Proceedings of Engineering and Technology Innovation, vol. 4, 2016, pp. 49 - 51

Using Ground-penetrating Radar to Promote the Investigating Efficiency in Mud Pumping Disaster of Railways

Chihping Kuo[1,*], Chihhao Hsu[1,2], Yenyu Chen[3], Chinwei Wu[1], Hongyi Wang[1], Dewei Chen[1], YiXuan Lin[1]

[1]Department and Institute of Civil Engineering and Environmental Informatics, Minghsin University of Science and Technology, Hsinchu, Taiwan.

[2]Taipei Engineering Division, Taiwan Railways Administration, MOTC, New Taipei City, Taiwan.

[3]SamHo Technology & Engineering Co., LTD, New Taipei City, Taiwan.

Received 20 January 2016; received in revised form 15 February 2016; accepted 03 March 2016

Abstract

Currently about 85% of the railway structure is constructed traditionally in Taiwan, which means the foundation of railways is composed by in-situ soil materials and covered by ballast, sleepers and tracks. The rail is continued by fish-plates and then bolted. While train passes here, the deflection caused by repeated loads. The repeatedly force transfers through ballast to the saturated foundation, may create vacuum to draw phenomenon, called pump effect or mud pumping. It could lead to serious train derailment capsized.

Present mud pumping detection method has to be performed during the non-operating time at night by visual. However, this approach may have omissions and shortcomings perspective concerns, and slow to find disasters during the rainy season. Using non-destructive testing techniques (ground-penetrating radar) to inspect the quality of rail bed is widely in foreign. However, detecting the distribution of mud beneath rail is an attractive subject here. By the usage of mention technology in this research, this technology is expected to be promoted.

This study has been agreed by the official administration, Taiwan Railway Bureau, to be carried out in Nanwan branch in Hsinchu by using ground-penetrating radar. Comparing with the visual inspection results, the mud pumping can be verified. Where most serious mud pumping phenomenon observed was open to prove the function. The study is expected to launch the road bed structure further rehabilitation plans and preventative maintenance engineering. Furthermore, cost due to misjudgment is expected to be saved and traffic safety improved.

Keywords: mud pumping, railway bed, ground-penetrating radar, disaster

1. Introduction

1.1. Phenomena and Effect of Railway-bed Mud-pumping

The general structure of railway bed is layout in Fig. 1. The loading from train transfers to the subsoil of ground through rails, sleepers, ballasts, and subballasts. Ballast plays important role in the loading transferring work. The loading has to be uniformly and equally transferred by ballasts. The rainfall requires to be drained rapidly by ballasts as well. When the ballasts were filled by subballasts, it would reduce the function of ballasts. Subballasts generally is used for adjudging the required elevation of rails and composed by mixed soils. In most cases, fine materials like silts or clays are more welcome than granulated ones like sands or small gravels due to the budgets. Fig. 2 shows the common phenomena observed in railway. The mud covers the sleepers and ballasts as pumping from subballasts. A serious issue is after the pumping occurred; the materials did not flow back to subballasts. Therefore the cavities exist inside the subballasts and induce the differential settlements for sleepers and rails. A potential disaster consequently threatens the safety of train's traffic.

Inspecting by naked vision is the traditional and now-used method for the inspectors in Taiwan Railway Bureau in Taiwan. Besides, they can only discover the cases that already pumped out the ballasts. The distributions and

* Corresponding author. Email: picnic.kuo@must.edu.tw

shapes of pumping or cavities are also difficult and impossible to be discovered in this way as illustrated in Fig. 3. A more efficient and convenient method has to be developed and proposed in this paper.

