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Influence and Control Strategy for Local Settlement for High-Speed Railway Infrastructure

Gaoliang Kang

Bureau of Transport & Department of Track Maintenance, China Railway Corporation, Beijing 100844, China

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ABSTRACT

This paper discusses the main impact factors of the local settlement and differential settlement of high-speed railway lines. The analysis results show that groundwater exploitation is the direct cause of differential settlement. Based on the study of ballastless track additional load and of vehicle, track, and bridge dynamic responses under different differential settlements, a control standard of differential settlement during operation is proposed preliminarily.

1. Introduction

By the end of 2015, the total high-speed railway route length in China exceeded 19 000 km, ranking first in the world. The "four north–south and four west–east" high-speed railway corridors have been preliminarily completed, with an express railway network built up along with other railways, covering most cities and most of the population and playing an important role in transportation. For the operation of such a gigantic railway network, the maintenance of high-speed railway equipment has become a key issue for operation companies to address. The *Major railway technical policies* [1] published in 2013 has explicitly proposed to "explore the status changing rules of equipment and facilities, improve the inspection and repair system, develop scientific inspection and repair standard, and intensify control over the maintenance quality." Improvements in operation management and maintenance and repair technology are extremely significant for the continuous and safe operation of the high-speed railway.

A ballastless track structure is mainly used for high-speed railways with a design speed of 300 km·h^{-1} and above in China. High-speed railways require a track structure with high reliability, high stability, and high regularity. Therefore, the requirements regarding foundation settlement and especially differential settlement are very strict. In order to save land, control settlement, cross rivers, and cross the existing transportation network, viaducts are widely used for high-speed railways in China; in fact, they account for a large proportion of the total length of the railway line (e.g., more than 80% of the Beijing–Shanghai and Shanghai–Hangzhou high-speed railways). The post-construction settlement (the final settlement after laying) of ballastless track bridge piers is extremely strict. Settlement of a pier is not allowed to be greater than 20 mm, and the differential settlement of adjacent piers must be less than 5 mm [2]. The question of how to control and maintain settlement is not only a difficult issue during survey, design, and construction, but also a great challenge confronting the operation and maintenance department.

2. The influence of differential settlement on high-speed railway infrastructure

2.1. The influence of groundwater change on high-speed railway foundation settlement

High-speed railways pass through a variety of complex en-

E-mail address: kgl710@sina.com

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vironmental and natural conditions such as weather, geology, hydrology, and so forth. Most high-speed railways currently in operation have shown good performance, but local settlement that exceeds limits also exists. For example, North China has a settlement area due to a dramatic change of groundwater level. In this area, the differential settlement of piers with a continuous beam and adjacent piers with a simply supported beam varies up to 54.6 mm. The total settlement was as high as 243.5 mm (as shown in Fig. 1), with a settlement rate of 21.1–117 mm per year.

Local and seasonal changes in groundwater level can also cause both positive and negative deformation of the piled foundation of bridges. Fig. 2 shows the relationship between the settlement of bridge piers and changes in groundwater level in Southwest China. According to the observed data, bridge piers were found to rise during the rainy season and sink during the dry season. The amplitude of groundwater level change can be up to 20 m, and the settlement and rising of the bridge pier were 19.0 mm and 38.6 mm, respectively.

Local settlement can cause rapid and severe settlement of the high-speed railway subgrade, which can significantly influence the construction and operation of the high-speed railway.

