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A Review on Composite Railways Sleepers; Recent Developments, Limitations & Future Perspectives

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Abstract

The current review on a number of composite railway sleeper technologies have been developed, there are still few places where they are used in rail tracks. This report thoroughly examines recent advancements in composite sleepers and discusses the major obstacles to their broad adoption and use. Currently, there are a variety of composite sleeper technologies on the market, ranging from those made of recycled plastic that have few or no fibers to those that have a lot of fibers. Although recycled plastic sleepers are inexpensive, employing them poses significant difficulties because to their poor stiffness, strength, and dynamic qualities, which are frequently incompatible with those of timber. The exorbitant cost of high-fibre sleepers, on the other hand, prevents their widespread use. Further limiting their use is the lack of information on the historical long-term performance of these new and alternative materials. This research also presents potential design strategies for resolving the obstacles to the use and adoption of composite sleeper technologies.

Keywords: Railway sleepers, Composite, Recycled plastic, Fibres

1.Introduction

Timber, concrete, and occasionally steel are the conventional materials used to make railroad sleepers, and these three materials are typically intended to last 20, 50, and 50 years, respectively [1-3]. More than 2.5 billion timber components have been installed globally [4]. Timber was the first material used. They offer outstanding dynamic, electrical, and sound-insulating qualities and are flexible. Steel railway sleepers were adopted as a substitute for lumber around the 1880s because wood was scarce and its usage was sensitive. The original ones are currently being replaced by contemporary steel ones in a 'Y' shape as their design has developed. In recent years, cement-based concrete has taken center stage in the railway sector, replacing timber and steel sleepers. Since their introduction in 1943, mono-block prestressed concrete sleepers have been utilized in heavy load and high-speed rail track installations all over the world [5]. This raises the question of why, as opposed to using only one type of sleeper material, the railway industry uses a variety of them. Without a doubt, the primary factor is that none of the materials now in use (wood, steel, and concrete) adequately satisfies all of the sleeper's criteria. The significant demand for novel sleeper materials on materials other than lumber. The traditional materials have not effectively met the demand criteria to resist mechanical, biological, and chemical degradation, according to a recent study on the potential reasons of failures of railroad sleepers [7] (Fig. 1).

(a)- Timber **(b)- Concrete**

Figure 1: Failures on different Railways sleepers

A new difficulty was created by the issues with timber's rot, splitting, and insect attack, as well as its dearth. Steel is a poor material for use in sleepers due to its susceptibility to corrosion, high electrical conductivity, fatigue cracking in the rail seat region, and difficulties in packing within the ballast. Conversely, prestressed concrete sleepers suffer from being heavy, having a high initial cost, having limited impact resistance, and being vulnerable to chemical assault, although offering more durability than lumber and steel. Due to their huge weights, they require expensive and sophisticated equipment for installation, are challenging to handle, and have much greater shipping expenses [8]. Additionally, because to their inconsistent behaviors, concrete and steel sleepers cannot replace timber ones in an existing track and need unique fasteners [6]. From an environmental perspective, manufacturing traditional sleeper materials has a number of drawbacks. For instance, it takes a lot of trees to build timber sleepers, and manufacturing cement and steel releases a lot of carbon dioxide into the atmosphere. Researchers from all around the world have been inspired by the aforementioned problems to create and research cutting-edge alternative sleeper technologies for the railway sector. Due to their numerous benefits, such as their high strength-to-weight ratio, exceptional resistance to corrosion, moisture, and insects, and thermal and electrical non-conductivity, the global market for composites is currently growing quickly [9]. This material can be designed to meet the unique needs of railroad sleepers [10]. As a result, it is thought that composite railway sleepers could be a good replacement for current concrete, steel, and especially timber ones in both mainline and heavy load rail networks. Additionally, composites show the material for the next-generation sleeper. In addition to outlining current advancements in composite railway sleepers and their shortcomings, this study offers a solution that gets beyond the problems with their use and acceptability.

