LONG-TERM PAVEMENT PERFORMANCE MONITORING OF A SWISS MOTORWAY

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Abstract

Within the scope of rehabilitating the heavily traveled Swiss motorway A1, in 1998 a long-term (10 years) in-situ measurement system was installed. This project is unique in Switzerland, as it allows to monitor vehicle weight (WIM) and frequency, as well as the measurement of vertical pavement deformations caused by a vehicle at different pavement depths.

Keywords: Weigh-in-motion, Temperature, Long Term Pavement Performance (LTPP).

Résumé

En 1998 un système de mesure in situ à long terme a été installé sur l'autoroute suisse A1 lors de la réfection de cette voie de liaison soumise à des charges de trafic très importantes. Ce projet est unique en Suisse en ce sens qu'il permet de réaliser un monitorage de la charge (WIM) et du nombre de véhicules ainsi que des déformations verticales provoquées par un véhicule à différentes profondeurs de la chaussée

Mots-clés: pesage en mouvement, température, performances à long terme des chaussées (LTPP).

Abstracto

Dentro del campo de actividades de la reparación de la muy transitada autopista suiza A1, fue instalado en esta última, en el año 1998, un sistema de medida a largo plazo (10 años). Este proyecto es único en Suiza, puesto que no sólo permite controlar el peso (WIM) y la fecuencia de los vehículos , sino que también mide las deformaciones del pavimento verrtical causadas por un vehículo en diferentes puntos bajos del pavimento.

Palabras Claves: Movimiento del peso, Temperatura, Capacidad (resistencia) del pavimento a largo plazo (LTPP)

1. Introduction

With the increasing number of vehicles on highways and increasing axle loads the need for durable “zero maintenance roads” with high bearing capacity increases. In most cases, traffic monitoring equipment records only the number of vehicles on a particular highway section. There is still insufficient information regarding axle loads and their impact on the pavement to provide a basis for the development and optimization of pavement-dimensioning models. Such information is also required for the development of materials and new structural concepts.

Within the scope of rehabilitating the heavily traveled Swiss motorway A1 between Zürich and Bern, in 1998 a long-term in-situ measurement system was installed to record amount and frequency of traffic loads, the numbers and type of vehicles as well as pavement temperatures and vertical deformations within the cross section of the pavement. The aim of the ongoing EMPA project is to collect and evaluate relevant data for improving the system properties and service life of roads.

2. Location

The approximately 250 m long test section is located on the A1 motorway near Lenzburg between Zürich and Bern in Switzerland (Figure 1). The measurement systems were installed in 1998 on the lane towards Bern. The pavement consists of the following layers:
Wearing course: 4 cm stone mastic SMA 11 S,
Upper base course: 8 cm base course asphalt concrete HMT 22 H,
Lower base course:10 cm base course asphalt concrete HMT 32 H und
Subbase: 10 cm subbase asphalt concrete HMF 22 S.

