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Review

Composite railway sleepers – Recent developments, challenges and future prospects

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ABSTRACT

A number of composite railway sleeper technologies have been developed but their applications in rail tracks are still limited. This paper rigorously reviews the recent developments on composite sleepers and identifies the critical barriers to their widespread acceptance and applications. Currently the composite sleeper technologies that are available ranges from sleepers made with recycle plastic materials which contains short or no fibre to the sleepers that containing high volume of fibres. While recycled plastic sleepers are low cost, the major challenges of using this type of sleepers are their limited strength, stiffness and dynamic properties which in most cases, are incompatible with those of timber. On the other hand, the prohibitive cost of high fibre containing sleepers limit their widespread application. Moreover, limited knowledge on the historical long-term performance of these new and alternative materials restricts their application. Potential design approaches for overcoming the challenges in the utilisation and acceptance of composite sleeper technologies are also presented in this paper.

Contents

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1. Introduction

The traditional materials used to manufacture railway sleepers are timber, concrete and in some cases steel, which are generally designed for 20, 50 and 50 years, respectively [1–3]. Timber was the earliest material used and more than 2.5 billion timber components have been installed worldwide [4]. They are adaptable and have excellent dynamic, electrical and sound-insulating properties. Around the 1880s, due to the scarcity of timber and the sensitivity to its use, steel railway sleepers were introduced as an alternative to timber. As their design has evolved, the original ones are now being replaced by modern 'Y' shaped steel ones. During the last few decades, the railway industry has focused on a cement-based concrete rather than timber and steel sleepers. Mono-block prestressed concrete sleepers were first applied in 1943 and are now used in heavy haul and high speed rail track constructions throughout the world [5].

This leads to the question on why the railway industry uses a variety of sleeper materials rather than a particular one? Undoubtedly, the main reason is that none of the existing materials (timber, steel and concrete) does satisfactorily meet all the requirements of a sleeper. The review by Manalo et al. [6] on alternative materials to timber indicated the high demand for new sleeper materials. A recent study on the potential causes of failures of railway sleepers [7] showed that the traditional materials have not satisfactorily met the demand requirements to resist mechanical, biological and chemical degradation (Fig. 1).

The problems of timber rotting, splitting and insect attack, as well as its scarcity introduced a new challenge. Steel's risk of corrosion, high electrical conductivity, and fatigue cracking in the rail-seat region, and the difficulty of them packing within the ballast made steel sleepers an inferior material for use in sleepers. On the other hand, prestressed concrete sleepers, which offer greater durability than timber and steel, suffer from being heavy and having a high initial cost, low impact resistance and susceptibility to chemical attack. Due to the heavy weights, their transportation costs are significantly higher, they are difficult to handle and require expensive and extensive equipment for installation [8]. Moreover, concrete and steel sleepers require special fasteners and cannot replace timber ones in an existing track because of their incompatible behaviour [6]. From an environmental point of view, the production of traditional sleeper materials create several problems; for example, many trees need to be cut down to make timber sleepers while the cement and steel industries emit huge amount of carbon dioxide into the atmosphere during their production. All the aforementioned issues have motivated researchers around the world to develop and investigate new and effective alternative sleeper technologies for railway industry.

Nowadays, the global market for composites is rapidly increasing because of the many advantages including high strength-to-weight ratio, excellent resistance against corrosion, moisture and insects, and thermal and electrical non-conductivity [9]. This material can be engineered according to the specific requirements of railway sleepers [10]. Therefore, it is believe that the composite railway sleepers can be a suitable alternative for existing concrete, steel and, particularly, timber ones in both mainline and heavy haul rail networks. Moreover, composites demonstrate the material for the future generation sleeper. This paper provides an overview of recent developments of composite railway sleepers and their limitations, and suggests a solution which overcomes the challenges inherent in their utilisation and acceptance.

2. Recent developments on composite sleepers

Several composite sleeper technologies have been developed in different parts of the world. These technologies have emerged as a potential alternative to timber sleepers. Different from steel and concrete, composite sleepers can be designed to mimic timber behaviour (an essential requirement for timber track maintenance), are almost maintenance free, and are more sustainable from an environmental perspective. This section discusses the different classifications based on the amount, length and orientation of fibres in composite railway sleepers that are currently available and including technologies that are still in the research and development stage.

(a) timber (b) steel (c) concrete

Fig. 1. Example of diverse failure modes of sleepers during service life [6,7].