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Review

Failures of mainline railway sleepers and suggested remedies – Review of current practice

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ABSTRACT

Over the last two decades, the premature failures of traditional railway sleepers have significantly increased the track maintenance costs. The primary obstacle to minimising this problem is the lack of understanding of the mechanism of sleeper degradation. This paper discusses the different deterioration mechanisms for traditional timber, concrete and steel sleepers and the potential protective measures to minimise these problems. This paper exhaustively reviews the failure mechanisms of these three commonly used sleeper materials with suggested solutions. Fungal decay, end splitting and termite attacks has been identified as the principal causes of timber sleeper failures. On the other hand, concrete sleepers are vulnerable to rail-seat deterioration, cracking and damaging under different loading conditions and adverse environments. Steel's risk of corrosion and fatigue cracking makes it an inferior-quality material for sleeper. Solution approaches are recommended and provided in this paper in order to the best utilise these different railway sleeper materials. New materials are also introduced as effective alternative to replace the traditional railway sleepers.

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1. Introduction and motivation

The Australian railway transport industry may realise a potential savings of $A80 million per annum in its operating cost if further improvements could be made in its railway operation and maintenance [1]. The premature deterioration of railway sleepers has become of great concern over the last two decades even the sleeper perfectly supported by the underlying ballast. For many years, timber, concrete and steel, which have targeted life spans of 20, 50 and 50 years, respectively have been used as sleeper materials. However, under certain circumstances and in particular environments, these traditional sleepers have not satisfactorily met the performance requirements due to their unexpected early failures. It has been reported that over 12 million timber sleepers are replaced every year in the USA due to in-service damage resulting in splitting and excessive wearing at a cost of around 500 million dollars [2] while another report indicates that the cost of sleeper renewal is about 12% of the total maintenance-of-way cost, that is, approximately twice that of the rail renewal [3], which has forced researchers and railway industry to think of effective ways of minimising this problem.

The demand for sleepers has been increasing over time, as the railways plays a significant role in the transport systems. In 2006, the International Federation for Structural Concrete [4] conducted a worldwide survey of annual demands for traditional sleepers in rail networks and is presented in Table 1.

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Table 1
Sleepers in world's railway networks.

Country	Total sleepers in track (×1000)	Demands per year (×1000)		
		Concrete	Steel	Timber
Argentina	–	60	–	–
Australia	600,000	–	150	200
Austria	9000	200	70	100
Belgium	9912	400	2	20
Brazil	50,000	500	60	300
Chile	5300	200	–	–
China	115,000	3000	–	–
Colombia	5080	–	–	–
Czech Rep.	17,000	250	–	3
Denmark	–	150	–	–
France	60,000	800	0	400
Germany	70,000	1400	100	100
Greece	6150	30	5	3
Hungary	20,388	–	–	–
India	163,500	4640	–	–
Italy	40,000	2000	–	–
Japan	34,000	400	–	–
Malaysia	3000	–	–	–
Morrocco	5000	–	–	–
Netherlands	8500	400	–	–
Norway	3000	60	–	–
Romania	16,000	12	–	–
Russia	150,000	3500	–	–
S. Africa	43,000	305	0	0
Spain	30,000	1200	0	30
Sweden	19,500	400	–	8
Switzerland	17,000	150	–	–
Taiwan	4000	120	0	12
USA	600,000	1000	10	13,000
UK	45,000	500	400	100
Venezuela	1225	–	–	–

This survey illustrates that concrete is the dominant material for sleepers in many countries except in the USA where there is a major demand for timber sleepers. It is estimated that, there are currently approximately three billion sleepers in the world's railway networks. Over 400 million of these sleepers are made from concrete and 2–5% of them requires replacement every year due to their premature failure [5]. Similarly, Australia has one of the largest rail networks in the world where approximately 13% are made from steel [6]. A sleeper's ability to resist cracking, oxidation, chemical degradation, delamination and wear damage for a specified period of time, under appropriate load conditions and specified environmental conditions, has become of great concern. Research and innovation are now focusing on the durability of sleepers as the lack of understanding of sleeper degradation mechanisms is a great concern [7]. This paper aims to present these failure mechanisms and provide suggestions for minimising them to provide useful information to engineers, designers as well as asset owners.

2. Failure of timber sleeper

Proper investigation of the causes of premature failures of sleepers to minimise the cost of track maintenance and to improve the track efficiency, is necessary. The Railway of Australia (ROA) [8] surveyed several states in Australia in order to understand the causes and modes of failure of timber sleepers. For this purpose, it examined 2200 timber sleepers in Queensland railway tracks and found different reasons for the sleeper damage including fungal decay, end splitting, termites, still sound, sapwood, shelling, rail cut, weathering, spike kill and knots (Fig. 1). Of those failure types, fungal decay (53%), end splitting (10%) and termite attacks (7%) were found to be the principal causes of timber sleeper failure.

2.1. Fungal decay

Fungal decay is the predominant mode of timber sleeper failure as timber is susceptible to bio-deterioration from many micro-organisms because timber is an organic material. A fungus can lie dormant in timber until it obtains at suitable environment containing moisture, oxygen and nutrients. Railway sleepers can absorb moisture, especially in rainy seasons, that makes fungi reactive and when they are in timber, can spread from one sleeper to another across non-nutritional surfaces that adversely affect a track's structural integrity [9,10]. Fig. 2 presents the fungal decay of a timber sleeper in a railroad track.

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