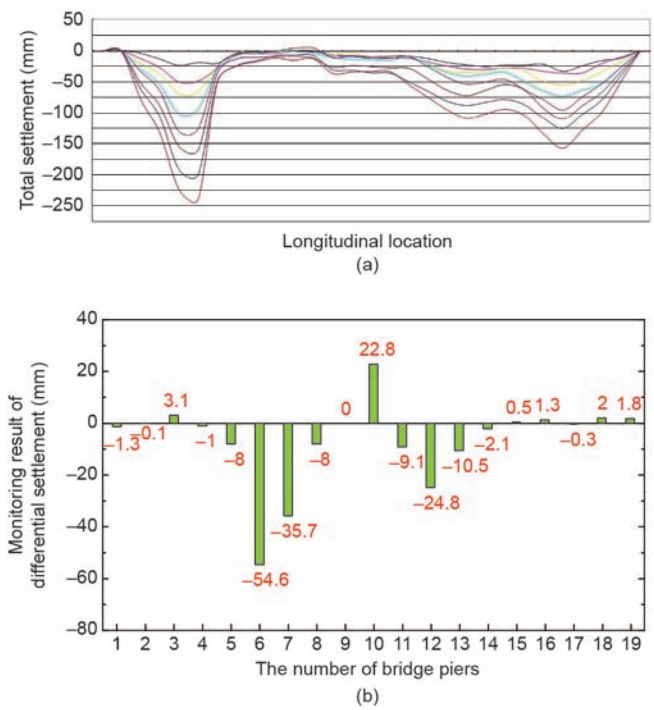

Fig. 1. Subsidence curve and differential settlement. (a) Total settlement distribution; (b) differential settlement distribution.

2.1.1. The influence of groundwater level changes on the differential settlement of bridge pile foundation

Research shows that groundwater level decline is the direct cause of local settlement [3–7]. When studying engineering settlement control of a high-speed railway in an area with local settlement, the conventional practice is to focus on the relationship between groundwater change and land subsidence, and then analyze the influence of land subsidence on the project according to the engineering control standard. The countermeasures that are mainly used involve shutting wells and controlling the usage of groundwater within a certain range on both sides of the high-speed railway [8–9]. Further studies have shown that the groundwater level, stratum characteristics, and pile foundation parameters are the three most important factors affecting the differential settlement of a foundation [10–13].

A decline of the groundwater level can decrease the hydrostatic pressure in the foundation soil. Under this constant total stress, the effective stress of the soil will increase, causing consolidation and settlement of the soil. The permeability coefficient, K, is one of the key factors affecting settlement of the foundation, and can represent the characteristics of different strata. The infiltration curve is more moderate with a greater permeability coefficient. For the same decline of groundwater level, the radius of influence, R, increases gradually with the increase of the permeability coefficient. Fig. 3 shows the relationship between groundwater level decline and the influence radius with different permeability coefficients (clay to sand).

The location of the groundwater level also has a great influence on bridge pile foundation settlement. A bridge pile foundation in Northern China in the funnel settlement area can be taken as an example. Here, the bearing layer is silty clay and the pile has a length of 45 m and a diameter of 1 m. When the groundwater level is below the bottom of the pile (outside the scope of the pile foundation), the homogeneous layered substratum can generate additional stress more uniformly, and has less influence on the pile area. When the groundwater level is located within the scope of the pile foundation (16 m below the top of the pile), the pile foundation differential settlement is predicted to develop as shown in Fig. 4, which shows that 1 m of groundwater level difference may cause differential settlement up to 7.8 mm.

In addition, the length and diameter of the pile and the soil properties have a great influence on the settlement of bridge pile foundation.

2.1.2. The influence of groundwater change on the differential settlement of high-speed railway subgrade pile foundation

Local groundwater level decline caused by the pumping of groundwater is the most important cause of settlement for the pile foundation subgrade of the high-speed railway. Water along

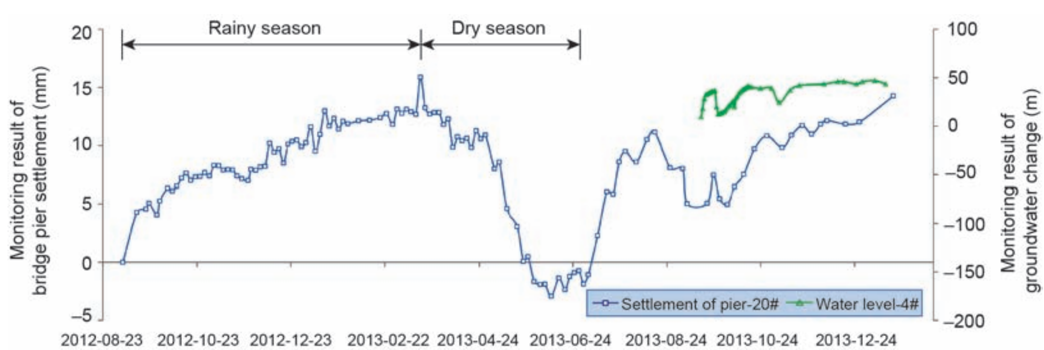

Fig. 2. Relationship between bridge pier settlement and groundwater change.