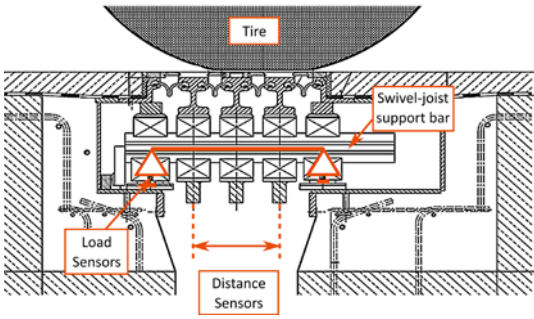
Expansion joint and bearings determine traffic load and monitor bridges

New MAURER measuring and evaluation systems are integrated in common bridge components.

Munich. **Real-time monitoring of bridges without on-site inspection is becoming increasingly feasible. Within the framework of the 'Digital Test Field Highway (DTA)', MAURER SE develops and operates measuring systems in two spherical bearings and one expansion joint – the small word 'in' being the operative word: various sensors are integrated in the components that have to be installed in almost any larger bridge.**

The instrumented components, among others, are part of the current pilot project 'Intelligent Bridge in the Digital Test Field Highway' of the Federal Ministry of Transport and Digital Infrastructure (BMVI). Federal Highway Research Institute (BASt) performs the project. The MMS Spherical Bearings and the MMS Expansion Joint (MMS for MAURER Monitoring System) have been developed over years and installed in a newly built replacement bridge at the highway junction Nuremberg (structure BW402e) in 2016. "The expansion joint and two bearings at axis no. 40 have successfully passed their first field test," reports MAURER project manager Dr.-Ing. Christiane Butz. "There is a continuous flow of data which are automatically evaluated."

Below, expansion joint and bearing are approached separately although naturally they mate in the project.



Positioning of the sensors at the MMS expansion joint.

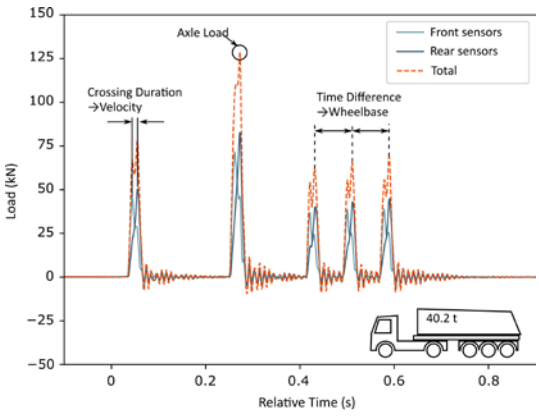
Graphic: MAURER

Swivel joist expansion joint classifies vehicles

Although not completed yet, the expansion joint project has already achieved its key goal: the MMS expansion joint is capable of classifying vehicles in real time. Starting point was the consideration that expansion joints are very well suited for measuring traffic loads since they have direct contact with the vehicles and are installed in almost any larger bridge. The new feature: all relevant data (speed, load, and time) are captured at the very same spot.

For vehicle classification, the peaks are singled out from the total load signal of every traffic lane, for they mark the contact with the tires. After the relevant data for each axis have been evaluated, the axis data are grouped and the vehicle type is determined based on axis arrangement and axial load. This corresponds to the function of a weighing device with an accuracy of presently about ± 10 % of the axial loads.

In total, the data allow for a relatively precise determination of the traffic loads and, among other things, can be used for maintenance management of the bridge.



Determination of vehicle parameters from the measuring data of the MMS expansion joint, taking a 5-axis trailer truck at 60 km/h as an example.

Graphic: MAURER

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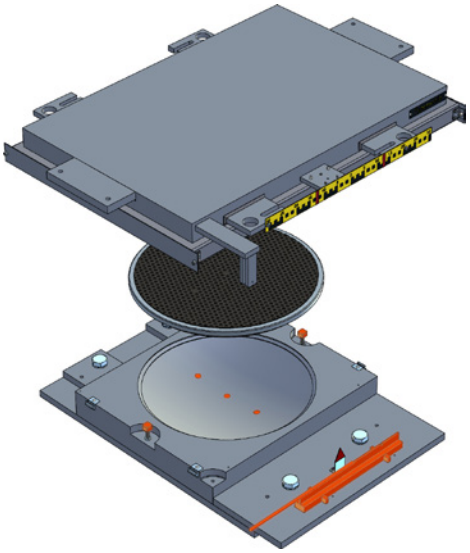
The MMS expansion joint has been developed from a four-profile watertight MAURER Swivel joist expansion joint. Its special features in detail:

- Weighing cells inside the bearings at both ends of each joist allow for precise localization of the load center of a tire on the expansion joint.
- The lamellas are segmented in longitudinal direction, thus reducing the interaction of the signals from different traffic lanes.
- The elastomeric seals are arranged in such a manner that the expansion joint remains watertight although segmented.
- Rhomboid sheets welded onto the lamellas reduce noise emissions and ensure a more regular force progression under crossing tires.
- Bowden cable sensors measure the distance between the first and third lamella and deliver the effective gap width or displacement, respectively.
- Acceleration sensors give insights into the vibration behavior of the lamellas.

