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Experimental study on bridge–track system temperature actions for Chinese high-speed railway

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ABSTRACT

Atmospheric temperature and directed solar radiation have a significant effect on the temperature field of high-speed railway (HSR) concrete bridge and ballastless track structure. However, temperature actions are random process of which distribution laws are difficult to explore, and existing statistical methods for structure temperature analysis are still not precise. So far, there are few researches for annual temperature spectra and design codes for bridge–track system. Based on the one-year observation data, this paper investigated the temperature actions for Chinese HSR bridge–track structure. By utilizing reliability high moment theory, a statistical method which could built virtual distribution was put forward. Based on the renewed study, the effects of waterproof for deck were taken into consideration, a temperature action model was proposed which is suitable for both bridge and track structure. In addition, for track structure, the previous temperature load models were modified. Apart from that, by proposing the concepts of temperature uniform and fluctuant spectra, the research evaluated service performance of structure. Finally, the distribution regularities of uniform temperature spectra were fitted by Fourier series, and the relationship between structural and atmospheric uniform temperature was established (formula (25)). As a result, according to 50 years recorded atmospheric temperature data, the prediction model of the structure extreme temperature was suggested, and by taking the recurrence interval of 100, 150 and 300 years, the extreme temperatures of the system are 52.23, 54.34 and 57.77 °C.

1. Introduction

The operation mileage of Chinese high-speed railway (HSR) is more than 19,000 km, while quite a part of them are 32 m span standard simply-support bridges with ballastless track laid on [1] (Fig. 1). The thermal stress produced by temperature action could tear the concrete and reduce its durability. What's more, due to the fact that the temperature deformation between bridge and track bed are inconsistent, large temperature difference could cause the separation between the track and bridge, which will affect the operation safety of high speed trains. In addition, bridges and track beds could be considered as a system in temperature action investigation, because both of them are concrete structures. In fact, the temperature action of bridge–track system is a random process, for which

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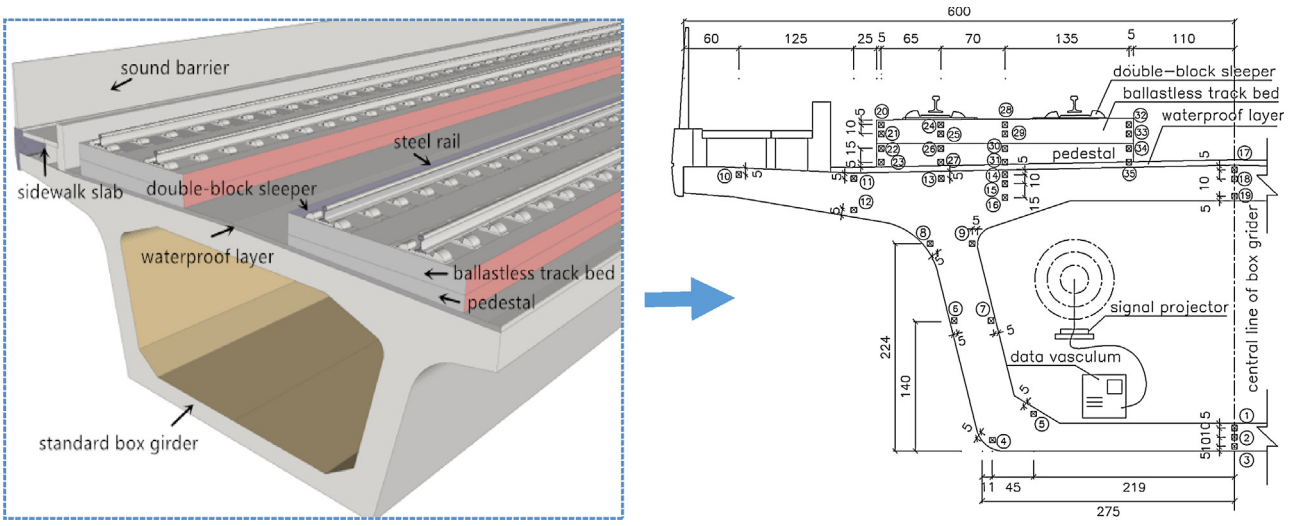

Fig. 1 – Typical section and temperature gauges of Chinese HSR bridge–track system (cm).

temperature travel-time curve is a sequence of random variables with the change law mainly affected by atmospheric environment temperature and direct solar radiation. In view of that, only using finite element model may not reflect the actual temperature distribution of structure and the research could cover many subjects. Therefore, experimental study with interdisciplinary knowledge is necessary.

Although the temperature load models of different bridge and ballastless track design codes are various in each country [2–5], it is a pity that there is neither the requirement of temperature loads for bridge–track system nor influence data of waterproof layer of the deck in Chinese HSR design code [5]. Compared with the box-girder, ballastless track similar to lamella structure, in which great axial force caused by temperature gradient could not be ignored, but there is no design code takes it into account. As for statistical method, most of research methods of structure temperature research are traditional, which depends on fitting curves to find distribution according to former experience to a great extent [6–8]. Therefore, the casualness and uncertainty of these methods are inevitable, with automation unrealized, and accuracy unsure.

At present, a large attention was paid to the effect of extreme temperature for structures' safety, and researches about structure non-linear temperature gradient caused by directed solar radiation are extensive [9–13]. But the annual temperature change laws of the structure in atmosphere environment are shortage of investigation, while the evaluation of service performance was ignored. For structure-atmospheric temperature relation imitation, most experimental researches only monitor it for several days, which could not reflect the real connection between them [14,15], so that longtime relation still needs to be investigated.

Based on one-year observed data, temperature actions of bridge–track system have been investigated. By utilizing reliability high moment theory, a statistical method which could built virtual distribution was put forward. Based on the renewed study, the effects of waterproof for deck were taken into consideration, a temperature action model was proposed which is suitable for both bridge and track structure. In addition, for track structure, the previous temperature load models were modified. Apart from that, by proposing the concepts of temperature uniform and fluctuant spectra, the research evaluated service performance of structure. Finally, the distribution regularities of uniform temperature spectra were fitted by Fourier series, and the relationship between structural and atmospheric uniform temperature was established. As a result, according to 50 years recorded atmospheric temperature data, the prediction model of the structure extreme temperature was suggested.

2. Engineering background

Quite a part of them are 32 m span standard simply-support bridges with ballastless track laid on. For instance, the HSR from Beijing to shanghai is 1318 km, while the total length of bridges is 1140 km which is 86.5% of the whole railway, most of which are 32 m span standard simply-support bridges. Chinese HSR brides and ballastless track are standard designed; the material, technics and sectional dimension are uniform. For this reason, the 32 m standard simply supported bridge and the ballastless track system which are investigated in this paper, could be the representative structure for most bridges and tracks of Chinese HSR.

Secondly, for temperature action research, although the climate condition of different area is not same, the change law between structure and atmospheric temperature is similar. As long as the inherent law between them has been handled, the bridge–track temperature distribution law and loading models could be investigated by the atmospheric temperature data of local weather stations.

Experimental object of this paper is a HSR 32 m span simply-support bridge with the CRTS I double-block ballastless track laying on. The bridge is located in east of China, at longitude 118°2′27″ east, latitude 28°14′3″ north, and the bridge direction is 9.5°. This area is in the subtropical monsoon climate zone, where is warm all year around.