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Relationships between wheel/rail interface impact and railseat flexural moment of railway prestressed concrete sleepers

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ABSTRACT: Wheel/rail interactions often generate interface impact forces to railway tracks due to the wheel/rail abnormalities. Accordingly, the damage of track components, especially for the concrete sleepers, is often observed and unpredictable as its current design concept relies mostly on the quasi-static behaviour. Limit states design concept then provides more logical entity for the design approach associated with the behaviours of such sleepers. This paper presents the experimental and analytical investigations, in order to evaluate the relationships between wheel/rail impact forces and resultant railseat flexural moment of railway prestressed concrete sleepers. It enables and enhances the methodology to analyse and design for the prestressed concrete sleepers at ultimate limit states.

INTRODUCTION

Over the years the tracks have been deteriorating due to increased traffic frequency, heavier wheel loads and improper maintenance. Increased wheel load leads to an increasingly detrimental response of the track system, resulting in a premature failure of its components. When increased wheel loading is expected on a given line, it is necessary to evaluate the feasibility all the components can sustain. A major component of railway track structures to distribute loads from rail foot to the ballast bed is railway prestressed concrete sleeper, or so-called 'railroad tie' (see Fig.1). In practice, railway concrete sleepers have been suspected for their untapped, reserved strength. It has also been observed that cracks in concrete sleepers are attributed to the infrequent but high-magnitude wheel loads produced by a small percentage of wheel/rail abnormalities. Current design philosophy for prestressed concrete sleepers is based on permissible stress principle taking into account only the static and quasi-static loads, which are inconsistent to the nature of loadings on tracks. Thus, the more rational design method is required on the basis of limit states approach, which will substantially improve the reliability and sustainability of the sleepers in their life cycle. In order to devise a new, innovative limit states design concept, the research efforts are required to perform comprehensive studies of the loading conditions, static and dynamic performance, impact resistance, and risk of the prestressed concrete sleepers [1]. To compliment the main goal, this paper carries out the fundamental concept on the relationships between impact forces applied and resultant bending moments, enabling further studies presented in the companion papers [2,3].

ANALYTICAL STUDIES

The analytical studies have been carried out using DTRACK, the package for dynamic analysis of railway tracks, developed under a collaborative research project of the Australian Cooperative Research Centre for Railway Engineering and Technologies (Rail CRC). A benchmark study has been done recently by Murray [4]. The further analysis of those data is presented in Fig. 3.

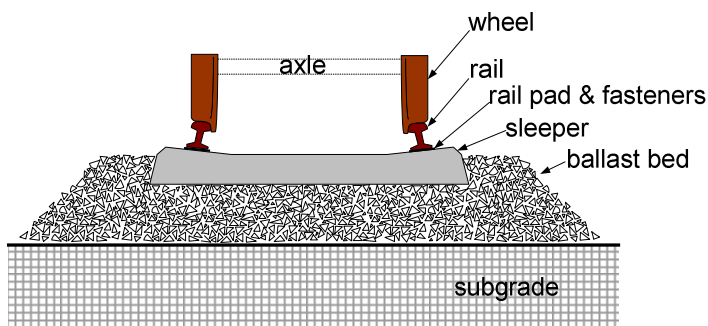


Figure 1 Typical ballasted track structure

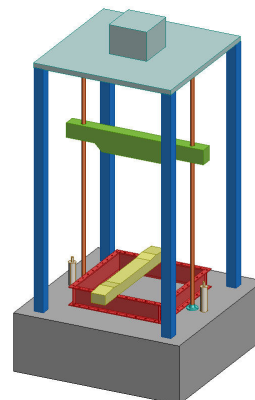


Figure 2 Drop-weight impact machine

EXPERIMENTS

The high-capacity drop-weight impact testing machine has been depicted in Fig. 2. The in-situ conditions of railway concrete sleeper were replicated [5-7]. Experimental setups for impact tests were arranged in accordance with AS1085.14 [8]. Attempts to simulate impact loading actually occurred in tracks were succeeded experimentally and numerically. The falling mass was dropped at increasing heights step by step until the sleepers start cracking. The strain gauges were installed at top and bottom fibres of the test sleepers to evaluate the resultant bending moment. The experimental results are shown in Fig.4.