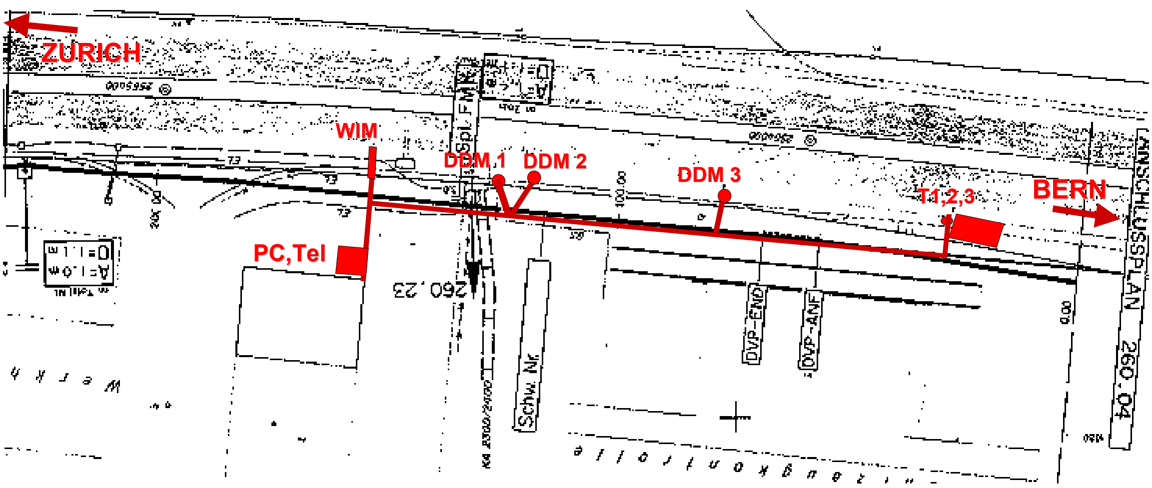


Figure 1- Location of test section on the A1 motorway, near Lenzburg.

The locations of the individual measuring devices for deformation, DDM (Differential Deflection Measurement), weight-in-motion, WIM, and Temperature, T, were chosen to minimize the cable lengths and the influence of the devices on one another. A schematic of the EMPA measuring station lay out is shown in Figure 2. Figure 3 depicts the location of the measuring devices in the individual layers.

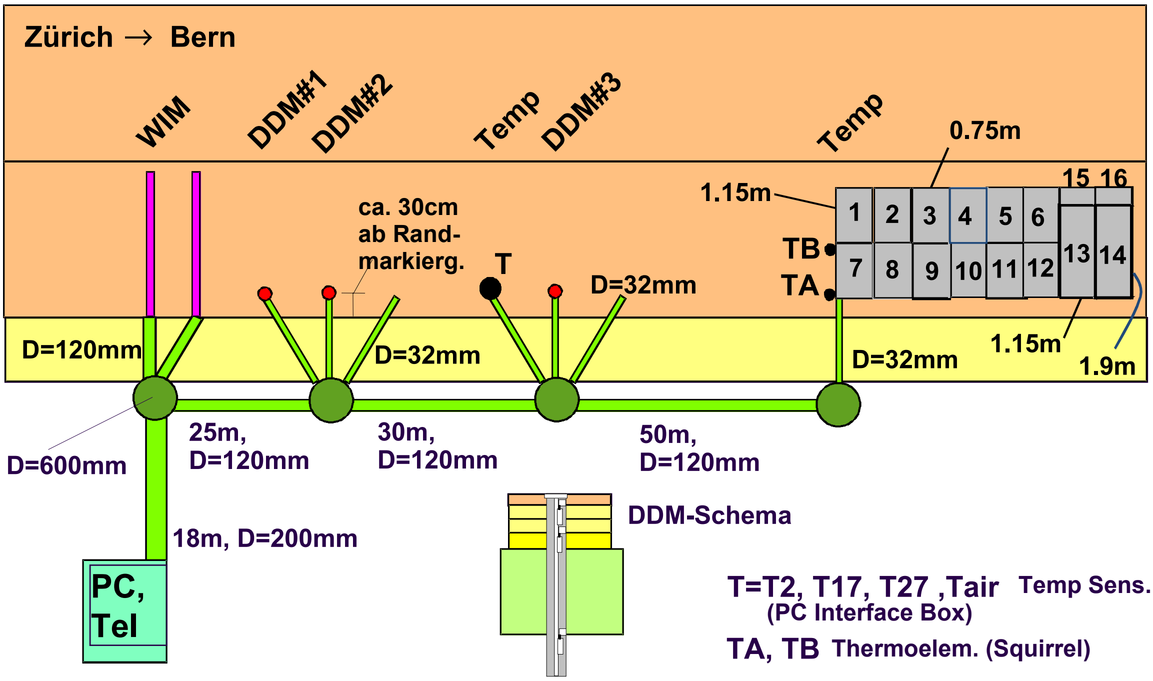


Figure 2- Schematic of the EMPA measuring section lay out, top view.

