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A COMBINED STRUCTURAL HEALTH MONITORING AND WEIGH-IN-MOTION SYSTEM FOR RAILWAY BRIDGES

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ABSTRACT

Many bridges in the world's transport infrastructure are old and have deteriorated over time. The solution to this problem is to either repair or replace a bridge or to establish its safety and maintain it in service. It is generally very costly to repair or replace a bridge. With reduced maintenance budgets there is an increasing interest in maintaining these old bridges in service for longer by using probabilistic methods to prove that they are safe. Bridge safety is assessed based on (i) the loading which it will experience in service and (ii) the resistance of the structure. Improved knowledge of loading and resistance allows a more accurate assessment of whether a bridge is safe to remain in service without the requirement for expensive repair or replacement strategies. A system that combines Structural Health Monitoring (SHM) with Bridge Weigh-in-Motion (B-WIM) can provide bridge owners with information about the true safety of a bridge structure. The B-WIM part of this system is a method of collecting traffic load data using measurements taken from the bridge as vehicles cross it (WAVE, 2001) (WAVE, 2001) (WAVE, 2001) (WAVE, 2001). Hence the traffic data is current and specific to the bridge in question. The SHM part of this system continuously monitors the bridge for new damage and assesses its remaining resistance.

Keywords: Bridge, Weigh-in-Motion, B-WIM, WIM, Structural Health Monitoring; Railway.

INTRODUCTION

Major transport networks rely heavily on the safety and serviceability of bridges located on these routes. Failure of a bridge can have devastating effects from both an economic perspective and regarding loss of human life. It is therefore imperative that the safety of these bridges is ensured. A vast number of bridges which are critical to the efficiency of road and rail transport networks are old and have deteriorated since their construction. In many cases these bridges have reached their design lives and, as such, a decision must be made as to whether the bridge needs to be repaired, rehabilitated or replaced, or whether it is safe to be retained in service. In order to assist with decision making, it is proposed that a combined railway Bridge WIM/SHM system be used to assess the safety of a bridge. The first section of this paper provides an overview of the development of a railway B-WIM system, one of the first of its kind for weighing trains in motion. A steel truss bridge in Poland, illustrated in Figure 1, is used for testing the system. During testing, four trains which passed over the bridge were weighed statically in a railway yard in Warsaw. The railway B-WIM system was then used to calculate the weights of the train carriages using the measured response from the test bridge and the accuracy of the system was assessed.

The second section of this paper proposes an algorithm for railway bridge SHM that can use the same data acquisition system as used for B-WIM. The SHM concept involves carrying out a wavelet analysis on the measured response from the bridge before and after damage has occurred. Damage in a structure can lead to localised singularities in the acceleration signal over the location of the damage. A wavelet transform can detect these changes to the frequency content of a signal and is therefore capable of locating the damage.

Fig. 1 - Nieporęt Railway Bridge

RESULTS AND CONCLUSIONS

Initial results for the railway B-WIM system showed that one of the four trains of known weight was predicted very accurately; however the accuracy of the other trains was relatively poor at first, with calculated carriage weights deviating by as much as 30% from their actual values. A more in-depth analysis showed that these trains were changing velocity as they traversed the bridge and that the large errors were directly correlated to this changing velocity. The standard B-WIM algorithm, which assumes a constant velocity during the passage of a vehicle, was adjusted to allow for the effect of this changing velocity and the results improved dramatically, with the vast majority of the calculated carriage weights falling within 5% of their actual values.

For the SHM part of the system, it was found that wavelet analysis was capable of locating damage in the steel truss bridge. For this method, three damage scenarios were considered involving a 40% reduction in stiffness to the bottom right, centre and left chords of the truss. It was found that the wavelet technique was capable of identifying the location of the damage, once a signal from the bridge before the damage occurred is available for the same train weight. This is due to the fact that the frequency content of the signal is also sensitive to train weight and therefore if the train weight changes, this tends to mask the damage. This approach may be feasible by using test trains on a track periodically to check for damage. However, in reality, it may not be feasible to run test trains over the bridge and bridge managers may wish to use acceleration data from regular train traffic. The effect of variable train weight was reduced by averaging the wavelet transforms for 1000 trains. By doing this, the wavelet technique was capable of identifying the location of the damage.

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