Long-term health monitoring of pavement deformations on an expressway

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Summary

The increasing traffic density and increasing axle loads on highways requires an efficient road maintenance. Within a long-term project over 10 years load and pavement deformations on a heavily travelled expressway are measured. A newly developed sensor based on the magnetostrictive principle measures the vertical deformations within the pavement layers in parallel to existing inductive sensors. Short-term data of the two different systems and long-term data of the new sensor over a one year period are presented and further improvements discussed.

1. Introduction

Higher traffic frequencies and higher axle loads in conjunction with seasonal influences as temperature cycling, ice and (salt)water increase the load on the highway pavements. The deterioration of the pavement accelerates. Better understanding of the deterioration process allows to optimise maintenance and to improve the durability of the pavement. In situ measurement of important parameters are essential to verify models of the deterioration process. Some studies and measurements are described in [1, 4]. Beside the knowledge of the vehicle weight and the traffic frequency, which are measured with a weigh-in-motion-system (WIM), the knowledge of the vertical deformations within the pavement layers are of interest. On the heavily travelled Swiss expressway between Zürich and Bern with approx. 300 trucks per hour a long-term measurement system was installed in order to record loads, traffic frequencies, pavement deformations and temperature [5]. This paper is focused on the deformation measurements. Of interest are the short-term elastic deformations as well as the long-term plastic deformation of the pavement. Since an existing inductive displacement sensor system deteriorated due to the harsh environment a new hermetically sealed sensor system based on the magnetostrictive principle was additionally installed. The principle of the new sensor relies on the measurement of the velocity of sound in the sensor rod. Beside the mentioned environmental conditions the replacement of the displacement sensors has to be simple, safe and fast [2, 3].

2. Measurement set up

To measure the deformations within the pavement and between the different pavement layers two systems of displacement transducers were installed. Figure 1 gives a overview of all measuring points including WIM and additional temperature sensors (T). Parallel to the existing system (D1 to D3) with inductive transducers a contactless working magnetostrictive based displacement sensor (W1) was installed. This sensor is able to measure simultane ously up to four positions along one measuring axis in different layers of the pavement. It contains a additional temperature sensor in the head.

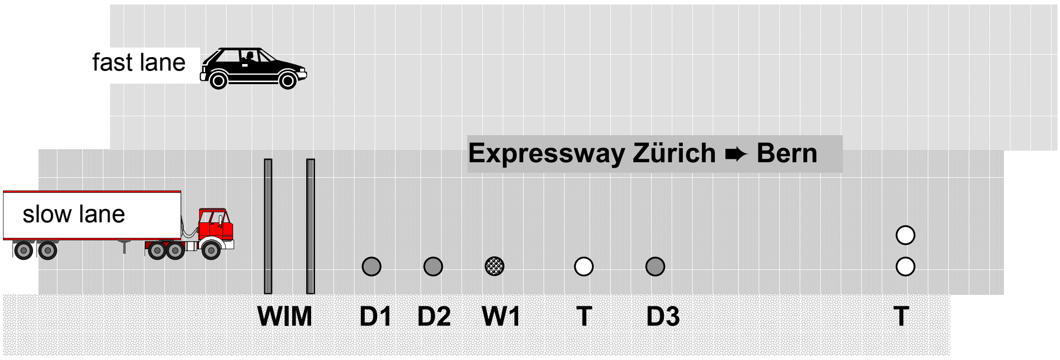

Figure 1: Overview of all measuring points on the test site

One advantage of the new sensor is the measurement of all displacements along one axis in all layers of the pavement. Figure 2 shows a schematic cross section of the two different displacement sensors installed on the test site.
The displacement sensors are single point sensors and therefore the measured amplitude depends on the position of the wheel (see chapter 3.1).

