ABSTRACT

The need to weigh and classify vehicles is based on the damage that large trucks cause to road infrastructure. Weigh-in-Motion (WIM) data can be used to predict future traffic volumes and weights for the planning of new constructions, the management of maintenance activities, the identification/reduction of overloading problems and the evaluation of the performance of pavements and bridges.

Most WIM systems are based on weighing sensors that are embedded in the pavement or placed on top of the road surface and which measure wheel or axle pressure that is applied as the vehicle passes over them. As the effect of the applied force is recorded during a very short period of time, accuracy is limited by the dynamic nature of the vehicle motion. Additionally, these systems are subject to durability problems due to traffic and the environment. An alternative approach to WIM which increases the length of the load-sensitive element and the durability of the system is to use a bridge as a weighing scales (Bridge WIM); this approach is the subject of the research reported in this thesis.

The installation of a Bridge WIM system is described. Axle weights are obtained from the information supplied by strain gauges under the bridge deck and axle detectors on the road surface as a vehicle passes over the bridge. Despite many advantages, Bridge WIM algorithms have generally failed to predict axle weights accurately due to vehicle and bridge dynamics and differences between theoretical models and measured bridge responses. Considerable work is carried out on the dynamic modelling of trucks on bridges for the purpose of providing a more accurate algorithm. New contributions include calibration procedures, dynamic algorithms and the extension to multiple longitudinal sensor locations along the bridge (traditionally measurements are made at just one longitudinal section).

Experiments were carried out at four different sites. Bridge WIM data was collected continuously in a 16 m simply supported skew bridge in Delgany (Ireland). A program that processes the traffic data from road and strain sensors into vehicle velocity, classification and weights is developed for this purpose. An innovative calibration procedure purely based on the experimental record (without any reference to the structural bridge behaviour) is introduced. A 110 m continuous box-girder bridge in Belleville (France) is used for checking the performance of a Bridge WIM system when the bridge response has a very significant dynamic component. An instrumented truck participated in the experiment. A Bridge WIM system is also tested in a 30 m two-span integral bridge in Luleå (Sweden) under harsh climatic conditions. Finally, a 32 m simply supported bridge in Slovenia is instrumented with strain sensors in different longitudinal locations allowing for the study of a multiple sensor algorithm.

The data input is particularly difficult to analyse from the dynamic response of bridges due to the wide range of trucks on bridges with different classifications and with different dynamic properties. Theoretical simulations are used for testing Bridge WIM accuracy in a variety of scenarios. A planar numerical approach and a three-dimensional finite element technique are employed for simulating the passage of a vehicle over a bridge. The finite element modelling of vehicles and bridges has been done with the general-purpose finite element analysis package MSC/NASTRAN for Windows. The dynamic interaction of the bridge-vehicle system incorporates the road surface profile and is implemented using a set of auxiliary functions to enforce the compatibility conditions at the bridge/vehicle interface. Apart from these dynamic models, other numerical data from truck models validated experimentally are provided by Green (Queen's University, Kingston, Canada) for further analysis. Accuracy results for different Bridge WIM algorithms are given according to the COST323 European Specification on WIM.

A dynamic Bridge WIM algorithm based on one longitudinal location has achieved better results than the static approach in a few particular cases. Other findings as a new experimental procedure and/or the sensor location have leaded to significant improvements in accuracy. A Bridge WIM algorithm based on multiple sensor locations has generally been found the most accurate. However, this algorithm might require an excessive number of sensors in relatively short span bridges and the convenience of this installation will depend on the required level of accuracy.