RAILWAY BALLAST DAMAGE DETECTION BY VIBRATION MEASUREMENT OF IN-SITU CONCRETE SLEEPER

WONG MAN TAT

Degree of Engineering Doctorate

CITY UNIVERSITY OF HONG KONG

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CITY UNIVERSITY OF HONG KONG
香港城市大學

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量度混凝土軌枕的震盪來診斷鐵路道碴的損傷

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Wong Man Tat
黃文達
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Abstract

The railway system is one of the most important transportation systems for modern society. To ensure its safety, the current railway track monitoring system is very comprehensive for monitoring the levels, alignments and gauges. However, the detection of damaged railway ballast still relies heavily on visual inspection. It is clear that visual inspection can only identify damaged ballast on the track surface. Ballast-damage under the concrete sleepers, which is the most critical hazard to railway traffic, is extremely difficult to “observe”. At present, destructive core tests are the most reliable way to inspect the ballast condition below the surface. However, this kind of test is time consuming, and if the test is not carried out properly the train service will be affected.

The main objective of this research project is to develop a practical damage detection method for assisting Permanent Way engineers and inspectors to quantify the “health” condition of ballast under the concrete sleepers during visual inspections. To achieve this goal, a very comprehensive literature review was carried out on the existing methods of track monitoring. It was found that the non-model-based methods have only limited success in detecting ballast-damage. To quantify the extent of damage, model-based methods are more reliable. Therefore, the proposed ballast-damage detection method follows the model-based approach. When the ballast is damaged, its stiffness in supporting the concrete sleeper is reduced, and this alters the vibration characteristic of the in-situ concrete sleeper. Therefore, it is possible to quantify the degree of ballast-damage by measuring the vibration of the in-situ concrete sleeper without lifting it up for ballast inspection.

At the beginning of this project, many methods (including analytical and numerical methods) for modelling the rail-sleeper-ballast system were developed and studied. After a series of comprehensive numerical and experimental case studies, a finite element based rail-sleeper-ballast modelling method was developed to enable ballast-damage detection.

One of the contributions of this project is the design and construction of a full-scale ballasted track test panel consisting of a plain track segment that follows the MTR Permanent Way design specification. A series of vibration tests were carried out to collect data from this ballasted track under undamaged conditions and under various ballast-damage scenarios.

The proposed ballast-damage detection method developed in this project follows the model updating approach. This approach, however, involves solving a numerical optimisation problem that is time consuming for on-site real time application. To make the proposed method more practical, investigations were conducted into the possibility of replacing the on-site model updating process with an off-site artificial neural network (ANN) training process. The training of ANN is time consuming, but it can be carried out in an off-line manner. After training, the use of ANN in calculating the ballast-stiffness distribution under the target sleeper, based on the set of measured modal parameters, can be done quickly.

The results from this project's numerical and experimental case studies are very positive and show that the proposed method is feasible. Detailed discussions concerning the pros and cons of the proposed method are given at the conclusion of this thesis. Nevertheless, some technical problems need to be overcome before this method can be put into real application. The directions for further research are given at the end of the conclusions section.