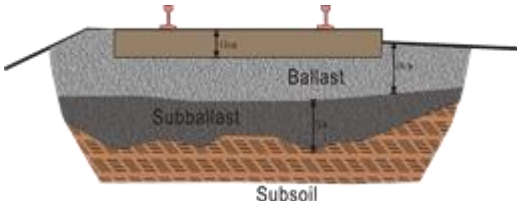

Fig. 1 General structure of railway bed

Fig. 2 Mud pumping observed in the Neiwan branch line in Hsinchu (2016.01.05)

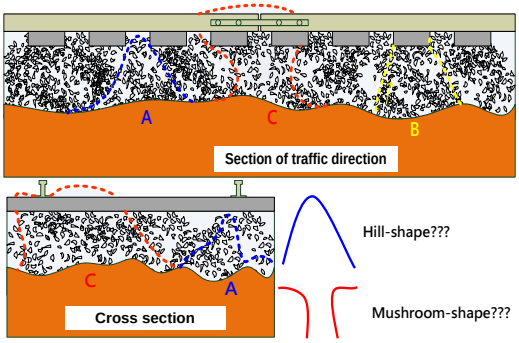

Fig. 3 How pumped materials distribute and form inside the subballasts requires more efficient method to be investigated and inspected

2. Method

Ground-penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. GPR can have applications in a variety of media, including rock, soil, ice, fresh water, pavements and structures. A GPR transmitter emits electromagnetic energy into the ground. When the energy encounters a buried object or a boundary between materials having different permittivities, it may be reflected or refracted or scattered back to the surface. A receiving antenna can then record the variations in the return signal. Dry sandy soils or massive dry materials such as granite, limestone, and concrete tend to be resistive rather than conductive, and the depth of penetration could be up to 15m. In moist and/or clay-laden soils and materials with high electrical conductivity, penetration may be as little as a few centimetres. Ground-penetrating radar antennas are generally in contact with the ground for the strongest signal strength. [1]

Generally GPR are adopted to check the elevation of subballasts and subsoils. However, the mothed is not popular in Taiwan. In this study, a GSSI 400MHz antenna with SIR-20 server were adopted to scan a 40m long railway. This section was selected for varies kinds of mud pumping occurrences observed here. Fig.4 shows the inspection work of pumping performed by the authors.

Fig. 4 Inspection for mud pumping in the Neiwan branch line in Hsinchu (2016.01.05)

3. Results and Discussion

The results from GPR scan shows the distributions and shapes of pumped materials inside the ballasts and subballasts. The blue line indicates the boundaries of pumped materials. Comparing with the pumping material surface that has pumped out the ballasts, the distribution of observed by vision and GPR are coincided. The depth of pumping material boundaries were also identical and proved after opening the ballasts as shown in Fig. 6. Using GPR to scan and inspect mud pumping is firstly performed in Taiwan. The result shows the boundaries of pumping materials can be estimated.

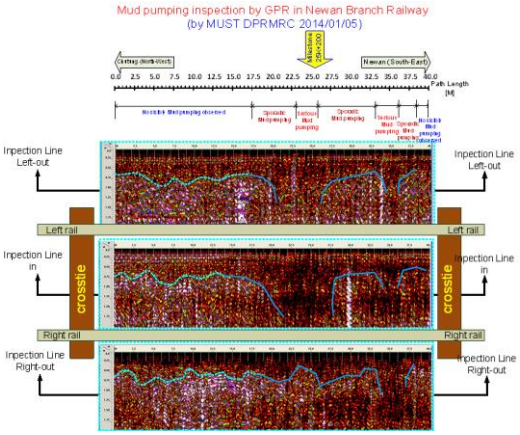

Fig. 5 The pattern of GPR scans and indicates the distributions and shapes of pumped materials inside the ballasts

Fig. 6 The boundaries of pumping materials were found by opening the ballasts

Acknowledgement

Financial support from Ministry of Science and Technology (MOST 104-2622-M-159-001 -CC3) is much appreciated. Study area was provided by Taiwan Railways Administration, MOTC. Related technique was provided by SamHo Technology & Engineering Co., LTD. Their kindly helps are very much appreciated.

References

[1] "Ground-penetrating radar," https://en.wikipedia.org/wiki/Ground-penetrating_radar, May 26, 2016.