Engineering Structures 155 (2018) 25–35

Contents lists available at ScienceDirect

Engineering Structures

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

Monitoring based nonlinear system modeling of bridge–continuous welded rail interaction

Alfred Strauss[a,*], Saeed Karimi[a], Martina Šomodíková[b], David Lehký[b], Drahomír Novák[b], Dan M. Frangopol[c], Konrad Bergmeister[a]

[a] University of Natural Resources and Life Sciences, Vienna, Austria
[b] Brno University of Technology, Brno, Czech Republic
[c] Lehigh University, Bethlehem, PA, USA

ARTICLE INFO

Keywords:
Continuous welded rails
Rail–bridge interaction
Admissible rail stress capacity
Temperature monitoring
Non-linear finite element modelling

ABSTRACT

The investigation of longitudinal loads and their influence on stresses and internal forces in continuous welded rails (CWR) connected to bridge deck has been discussed intensively in the last 20 years. These discussions originated from the 1995 UIC-recommendation 774-3R, and led to the introduction of the Eurocode 1. These standards are very conservative. For instance, the code used a bi-linear stiffness–displacement law for the validation of the rail–bridge structure interaction and its effects on the rail stresses lead for short bridge spans to rail interruptions. The objective of this paper is to formulate the capacities and boundary conditions of the rail–structure interaction by means of extended numerical linear and nonlinear analyses, which are not fully comprehended in the standard specifications and therefore result in conservative interaction laws. The analyses have been carried out by means of monitoring-based nonlinear finite element modeling using advanced beam–spring interaction laws and specified thermomechanical considerations for capturing the real thermal expansion of bridge structures.

1. Introduction

Continuous welded rails (CWR) are loaded by longitudinal stresses caused by seasonal temperature changes, bending of the bridge system, and the passing trains. The maintenance of CWR and the lateral buckling behavior due to compression forces caused by temperature changes were discussed in the early 80s by Klaaßen and Schmälzlin [10,8,7,14] and Prommersberger and Rojek [15]. In 1983, the Office for Research and Experiments (ORE, now the European Rail Research Institute, ERRI), of the International Union of Railways (UIC) published the theory and application of CWR on bridge structures subjected to temperature changes in rail and bridge [5]. Details with respect to the influence of the bending of the supporting structures on the longitudinal stress in the rail are reported in Pahnke [13] and details about the track–bridge interaction in UIC774-3R "Union Internationale des Chemins de fer" [22]; in Ruge et al. [16,17] the focus is placed on stresses additional to those from seasonal temperature change due to the sudden change of the coupling stiffness between track and bridge during passing of trains. The history of the CWR and the development of the investigation of track–bridge interaction effects as well as the backgrounds of the verification procedure of additional rail stresses is also presented in Wenner et al. [23,24]. Practical design aspects concerning the track–bridge interaction can be found in Chaudary & Sinha [3] and in Monnickendam [12]. Some of the above mentioned aspects are already implemented in the Eurocode 1.

The recommended linear summation/superposition of the stresses caused by the structure, relative structure–rail displacement and the bending of the structure does not meet the real performance and leads in some cases to significant oversizing or underestimation of the rail capacity. Therefore, the major objective of this study is the verification of the assumption that code specific calculation formats for the bearing capacity of rails are too conservative and need to be improved by using e.g. advanced linear and non-linear numerical analysis techniques taking into account the large scale the realistic behavior of the interaction between the track and bridge deck. The non-linear modelling approaches, used in this contribution, were not aimed at emulating existing models, at expanding them or at defining their limits. The intention was rather to develop a model with the ability to reflect the results of monitoring systems of three bridges, which will consequently enable the transferring of those results to bridge systems in general. In this paper the focus was mainly on the L110 bridge, for which analyses have been carried out by means of monitoring-based material nonlinear

* Corresponding author.
E-mail address: alfred.strauss@boku.ac.at (A. Strauss).

https://doi.org/10.1016/j.engstruct.2017.10.053
Received 25 February 2017; Received in revised form 17 October 2017; Accepted 17 October 2017