The total signal evaluation technology is installed in a control cabinet at the bridge.



The measuring points inside the MMS Spherical Bearing.

Graphic: MAURER

Calibration rides allow for the calculation of dynamic correlations

The deviation of the measured load and speed values from the real values of the vehicles crossing the bridge presented a challenge. The reasons are dynamic correlations between tire and expansion joint as well as speed-dependent vibration of the expansion joint after each crossing.

In order to evaluate and computationally compensate these dynamic effects, calibration rides with two different defined trucks were carried out in September 2016 and April 2018: one 3-axis dumper (total weight 27.7 t) and a 5-axis trailer truck (40.2 t). The tests were run at 5, 30, 60 and 90 km/h.

Moreover, a numerical simulation model was built capable of reproducing the dynamics of vehicle and expansion joint and their correlation. With this model, calibration rides can now be carried out virtually and the results enable an even better analysis. "The better we understand coherences, the more accurate are the results delivered by our expansion joint, which means: the measured values are adjusted more precisely", explains MAURER development engineer Dr.-Ing. Daniel Rill. "Now the fine-tuning of the result evaluation is an issue in the expansion joint project."

MMS Spherical Bearings deliver a 3-stage monitoring

The primary result of the bearing project is that the intelligent MMS Bearings – besides their proper bearing function – cover three monitoring areas in addition:

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- determination of traffic loads,
- monitoring of the bridge and
- self-monitoring of the bearing.
  (Please note: the expansion joints are self-monitoring as well.)

Bearings are essential elements of many large bridges, which directly respond to many changes in the bridge condition. Therefore, measuring and analyzing these responses is ideal for obtaining information on the bridge condition. The success achieved by the project: the resolution of the measured signals is so high that the traffic load can be derived from these signals. The bearings function as a B-WIM system (Bridge Weigh-in-Motion).

The two MMS Spherical Bearings are equipped with sensors: bearing 40/1 with pressure sensors for load measurement, bearing 40/3 in addition with path sensors for rotation, sliding gap, and relative displacement. The described truck calibration rides were planned and carried out in such a manner that the data collected could also be optimally used for bearing evaluation.

With the help of an evaluation algorithm, quasi-static and variable vertical bearings loads, bearing displacement and rotation are identified based on the bearing data. In this way, traffic loads can be precisely measured at regular speeds of 80 to 90 km/h with an accuracy of ± 10 %.

In addition, the bearings deliver the natural frequencies of the bridge.

Monitoring with a view to the future

As a next step, better compensation algorithms are to be developed through in-depth analysis of the main influencing factors to make the measuring results even more convincing. Through understanding of the correlation between bridge condition and traffic effects, more accurate models for condition prognosis could be developed. This would enable a more efficient and economic maintenance management of the bridge infrastructure.

The BMVI financed pilot project 'Intelligent Bridge in the Digital Test Field Highway' is part of the projectcluster 'Intelligent Bridge' of the BASt that belongs to the National Highway Innovation Program. The MMS Spherical Bearings and the MMS expansion joint were built in the new replacement structure BW402e (motorway interchange Nuremberg) by the highway directorate of Northern Bavaria. The successes of the project also result from the good and constructive cooperation of the project partners.

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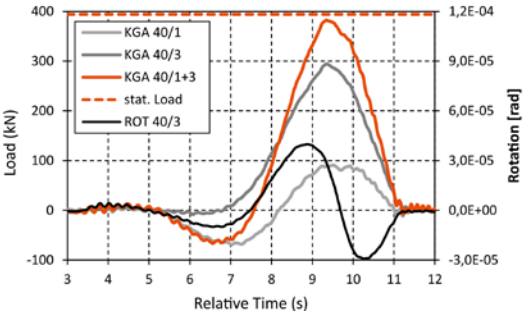

Loads and distortions at the MMS Spherical Bearings, measured upon crossing of a 5-axis trailer truck at 90 km/h.

Graphic: MAURER

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Quick facts about MAURER SE

The MAURER Group is a leading specialist in mechanical engineering and steel construction with over 1,000 employees worldwide. The company is market leader in the area of structural protection systems (bridge bearings, expansion joints, seismic devices, tuned mass dampers, monitoring systems). It also develops and produces vibration isolation of structures and machines, roller coasters and ferris wheels as well as special structures in steel.

MAURER participates at many spectacular projects worldwide, like for example the world's biggest structural bearings for the Signature Bridge in Wazirabad, Delhi, earthquake resistant expansion joints for the Bosporus bridges in Turkey, semi-active tuned mass dampers for the Danube City Tower in Vienna, or uplift bearings for the Zenit-Football-Arena in St. Petersburg. Among the most prestigious steel structures are the BMW World in Munich or the Terminal 2 of Munich Airport. MAURER's most spectacular amusement rides include the world's biggest transportable Ferris wheel hi-Sky in Munich, the Rip Ride Rockit Roller Coaster in the Universal Studios Orlando or the Fiorano GT Challenge in Abu Dhabi.

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