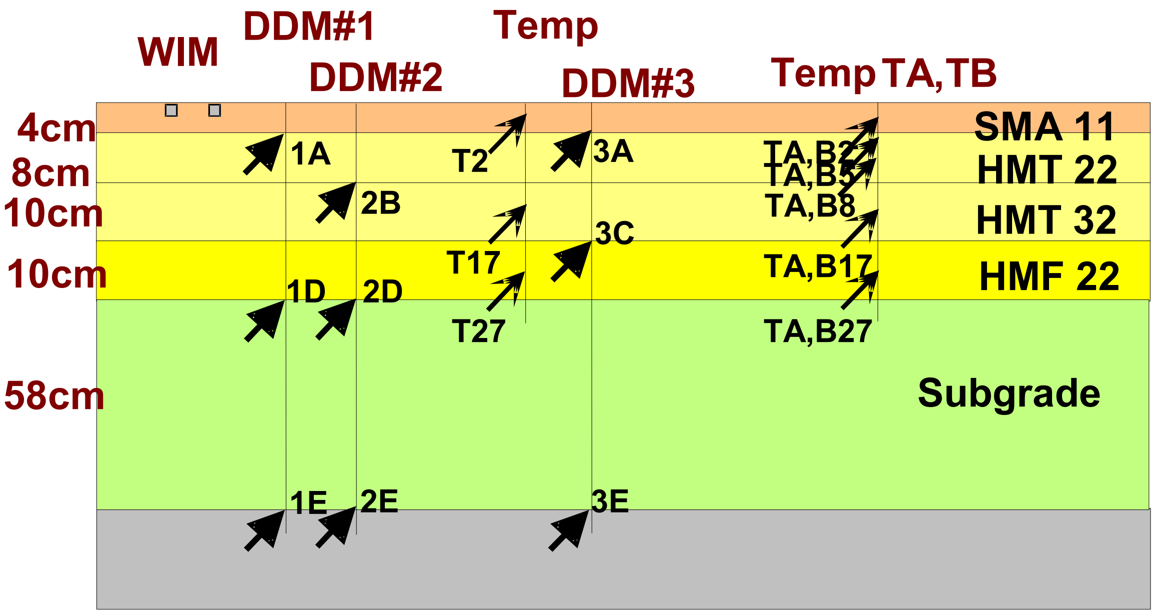


Figure 3- Location of the measuring devices in the individual pavement layers, elevation.

3. WIM-Measurements

The monitoring of vehicle weight and frequency is conducted by a WIM (weight-in-motion) system that consists primarily of two load cells with piezo-electric quartz sensors. These sensors measure the weight and the axle loads of a passing vehicle. The data is collected by an on-site computer and transferred via modem for evaluation purposes. A single axle load of at least 6 tons triggers a special program to register the loads induced by the vehicle. From the characteristic load/time signal, the vehicle type is determined. In addition, the load equivalency factor with respect to the equivalent single axle load (ESAL) of 8.16kN is calculated.

According to the data evaluation for the year 2000, average number of heavy vehicles per hour was between 230 and 310, extending up to 700 heavy vehicles during rush hour (Figure 4). Over the course of the year, the volume of heavy traffic was equally distributed. However as expected, during holidays (Easter, Christmas) and vacation time (July/August) traffic was significantly lower.

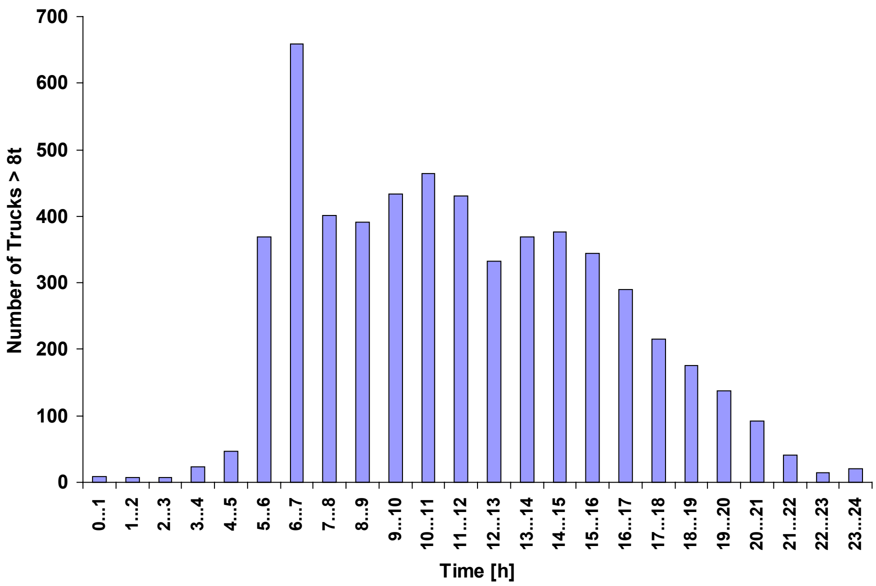
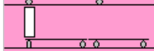
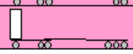