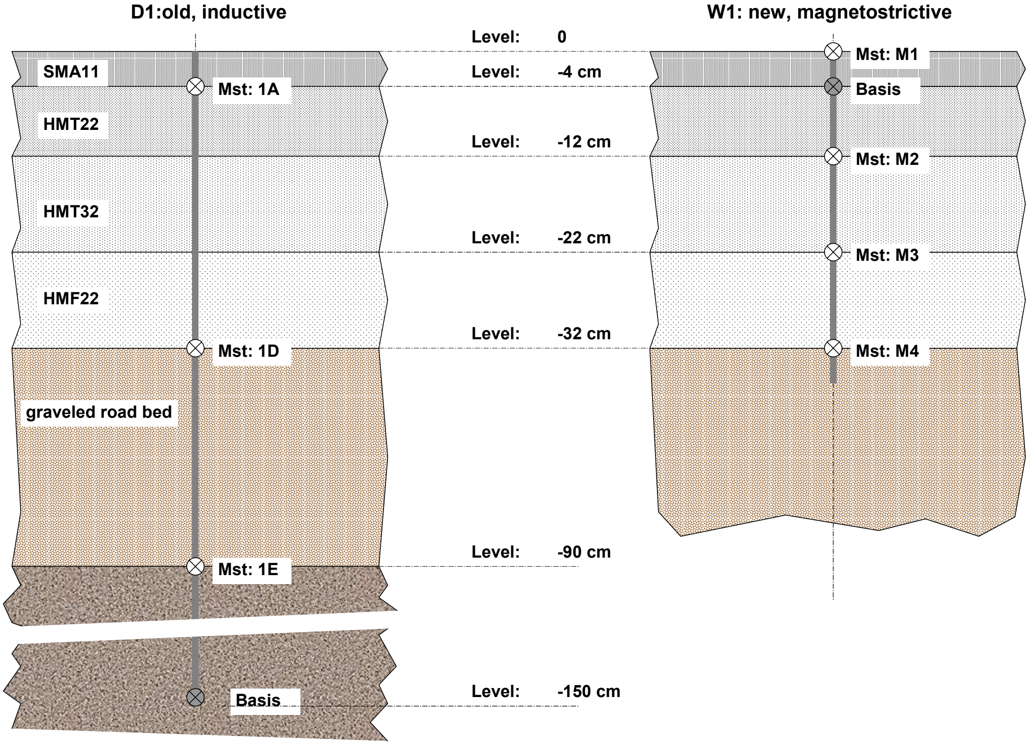

Figure 2: Schematic cross section of the installed displacement sensors

3. Measurement results

The measurements can be divided into measurements of the elastic deformation and those of the plastic deformation. Elastic deformation measurements show the reversible compression of the pavement as caused by passing trucks. Plastic deformation measurements show the irreversible long-term behaviour of the pavement layers.

3.1 Short-term results

Measurements with both sensor systems were performed during regular traffic (random traffic loads). Figure 3 shows the records of a 4-axle vehicle measured with sensor D1. Similar results are obtained with the magnetostrictive sensor. The measurements show a local indentation of the whole pavement into the graveled road bed.

