

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 more and more feasible. Within the framework of the 'Digitales Testfeld Autobahn - DTA' (Digital Test Field Highway), MAURER SE develops and operates measuring systems in two spherical bearings and one expansion joint – the small word 'in' being the decisive word: Various sensors are integrated into components that have to be installed in almost any larger bridge.

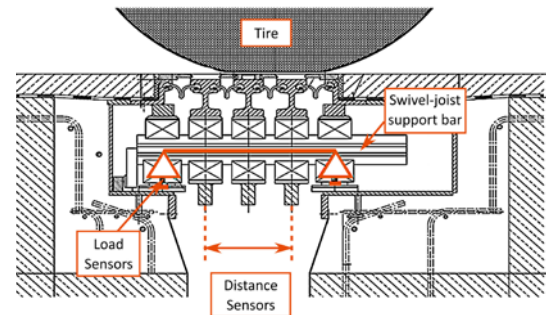
The sensor-equipped components are, among others, a part of the current pilot project 'Intelligente Brücke im Digitalen Testfeld Autobahn' (Intelligent Bridge in the Digital Test Field Highway) of the German Federal Ministry of Transport and Digital Infrastructure (BMVI), which is coordinated by the Federal Highway Research Institute (BASt). The MMS Spherical Bearings and the MMS Expansion Joint (MMS for Maurer Monitoring System) have been developed over the years and were installed within a newly built replacement bridge at the highway junction Nuremberg (structure BW402e) in 2016. "The expansion joint and the two bearings at axis 40 have successfully passed their first field test", reports MAURER project manager Dr.-Ing. Christiane Butz. "Data flows continuously, which is evaluated automatically."

In the text below, the expansion joint and the bearings will be discussed separately, although they are researched together in the project.

Swivel Joist Expansion Joint Classifies Vehicles

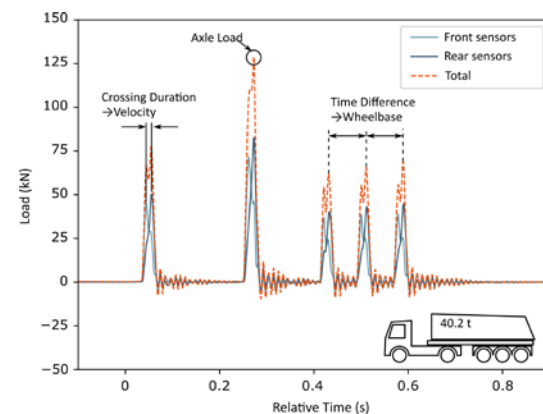
Although not completed yet, the expansion joint project has already achieved its key goal: the MMS Expansion Joint is capable of classifying vehicles in real time. Expansion joints are very well suited for measuring traffic loads since they have direct contact with the vehicles and are present in almost any larger bridge. The new feature: All relevant data (speed, load, and time) is obtained at the same location.

For vehicle classification, the peaks are singled out from the total load signal of every lane, as they mark the contact with the tires. After the relevant data for each axle has been evaluated, the values of the individual axles are grouped and the vehicle type is determined based on axle configuration and axle load. This corresponds to the function of a Weigh-In-Motion device with presently an accuracy about 10% of the axle loads.



Location of sensors in the MMS Expansion Joint.

Graphic: MAURER



Determination of vehicle parameters from the measurement data of the MMS Expansion Joint. Example shows a five-axled truck at 60 km/h.