Figure 4-Daily distribution of heavy trucks averaged over the year 2000.

As shown in Table 1 the data indicate that some truck types exceeded the legal weight limits allocated for their category. However, for 98% of all heavy vehicles the load of the axles itself was more or less within the given limits.

Table 1- Legal weight limits and number of trucks

			Load categories [t]				
Truck Typ	Code	Weight Limit [t]	20 - 25	25 - 30	30 - 35	35 - 40	>40
	220	18	**941**	**94**	**27**	**23**	**7**
	422	38	45377	31418	18926	1351	**81**
	230	28	7656	6431	**735**	**20**	**3**
	280	32	3960	9856	735	**777**	**87**
	326	35	29134	25870	20563	**1116**	**120**
	329	40	11198	11403	9323	1156	**1434**
	336	40	488	522	440	197	**200**
	339	40	184	174	156	113	**179**

4. Temperature Measurements

Due to the fact that the behavior of asphaltic materials is highly temperature sensitive, monitoring temperature was seen as an imperative part of this project. Temperature sensors were installed at various depths within the layers of the pavement. Figures 2 and 3 show the position of the sensors and Figure 5 shows the variation of temperature down to a depth of 32 cm using isothermal lines. The top and bottom figures show summer and winter values respectively. As expected the higher day temperatures appear in the late afternoon still under heavy traffic conditions (Figure 4). As compared to summer, the winter values show less of a variation between day and night between the layers.