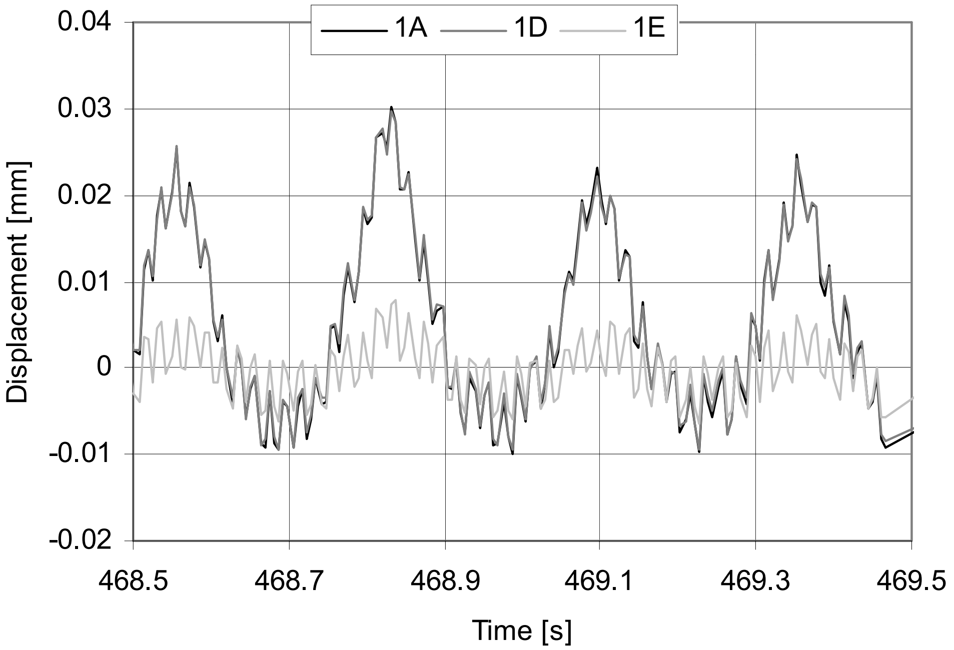

Figure 3: Passing of a 4-axle vehicle with tractor and trailer

Measurements with well defined traffic loads allow the comparison of the sensitivity of the two sensor systems. For this purpose a 2-axle truck weighing 17 tons was used. Figure 4 shows the comparison of the inductive and the magnetostrictive sensors. For purpose of clarity the data of the two sensors are shown with opposite signs. They show a similar pattern. The difference in the amplitudes can be explained by the different position of the wheels relative to the sensors.

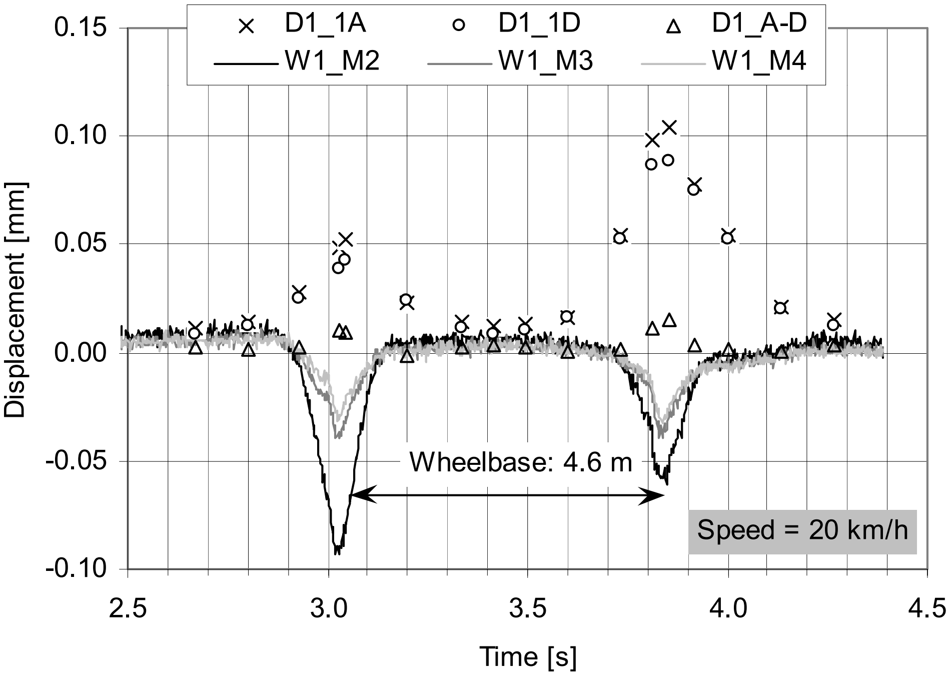

Figure 4: Comparison of the two sensors during truck passing

From previous measurements and calculations a combined measuring uncertainty of 4 µm for W1 was found. Since the magnetostrictive sensor measures several positions along its axis the decrease of the elastic vertical displacement within the pavement can be shown (figure 5).

