Engineering Failure Analysis 60 (2016) 280–295

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Numerical investigation into thermal load responses of railway transom bridge

Olivia Mirza [a], Sakdirat Kaewunruen [b,*], Cong Dinh [a], Edin Pervanic [a]

[a] *School of Computing, Engineering & Mathematics, University of Western Sydney, Kingswood, NSW, Australia*
[b] *School of Civil Engineering, University of Birmingham, B15 2TT, UK*

A R T I C L E I N F O

Article history:
Received 9 May 2015
Received in revised form 19 November 2015
Accepted 19 November 2015
Available online 22 November 2015

Keywords:
Railway infrastructure
Tracks
Bridge
Thermal load
Finite element analysis
Failure analysis
Longitudinal behaviour

A B S T R A C T

Australian railway networks suffer a large fluctuation of extreme heats each year due to their wide variety of geographical conditions. Depending on climatic, cloud and radiation conditions, an ambient temperature of 20 °C could induce an equivalent thermal load absorption of track components as much as 30 °C to 35 °C or even more. As such, relatively high turnover of timber sleepers (crossties in a plain track), bearers (skeleton ties in a turnout), and transoms (bridge cross beams) can often be observed due to their unstable deformation and rapid deterioration. This paper investigates an application for the replacement of ageing timber transoms mounted on existing railway bridges using fibre reinforced foamed urethane (FFU) transom beams, which are proven to provide environmental, safety and financial benefits. Clear benefits of the FFU material are the maintainability and constructability, especially for existing railway bridges. In this study, numerical simulations using finite element package ABAQUS have been carried out to illustrate the effect of thermal loads on the structural behaviour of a railway transom bridge. The model was developed using a case study of an actual railway bridge in Kiama, Australia and it has been validated by field data measurements. It is found that nonlinear structural behaviour of the bridge components exists at highly elevated temperatures. The better insight into the thermal load responses will lead to safer and more reliable rail stress adjustment practice, preventing rail misalignment or buckling.

1. Introduction

Critical structural components of railway track and structural systems are designed to interact in order to transfer the imposed dynamic loads from the wheels of the railway vehicle to the foundation or support structure of the rail track [1–4]. These dynamic loads include both vertical loads influenced by the unsprung mass of the vehicles and lateral loads mobilized by centrifugal action of cornering or the momentum of breaking vehicles [5]. In general, three dominant forms of railway bridge structures are transom bridges, ballast-top bridges, and concrete viaducts. Based on the current design approach, the design life span of structural bridge systems is around 100 years [6]. Fig. 1 shows a typical railway transom bridge with existing physical constraints. The rail track is built on timber cross beams, so-called 'transoms', which are supported by long-span steel girders between bridge piers.

In recent years, New South Wales (NSW), Australia has experienced unpredictable temperatures and weather conditions. Kiama, being in the south coast of NSW, also experience these unpredictable conditions. The Bureau of Meteorology Australia has recorded its coolest summer in 2011–2012. Last record of similar temperatures was back in the summer of 1996–1997. The max mean temperature for Kiama during December for that period was 23.6 °C making it one of the coldest summers on record. Strong cold southern

---

* Corresponding author at: Birmingham Centre for Railway Research and Education, University of Birmingham, Birmingham B15 2TT, UK.

E-mail addresses: o.mirza@uws.edu.au (O. Mirza), sakdirat@hotmail.com, s.kaewunruen@bham.ac.uk (S. Kaewunruen), Cong.Dinh@manly.nsw.gov.au (C. Dinh), 16545117@student.uws.edu.au (E. Pervanic).

http://dx.doi.org/10.1016/j.engfailanal.2015.11.054

Fig. 1. Ageing railway transom bridge.

winds of up to 85 km/h were also recorded [7]. This observation was drawn from the Bombo Headland observation station. However, there is no cloud observation due to the nearest one being 34 km away in Wollongong. These unpredictable weather conditions make it very difficult to practically design structural parameters relating to any bridge in the local area in the first place. As such, the initial design generally adopted the average environmental data from reliable sources available at the time, and then rail creep monitoring at the bridge ends forms an essential part of rail maintenance and operation management. In this study, a railway transom bridge over the Minnamurra River, in Kiama, NSW, is investigated. The railway bridge links Sydney to the South Coast and spans over 100 m of waterway. As mentioned, there is no adequate data taken for the bridge under higher temperature conditions. The renewal of the bridge was conducted in 2012 by replacing timber transoms with fibre-reinforced foamed urethane (FFU) transoms.

The thermal response of the bridge is crucial when analysing the impact it has on certain component and the whole structure. In the case of thermal expansion occurring, the ballast, sleeper, the steel rail and the rail pads could make the bridge inadequate to support moving trains. As a result, it is important to understand the effect of elevated temperature and thermal expansion on the bridge. 3D finite element analyses using ABAQUS have been conducted to simulate the effect on the railway line due to higher temperatures that are normally experienced during that time of the year. This is focussed specifically in regard to the thermal behaviour of the rails and the supports. The finite element analyses can predict the failure mode and failure zone of the bridge when exposed to elevated temperatures. The outcome of this study will allowed the practice engineers to redesign and strengthened the bridge for future railway bridge construction.

2. Minnamurra railway bridge and its support structures

Bridge transoms or sleepers are the members oriented perpendicular to the rails and distribute the rail vehicle loads imposed through the rail to the superstructure below. Transoms also provide lateral separation of the rails and stability of gauge width between the rails. Currently the most common materials used for intermediate transoms on railway bridges are hardwood timbers. Feasible alternatives for the replacement of deteriorated hardwood timber transoms have been developed recently in Australia [8–10]. According to Manalo et al. [11], existing materials used for railway transoms are timber, concrete and steel with each having their own strengths and weaknesses.

Concrete and steel are not considered to be a viable alternative to timber transoms. Due to high-frequency dynamic forces, high stiffness characteristics and reduced capacity to flex under load (poor tensile strength), traditional concrete transoms typically require a much deeper section than timber transoms. This depth makes traditional concrete transoms relatively expensive and quite heavy, with a typical weight of 285 kg. It was also found that concrete structures tend to be the most cost-effective solution for the railway sleeper application in plain tracks. Benefit cost ratio of concrete sleepers was superior to composites [12–13]. In contrast, concrete transoms for railway bridge application fail to enter the rail market due to excessive weight and thickness. In many practical cases, such conversion is not always possible due to ageing bridge structural systems and associated foundation [14–15].

Recent developments of new materials and composites create opportunities to adopt such new alternative materials in practice. As part of a field trial, '*fibre reinforced foamed urethane*' (FFU) transoms have recently been installed on a railway bridge in Kiama crossing