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„Vibration-reduction in concrete pavements
by optimization of the slab geometry“

## Short Report

The dimensions of concrete pavement slabs are based upon experience. Due to this prevention of shrinkage cracks, temperature fluctuations, lane width and loading are the primary basis for determining the slab dimensions. All common design methods are based on a quasi-static, mainly empirical consideration of occurring loads.

This research project investigates whether concrete pavement slabs are forced to oscillate by traffic. Furthermore, it analyzes how the energy brought into the roadway can lead to various damages of the roadway surfacing. . The length of the plate is especially important in this investigation.

For detecting realistic acceleration data, a measurement point was installed on the German highway A 5, southbound, between the motorway interchange ‘Heidelberg’ and the exit ‘Heidelberg-Schwetzingen’. The design of the roadway surfacing consists, according to the RStO 12 table 2, line 1.2, of a 27 cm thick concrete slab on a 20 cm thick solidification layer with fleece liner.

For the first time, accelerometers were used to detect the system behavior.

Since the measuring point on the highway is highly frequented (DTV 88079 veh/d; 11.3% heavy traffic [SVZ 2009]), the reaction of the deck to the currently existing truck traffic may be measured at any time. In addition to these measurements, measurements with a vehicle of known dimensions, defined loading weight and defined tire pressure have been executed. For this purpose, a two-axle truck (Mercedes Benz Axor) was used. The maximum possible loading weight was used for testing, leading to an axle load of 8.64 t on the back and 7.42 t on the front axle.

To be able to make statements about the oscillation behavior of the concrete slab, the power-density spectra were determined both from the measured acceleration data, as well as from the deflection data of the slab. This way, continuous vibrations and resonance effects can be detected based on accompanying excessive energy densities within the associated frequency band. Visual checks and an evaluation of the frequency spectrum allowed to recognize several defective sensors, which were excluded from further analysis.

The analysis of the peak values of the accelerations of the slab showed a small number of values with a very large amplitude. In this case, also the mean value deviates from zero. The analysis of the power density of the acceleration and deflection values showed an accumulation of the spectral energy distribution ranging from 30 to 50 Hz, which then falls exponentially. An excessive frequency, which would favor the occurrence of a static oscillation mode or a modal oscillation waveform could not be recognized. Thus, the hypothesis of a dynamic vibration behavior of the slab cannot be confirmed. A harmonic oscillating behavior or post-pulse oscillation of the slab is prevented by the very strong damping of the system.

During the evaluation of the measured data statements could be made about various improvement possibilities relating to the choice, number and placement of sensors, the detailed design of the measuring point and of additionally measuring units, which would be useful for the calibration of the measurement systems.

For the numerical simulation of the vibration characteristics a three-dimensional finite element model was created with the FE program ADINA. The slab was modeled of 8-node elements resting free on the layer below, with the possibility of lifting of the slab from the subgrade. Symmetry effects could not be used within the modeling, so that the entire slab had to be modeled. In order to better reflect the approximation of the load to the joint and the slab transition, a part of each of the neighboring plates was modeled before and behind the main slab and connected using dowels.

Using drill samples the real material properties and layer thicknesses were determined and the FE model was adjusted accordingly. In contrast to the static calibration of the system, for which reliable calculation methods were used, the dynamic calibration could not be calculated in the same manner because there is no existing numerical solution. Consequently, the measured data were used here. The real excitation of the slab, caused by a truck driving over it, cannot be reproduced exactly as this is a dynamic multi-mass oscillator. The correspondingly induced load fluctuations were considered in a simplified way by assuming a normally distributed variation in the load of 10% of the axle load.

In simulations with different plate lengths the impact they have on the relative movements of the plate edges at the joint during load transition from one plate to the other was examined. An increase of the relative movement with increased plate length could be observed, especially for plate lengths of more than 5 m. In contrast, the influence of the system damping on the deflection behavior turned out to be insignificant. Overall, the deflection behavior of the deck slab is very strongly influenced by the properties of the substructure or the subgrade.

A swing of the plate over their initial position was never recorded. However, through the very high speed of the rebound movement of the unloaded plate edge, there is a slight lift between the underside of the slab and the surface of the subgrade. This is evidence towards the theory of pumping and the associated substance migration into the so-formed cavities.