwerverkehr, Beton- und Stahlbetonbau 102, Issue 9, Ernst & Sohn Verlag, Berlin 2007.

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**HBM GmbH**

**www.hbm.com** **Tel. +49 6151 803-0**
**E-Mail: info@hbm.com** **Fax +49 6151 803-9100**