Graphic: MAURER

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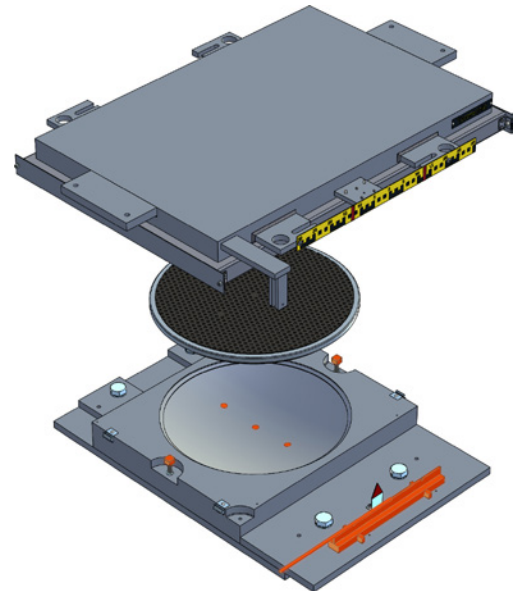
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In total, the data allows for a relatively precise determination of the traffic loads and, among other things, can be used for maintenance management of the bridge.

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

- Load 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 lamellae are segmented in longitudinal direction, thus reducing signal interference from the different traffic lanes.
- The elastomeric seals are arranged in such a manner that the expansion joint remains watertight although segmented.
- Rhombic plates welded onto the lamellae reduce noise emissions and ensure a smoother force distribution of the crossing tires.
- Draw wire 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 lamellae.

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



Location of Sensors in the MMS Spherical Bearing.
Graphic: MAURER

Calibration runs allow for the calculation of dynamic correlations

The deviation of the measured loads and speed values from the real values of the vehicles crossing the bridge presented a challenge. The reasons are dynamic interactions 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 runs with two different trucks with defined parameters were carried out in September 2016 and April 2018: One 3-axle dump truck (total weight 27.7 t) and a 5-axle trailer truck (40.2 t). The tests were run at 5, 30, 60 and 90 km/h.

Moreover, a numerical simulation model was developed, capable of reproducing the dynamics of the vehicle and the expansion joint and their interaction. With this model, calibration runs can now be carried out virtually and the results enable an even better analysis. "The better we understand the interrelations, the more accurate are the results delivered by our expansion joint. Which means that the measured values are corrected more precisely", explains MAURER development engineer Dr.-Ing. Daniel Rill. "Now the fine-tuning of the result evaluation is the focus of the expansion joint project."

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MMS Spherical Bearings deliver a 3-stage monitoring

The primary result of the bearing project is that the intelligent MMS Bearings cover three levels of monitoring besides their proper function as bearings:

- determination of traffic loads
- monitoring of the bridge and
- self-monitoring of the bearing.

(NB: 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. One achievement of the project is, that the resolution of the measured signals is high enough to derive the traffic load from these signals. So, the bearings function as a B-WIM system (Bridge Weigh-in-Motion).

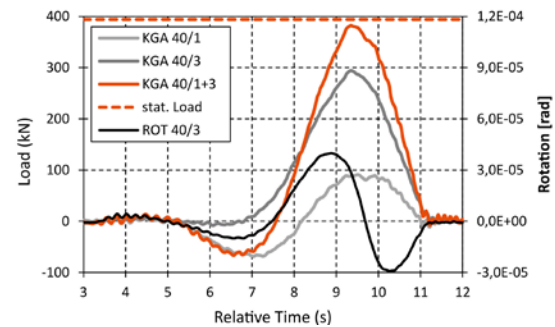
The two MMS Spherical Bearings are equipped with sensors: bearing 40/1 with pressure sensors for load measurement, bearing 40/3 also with position sensors to determine rotation, sliding gap, and relative displacement. The described truck calibration runs were planned and carried out in such a manner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

Quasi-static and fluctuating vertical loads, displacement and rotation are identified based on the bearing data with the help of an evaluation algorithm. Through this evaluation algorithm, traffic loads can be measured at regular speeds of 80 to 90 km/h. with an accuracy of $\pm 10\%$.

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 meaningful. By understanding 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.



Loads and rotation of MMS Spherical Bearing, measured during the crossing of a five-axled truck at 90 km/h.

Graphic: MAURER

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The BMVI financed pilot project 'Intelligente Brücke im Digitalen Testfeld Autobahn' (Intelligent Bridge in the Digital Test Field Highway) is part of the project cluster 'Intelligente Brücke' (Intelligent Bridge) of the BAST that is part of 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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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 Bosphorus 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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