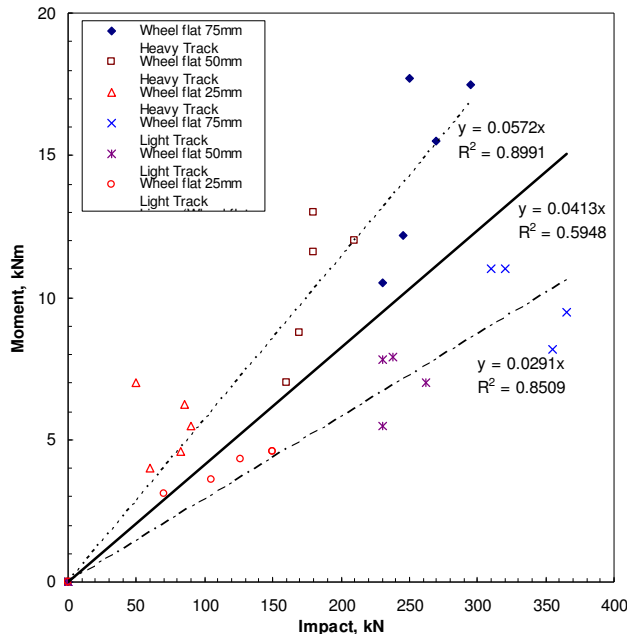


Figure 3 Analytical results

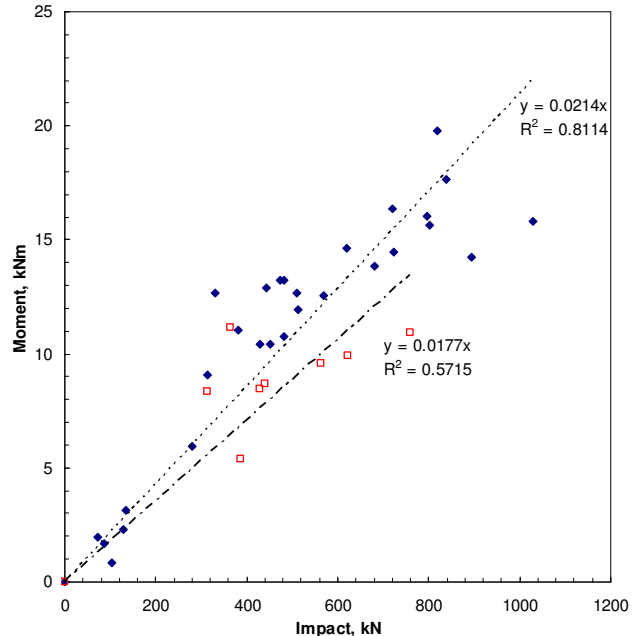


Figure 4 Experimental results

RESULTS AND DISCUSSIONS

The analytical results yield the scatter data of different track models as shown in Fig 3. It is found that the heavy and light tracks possess different relationships between the railseat moment and impact force. The function between railseat moment (M) and impact force (I) for the light track is about $M = 0.03I$ while $M = 0.06I$ can be used for heavy tracks. These analytical solutions provide the general approximation for uses in track designs as the discrepancies are less than 15%. However, the experimental results illustrated in Fig.4 show that the test setup well simulates the actual light tracks. The relationship between artificial impacts and railseat moment is about $M = 0.02I$ with the correlation index of over 80%. This result also shows that there certainly is the energy loss in the test system, including impactor and foundation. The larger impact force given, the more energy lost. Based on this relationship, the ultimate impact resistance can be identified and simulated for the next phase of experimental studies.

CONCLUSIONS

The relationships between wheel/rail interface impact force and flexural moment acting at railseat of railway concrete sleepers are investigated experimentally and numerically. It is discovered that each particular track exhibit distinctive relationship and the best way to determine the bending moment along the railway sleepers is to employ the advanced dynamic analysis of railway tracks. However, in railway practice, the analytical and experimental results in this study confirm and provide the faster and adequate means to predict the bending moment on the sleepers from the anticipated wheel/rail interaction.

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