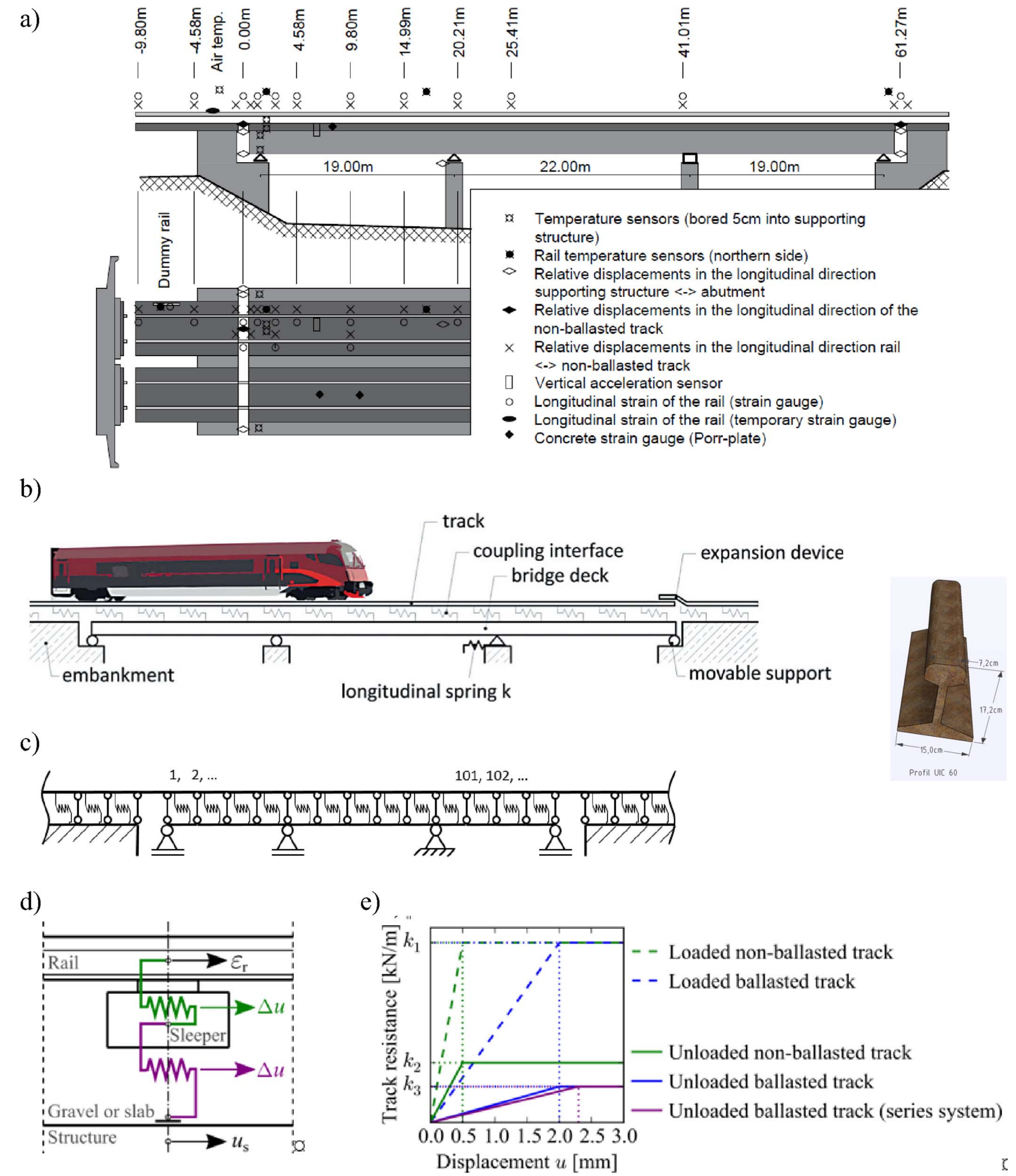

Fig. 1. (a) Static scheme and the monitoring systems of the L110 railway bridge (south view); (b) Spring-Beam model; (c) FEM Spring-Beam model; (d) rail structure interaction spring system for a singular supporting point; and (e) the track resistance – displacement model.

finite element modeling using advanced beam–spring interaction laws and specified thermomechanical considerations for capturing the real thermal expansion. The springs, describing the interaction between the CWR system and the bridge structure, follow a bi-linear shear-resistance law according to EN 1992, see Fig. 1(e). Each spring, associated with a sleeper, is activated in its individual way, due to the thermal and mechanical loading of the rail and bridge system, in its linear elastic or linear plastic material-law, which is also formulated for a mechanical loaded and unloaded situation, see Fig. 1(d) and (e). Hence, during the loading process and also during its numerical description there are