Dynamic Properties Evaluation of Railway Ballast Using Impact Excitation Technique

Ngamkhanong, Chayut; Tang, Tao; Kaewunruen, Sakdirat

DOI:
10.3390/proceedings2161149

proceedings

i-RISE 2018

MDPI

Extended Abstract

Dynamic Properties Evaluation of Railway Ballast Using Impact Excitation Technique †

Chayut Ngamkhanong [1,2,*], Tao Tang [1] and Sakdirat Kaewunruen [1,2]

[1] Department of Civil Engineering, The University of Birmingham, Birmingham B15 2TT, UK; tangtao4650@gmail.com (T.T.); s.kaewunruen@bham.ac.uk (S.K.)

[2] Birmingham Centre for Railway Research and Education, The University of Birmingham, Birmingham B15 2TT, UK

* Correspondence: cxn649@student.bham.ac.uk; Tel.: +44-(0)-7532-630-572

† Presented at 2018 International Symposium on Rail Infrastructure Systems Engineering (i-RISE 2018), Brno, Czech Republic, 5 June 2018.

Published: 17 September 2018

Railway ballasted track, traditional railway track, consists of steel rails, sleepers, fastener system, ballast, sub-ballast and subgrade. Railway ballasted track has been widely used in railway system around the world. Ballast, which supports the sleepers uniformly, is highly experienced deterioration. The functions of ballast are to transmit the load from sleeper to sub-ballast and sub-grade, provide stability and adequate permeability for drainage of the railway track. By nature, one of the most track deterioration is located on ballast, which has highly nonlinearities [1]. The ballast deterioration can produce high settlement and lead to track deterioration. Based on the fact that the impact of climate change affect and produce huge losses in railway system, the effect of environmental are needed to consider. In fact, flooding can cause train disruption and destabilize the track. Based on the open literature, the behaviour of ballast under water has not been studied. In this study, the dynamic properties of railway ballast, such as frequency, damping, stiffness, are studied with the consideration of effect of water.

This study provides an easy tool and non-destructive method for evaluating the dynamic characteristics of railway ballast. It should be noted that this method has been used and developed for evaluating the characteristics of rail pad [2]. The approach enables testing of railway ballast with the influence of water in the dynamic characteristics. To measure the dynamic characteristics of railway ballast, the accelerometer is attached on the concrete cube located on top of railway ballast. The concrete cube is considered as a mass in the single degree of freedom system, as shown in Figure 1. The vibration characteristics of ballast are considered using Prosig P8004 noise and vibration measurement systems (Figure 2). The ballast in flooding condition is compared to dry ballast. Spring and dashpot are represented by ballast for dynamic stiffness and damping, respectively. The height of ballast is 30 cm. The concrete cube is impacted vertically with the impact hammer in order to obtain the free vibration curve for damping calculation.

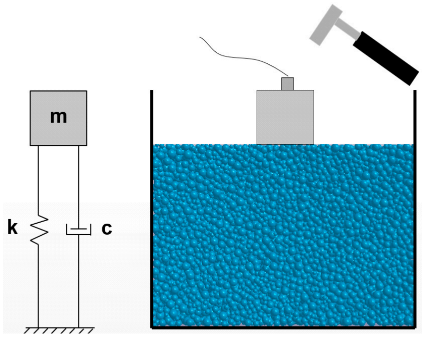

Figure 1. Analytical model and schematic test rig.

Figure 2. Hammer and Prosig 8004 portable.

The frequency response functions (FRF) are then evaluated in DATS analysis software to describe the modal parameters of railway ballast. In addition, the FRF curve can be determined taking the fourier transform of the equation of motion of SDOF system. The FRF curves obtained by analytical solution are then compared and fitted the experimental. The Equation (1) is used to fit the experiment measurement of FRF. The magnitude of FRF H(f) is in terms of frequency.

$$H(f) = \frac{1}{m}\frac{4\pi^2(\frac{m}{k_p})f^2}{\sqrt{[1-4\pi^2\left(\frac{m}{k_p}\right)f^2]^2+[4\pi^2\left(\frac{m}{k_p}\right)\left(\frac{c_p^2}{k_p m}\right)f^2]}} \quad (1)$$

where m, c_p and k_p represent the effective mass, damping, stiffness of ballast layer, respectively. In this study, the dynamic properties of various levels of water are compared. The results show that the water can affect the dynamic characteristics of ballast. Moreover, the frequency response function (FRF) curves of ballast in dry and flooding conditions are shown in Figure 3. The results of modal dynamic parameters can be obtained using curve fitting methods of SDOF vibration theory as demonstrated in Table 1.

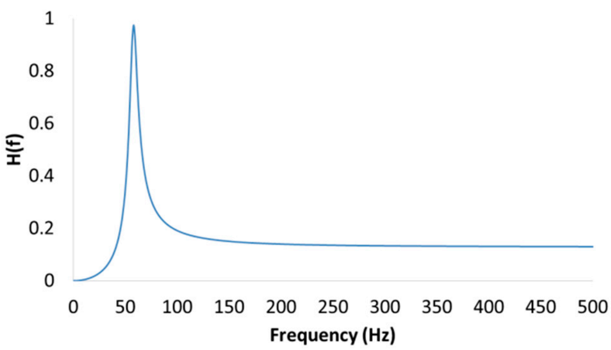

Figure 3. FRF Curve.

Table 1. Ballast properties.

Case	K (kN/m)	C (kNs/m)	f(Hz)	Correlation Coefficient (%)
Dry	1,036	0.3721	59	99.85
Flooded	708.4	0.6364	47	9.81

The FRF curves obtained by both analytical and experimental show a very well agreement. It is clearly seen from the results that the ballast properties will be changed when the ballast is under water. The modal testing has proven to be an effective method for estimation of the dynamic stiffness and damping constant of the track component. The results obtained can be used for further numerical modelling for whole railway track during operation to study the effect of flooding on railway ballast which can affect the overall railway track behaviour. The understanding from this paper will also help improve the practical maintenance issues and enable predictive track maintenance regime in railway industry.

Acknowledgments: The authors are sincerely grateful to the European Commission for the financial sponsorship of the H2020-RISE Project No. 691135 "RISEN: Rail Infrastructure Systems Engineering Network", which enables a global research network that tackles the grand challenge of railway infrastructure resilience and advanced sensing in extreme environments (www.risen2rail.eu) [3].

References

1. Ngamkhanong, C.; Kaewunruen, S.; Baniotopoulos, C. A review on modelling and monitoring of railway ballast. *Struct. Monit. Maint.* **2017**, *4*, 195–220.
2. Kaewunruen, S.; Remennikov, A.M. Monitoring structural degradation of rail bearing pads in laboratory using impact excitation technique. In Proceedings of the 1st International Conference on Structural Condition Assessment, Monitoring, and Improvement, Perth, Australia, 12–14 December 2005; pp. 389–394.
3. Kaewunruen, S.; Sussman, J.M.; Matsumoto, A. Grand challenges in transportation and transit systems. *Front. Built Environ.* **2016**, *2*, 4, doi:10.3389/fbuil.2016.00004.