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Experiments into impact behaviour of railway prestressed concrete sleepers

Sakdirat Kaewunruen [a,*], Alex M. Remennikov [b]

[a] RailCorp – Track Engineering, Level 13, 477 Pitt St., Sydney, NSW 2000, Australia
[b] School of Civil, Mining, and Environmental Engineering, Faculty of Engineering, University of Wollongong, Wollongong, NSW 2522, Australia

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ABSTRACT

On railway track structures, dynamic impact loads with very high magnitude but short duration are often caused by wheel or rail abnormalities such as flat wheels and dipped rails. The possibility of the large impact loading to cause an extreme failure to an in situ concrete sleeper could be very low about once or twice in the design life cycle. However, to the current knowledge, the behaviour of the in situ prestressed concrete sleepers under the ultimate impact loading has not yet been comprehended, resulting in the design deficiency. A high-capacity drop-weight impact testing machine was thus constructed at the University of Wollongong, in order to evaluate impulsive resistance of in situ prestressed concrete sleepers under impact loads. This paper describes the detail of the high-capacity impact testing machine, as well as the instrumentation, the calibration, and the analysis of failure mode, crack propagation, flexural toughness, and energy absorption mechanisms with respect to railway prestressed concrete sleepers. The impact tests were carried out using the prestressed concrete sleepers manufactured in Australia. An in situ track test bed was simulated in laboratory and calibrated against the frequency response functions obtained from the experimental modal analysis. The experiments using the high-capacity impact testing machine to investigate the impact energy transfer mechanism of the prestressed concrete sleepers are highlighted.

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1. Introduction

Railway sleepers (or called ‘railroad tie’) are an important element of railway track structures. Their designed function is to distribute loads from the rail foot to the underlying ballast bed. Fig. 1 shows a typical ballasted railway track. Substructure (ballast, sub-ballast, subgrade, and formation) and superstructure (sleeper, rail pad, fastener, and rail) constitute a railway track system. It is believed, based on the industry experience, that prestressed concrete sleepers have reserves of strength that are untapped. It is thus important to ascertain the spectrum and amplitudes of forces applied to the railway track, to understand more clearly the manner in which track components respond to those forces, and to clarify the processes whereby concrete sleepers in particular carry those actions. In addition, cracks in concrete sleepers have been visually observed by many railway organizations, including the field trials by the authors [1]. As noted in a review report [2], the principal cause of cracking is the infrequent but high-magnitude wheel loads produced by a small percentage of abnormal wheels or railhead surface defects. Those loads are of short duration but of very high magnitude. As an example, the typical loading duration produced by the wheel flats could vary between 1 and 10 ms, while the force magnitude could reach up to 600 kN per rail seat. Existing design philosophy [3] for prestressed concrete sleepers is based on the allowable stress principle taking into

* Corresponding author. Tel.: +61 02 8922 1151; fax: +61 02 8922 1154.
E-mail address: sak.kaewunruen@railcorp.nsw.gov.au (S. Kaewunruen).

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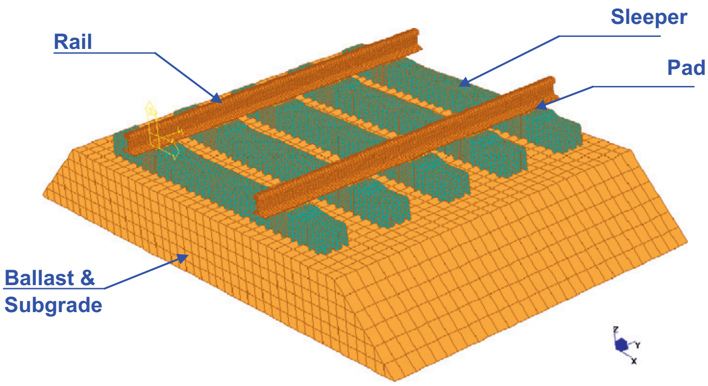

Fig. 1. Typical components of railway tracks.

account only the quasi-static wheel loads, which results in overly conservative, deficient design for concrete sleepers. Limit states design concept, which considers the probabilistic dynamic loading condition, is a more logical entity for the development of a new design approach for prestressed concrete sleepers. Current knowledge to date is insufficient with respect to constituting the new limit states design concept. As a result, the research tasks are required to perform fundamental studies of the loading conditions, the static behaviour, the dynamic response, and the impact resistance of the prestressed concrete sleepers [3]. A major research effort at the University of Wollongong was to evaluate the ultimate capacities of concrete sleepers under static and impact loads.

This paper focuses on the impact testing methodology of prestressed concrete sleepers, and the study on energy transfer mechanism in a simulated track environment. The emphasis of this paper is also placed on the experimental verification of the ultimate impact resistance and failure modes of railway prestressed concrete sleepers. The prestressed concrete sleepers used were designed in accordance with Australian Standard: AS1085.14 [4]. The support condition provided by the track were simulated using a resilient material and validated against the in-field and laboratory vibration measurements [5]. In this paper, the experiments using the high-capacity impact testing machine to evaluate impact response of the prestressed concrete sleeper in a rail track with soft support condition are demonstrated. The test results could be used for validating a numerical model for design purpose and for predicting a transfer mechanism of other track configurations upon which it is beyond the scope of this paper.

2. Experimental overview

2.1. Specimens

The prestressed concrete sleepers were supplied by an Australian manufacturer, under a collaborative research project of the Australian Cooperative Research Centre for Railway Engineering and Technologies (Rail CRC). The typical full-scale prestressed concrete sleepers, which are often used in broad gauge tracks, were selected for these tests. The dimensions and shape of the prestressed concrete sleeper specimens are shown in Table 1. The high strength concrete material was used to cast the prestressed concrete sleepers, with the characteristic compressive strength at 28 days of 55 MPa, and the prestressing steels used were the high strength with rupture strength of 1860 MPa. However, the cored samples, drilled from the sleepers, were taken for a confirmation test, as per the Australian Standard AS1012.14 [6], given that the average compressive strength at the test age of about 2 years was 80 MPa. It had been believed that the high strength prestressing wires were of high quality and the strength would not change during time. The test specimens of prestressed concrete sleepers are shown in Fig. 2.

2.2. Support condition

In a railway track, a sleeper is supported by a layer of loose, coarse, granular materials with high internal friction, so-called 'ballast'. It is often a mix of crushed stone, gravel, and crushed gravel through a specific particle size distribution. Using a typical ballast bed leads to difficulties in controlling the boundary conditions in either the experiments or the

Table 1
Dimensions and masses of the test sleepers.

Mass (kg)	Gauge length (m)	Total length (m)	At railseat (m)		At centre (m)	
			width	depth	width	depth
299.5	1.60	2.85	0.22 (top) 0.25 (bottom)	0.21	0.22 (top) 0.25 (bottom)	0.18

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