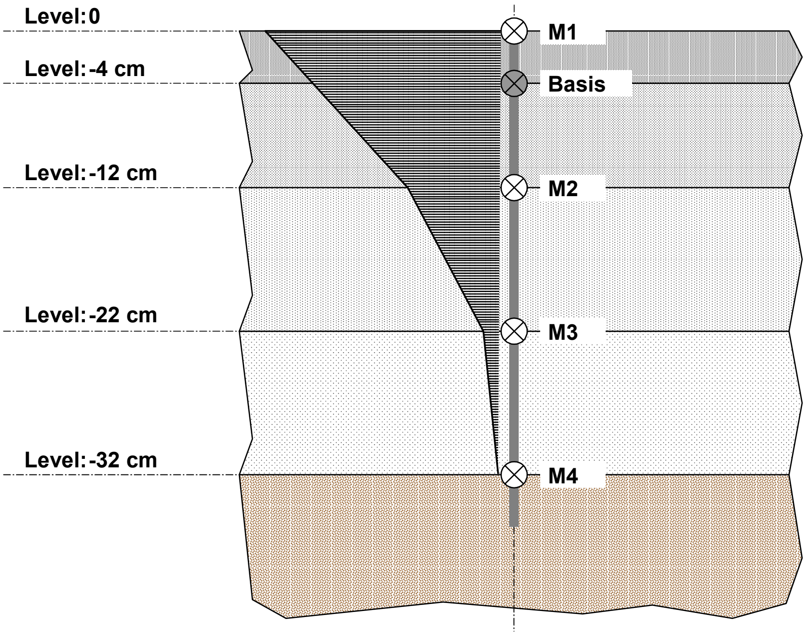

Figure 5: Typical decrease of the vertical displacement within the pavement

3.2 Long-term results

Figure 6 shows the recorded displacements since July 2001. Settling effects could be observe after the installation and are omitted in the figure. During the shown period the pavement deformations are small and seasonal effects are dominating. To separate compression of the pavement from the seasonal effect longer observation times are necessary. A standard deviation of less than 0.1 mm for the long-term measurements is obtained.

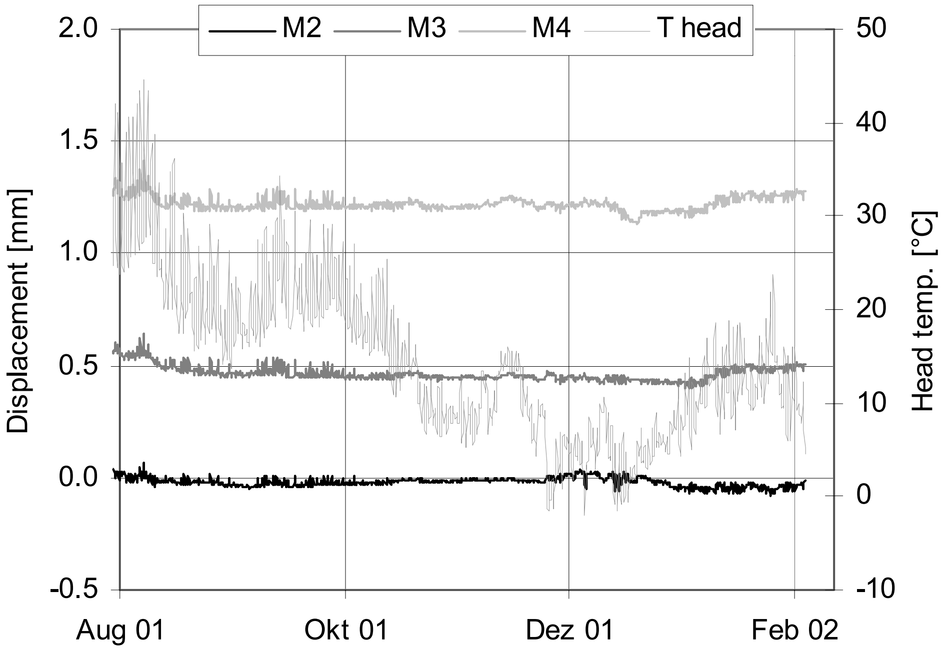

Figure 6: Long-term records of the magnetostrictive sensor

4. Conclusions

In addition to measurements of load, traffic frequency and pavement temperature on an expressway deformation measurements of the pavement were carried out. The first year experience with long-term monitoring demonstrated the feasibility and reliability of the new magnetostrictive sensor system. In the short-time measurements the sensitivity of the inductive and the magnetostrictive were compared. The measuring uncertainty for short- and long-term measurements was found within the requirements. The deformation measurements in the top layer have to be improved and a remote logging system for all data on this test site has to be established.

5. Literature

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