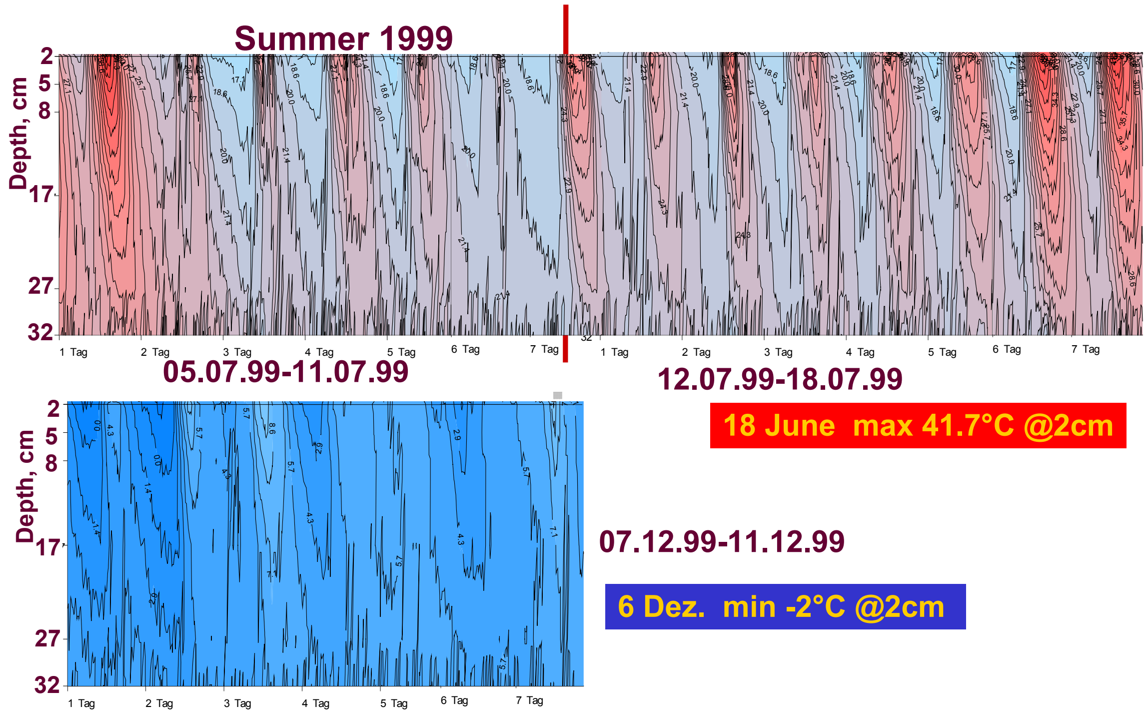


Figure 5- Isothermal lines in summer and winter

5. Deformation measurements

A number of Differential Deflection Measurement (DDM) devices measure the relative vertical deformations of the pavement at various depths (Figures 2 and 3) in order to determine the structural impact of vehicles on the different layers of the pavement. Recently, for validation purposes, additional new measurement devices (Figure 7) were installed based on the magnetostrictive principle [Reference 1]. These measurement devices were designed by EMPA and will be less expensive than the DDMs.
The vertical deformations were registered with the help of Linear Voltage Deferential Transducers (LVDT) and the data were stored by a PC. Figure 6 shows an example of these vertical deformations induced by trucks.

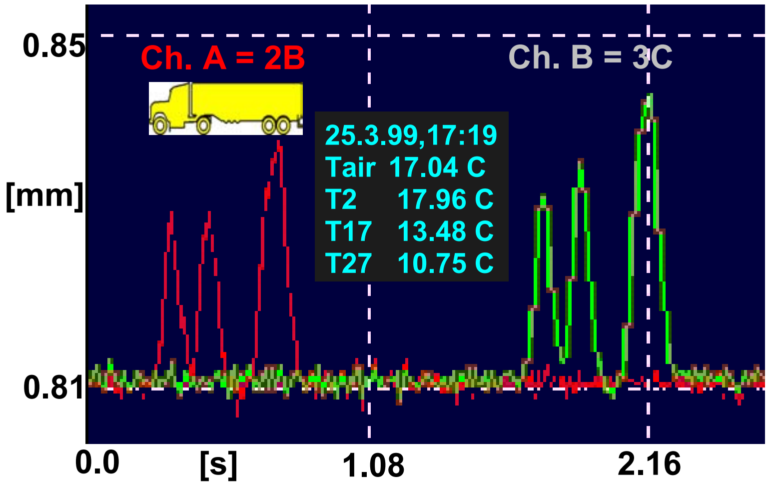


Figure 6- Deformations induced by two truck types.

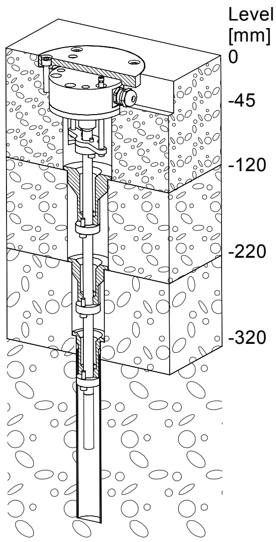


Figure 7-Magnetostrictive sensor

5. Conclusions and Further Steps

This is part of a long term investigation that will go on for another eight years its primary goal being to link the WIM data to temperature and deformation measurements in the pavement. So far the measurements proved successful, providing valuable WIM input data for the next revision of Swiss Standards. In addition the test section turned out to be a validation tool for the development of new measurement devices, such as the new magnetoresistive sensor by EMPA. Furthermore, the installation of a new WIM system that will measure not only the axle loads but also the pressure distribution under the individual tire is planned.

6. Acknowledgements

We would like to thank the canton Aargau for their financial and technical support during this project.

7. References

1. “*Long term monitoring of highway deformations*”, P.Anderegg, R. Brönnimann, C.Raab, M.N.Partl, Proceedings of the SPIE’s 5th International Symposium on Nondestructive evaluation and Health Monitoring of Aging Infrastructure Vol. 3995-50. 5-9 March 2000, New port Beach Ca. USA.

2. *“Eine Strassenbauforschung mit Schwung”,* M.N. Partl, Schweizer Bauwirtschaft, No. 49 December 8th 2000. In German.