Summary

This paper presents an approach for the identification of operational loads given measured static responses of a bridge structure and its corresponding analytical model. In an optimization process single vehicles and corresponding attributes are identified from data recorded during the presence of one or multiple vehicles on the bridge. The vehicle attributes gross weight, velocity, axle loads and axle spacings are determined. The problem is solved by means of two encapsulated evolutionary optimization routines. The objective function is represented by the calculation of the difference between measured and computed strains. For measurement, only two sensors which are installed in one cross section without any installations on top of the bridge are required.

The application to real measurements as well as obtained results will be shown. The results demonstrate that structural health monitoring in conjunction with adequate mechanisms can successfully support the acquisition of additional, valuable information.

Keywords: Concrete bridges; monitoring; long-term measurements; load identification; weigh-in-motion; genetic programming.

1. Introduction

Compared to rail, inland waterways and air, Europe’s road network is of prime economic significance for transport. The main part of passenger and freight transport is realised on roads and motorways. Prognoses on the transport development in Europe indicate an intensification of this situation: The EU-15 traffic prognoses for 2010 show an increase in passenger transport of almost 23 % and in freight transport of about 30 % in comparison to 2000 [1]. In addition to a general increase in transport on European roads, overloaded vehicles are observed frequently and the number of heavy haulage permits rises from year to year. A continuous increase in road transport and changed traffic loads imply higher demands to existing structures. To guarantee security and durability, the structures’ condition is regularly rated by inspectors. The ratings are partly based on visual inspections and thus subjective [2]. Objective statements about a structure can be obtained from structural health monitoring [3].

The clear and objective assessment of civil structures requires knowledge about the actual traffic situation in terms of acting traffic loads, their distributions and frequencies. Weigh-in-motion (WIM) systems were developed to acquire traffic data. Vehicle loads and vehicle types are determined without the interruption of the traffic flow. Basically, two systems can be distinguished: Systems in or on the pavement and systems on bridges. The bridge systems use existing bridges as measuring devices. Strains and deformations of the structure are recorded continuously. On the basis of measured structural responses load identification is performed. A common approach to solve the problem is the adaptation of an analytical model’s load component by comparison of a prediction with a measured observation. The model’s system component is assumed to be known a priori. Thus, the problem is solved inverse. Inverse problems are usually ill-posed and unique solutions can hardly be found. Optimization techniques may support solving this kind of problems. The question is not to obtain a single solution – it is more to retrieve an optimal solution. Bridge WIM may be successfully combined with structural health monitoring. This way, early damage detection is performed and additional, valuable information is obtained.

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2. Approach, Implementation and Application

The Soft-WIM algorithm was developed and implemented in the programming language C++ in order to obtain detailed information about vehicles that pass the monitored superstructure of a bridge. Soft-WIM is based on two encapsulated evolutionary optimization kernels to analyse the recordings of two essential sensors. The sensors are installed in one cross section of the bridge's superstructure. Because of its high flexibility, genetic programming was chosen to solve the problem by means of optimization. Gross weights, velocities, axle loads as well as axle spacings of passing vehicles are determined. Single vehicles and corresponding attributes are identified from data recorded during the presence of one or multiple vehicles on the bridge at a given point of time.

For the analysis of measured data a differentiation according to the kind of recorded structural response is drawn (Fig. 1): One optimization kernel (EA kernel 1) serves for the analysis of measured global structural responses, whereas the other (EA kernel 2) analyses local responses. Global reactions of a bridge are recorded from sensors, which are located in the cross section to record significant values for the whole or quite a long time a vehicle crosses the bridge. Reactions of the bridge superstructure due to vehicle loads are global by this definition. Local reactions are obtained from sensors being placed close to acting forces and in consequence their recording is of short duration. The response of the bridge deck due to single wheel loads is considered as local.

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<table>
<thead>
<tr>
<th>EA kernel 1</th>
<th>EA kernel 2</th>
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<tr>
<td><strong>signal comprises global reactions</strong></td>
<td><strong>signal comprises local reactions</strong></td>
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<td>→ identification of vehicle properties</td>
<td>→ identification of axle properties</td>
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| • time of occurrence $t_{0,V}$ of vehicle $V$ | • time of occurrence $t_{0,A_i}$ of the $i$th axle $A_i$
| • gross vehicle weight $G_V$ | • axle load $F_{A_i}$ |
| • velocity $v_V$ | • axle spacing $x_{A_i}$ |

![Fig. 1](image)

Iterative analysis of two sensor signals to identify single vehicles

In the paper a short overview on evolutionary optimization algorithms will be given. The overall approach including the chosen evolutionary optimization will be presented. Its application within the monitoring of the superstructure of a post-tensioned concrete will be illustrated. This monitoring was performed for more than 15 months. Sample measured global responses as well as local responses will be shown to demonstrate the proposed concept. Results obtained from the analysis of recorded data will be shown. It will be concluded that structural health monitoring in conjunction with adequate mechanisms can successfully support the acquisition of additional information. By means of appropriate analysis techniques, measured data, which may be obtained during structural health monitoring, can be explored for valuable information beyond the monitored structure.

3. References