2.Recent Research on Composite Sleepers

In various parts of the world, a number of composite sleeper technologies have been created. These innovations have come to light as a possible replacement for timber sleepers. Composite sleepers, as opposed to steel and concrete, may be made to replicate the behavior of wood, which is necessary for maintaining timber tracks. They also require nearly no maintenance and are more environmentally friendly. This section examines the various categories of composite railway sleepers that are currently in use, including technologies that are still in the research and development stage, based on the quantity, length, and orientation of fibers.

2.1 Type-1 Sleepers Have Minimal or No Fiber Reinforcements.

Type-1 sleepers are made of recycled plastic (such as plastic bags, used auto tires, coffee cups, milk jugs, and laundry detergent bottles) or bitumen with fillers (such as sand, gravel, recycled glass, or short glass fibers less than 20 mm). These sleepers' structural behavior is primarily influenced by polymers. Although some of these solutions used short glass fiber to increase stiffness and/or prevent cracking, they did not significantly improve structural performance as needed for heavy load railway sleeper use. Some railroad maintenance firms have adopted and are testing the use of these materials as a result of the increased demand for alternate sleeper materials. Type-1 sleepers have a number of advantages as a sleeper material, including being simple to drill and cut, having good durability, using fewer resources, being inexpensive, and being tough. Its drawbacks include poor strength and stiffness, limited design flexibility, vulnerability to temperature and creep, and low fire resistance. [11,12].

2.2 (Type-2) Longitudinally Long Fiber Reinforced Sleepers

Type-2 sleepers are sleeper technologies that have no or very short random fibers in the transverse direction and long continuous glass fiber reinforcement in the longitudinal direction. Long glass fiber plays a major role in determining the strength and stiffness in the longitudinal direction, whereas polymer predominates in the transverse direction. In bridge applications (such as transoms), when the sleepers are subjected to high levels of combined flexural and shear forces, these sleepers are less than ideal because the stresses in the sleepers are dominated by flexural loading. The benefits of the sleeper in this category include ease of drilling and cutting, good durability, exceptional flexural strength, and a high modulus of elasticity. However, this sleeper has certain difficult problems, including low shear strength and shear modulus, restricted design flexibility, poor fire resistance, and expensive cost. The synthetic FFU (Fiber-reinforced Foamed Urethane) sleeper [13-15].

3.Issues with Use of Composite Sleepers

The newly produced composite sleepers have a number of benefits, but the railway industry has only just begun to accept them. The common problems with employing composite sleepers are discussed in this section.

3.1 Composite Sleepers Price

One of the key causes for the sluggish market adoption of most composite sleeper technologies has been attributed to their prohibitive pricing. According to Recycled Technologies International (RTI), their prices for Type-1 sleepers range from 85 to 105 USD, not including installation, which adds significantly to the cost and can be between 70 and 200 USD each sleeper [18]. However, its lower life cycle cost is projected to balance out its high initial cost [16,17,18], which must be comparable to or barely greater than that of traditional ones in order to catch the attention of the railway sector. Similar to this, streamlining the production procedure and material consumption would produce a more affordable sleeper product.

3.2 Material Voids

The raw components are combined, melted, and compounded during the production of a plastic composite sleeper (Type-1), and the resulting homogeneous mixture is then extruded into molds. The chilling procedure begins after the molds are filled. There is a significant chance that voids will grow inside the materials during this time. Composite sleepers in the rail-seat region have reportedly sunk into their bodies while in use [19]. Additionally, voids have the potential to rupture and transmit loads from one component to another, which can result in a stress concentration and local sleeper failure before the end of the product’s design life. Depending on the manufacturing processes used, this issue can arise during the creation of any material, but not for timber made from real trees.

3.3 Limited Insight About Performance Throughout Time

Although the majority of composite sleeper manufacturers have assessed the static performances of their products, it is still uncertain how the different types of sleepers will perform over the long term in terms of dynamic characteristics, impact resistance, fatigue, and durability. A sleeper is frequently susceptible to dynamic, impact, and fatigue loads, as well as important weathering action, as mentioned in the following subsections, so it is imperative to analyze these issues before installation.

3.4 Ultra-Violent Radiations

Railway sleepers used outdoors are frequently exposed to ultraviolet (UV) light from the sun, which has enough energy to rupture a structure's chemical connections. While UV can influence the lignin of wood, the matrix in a fiber-reinforced polymer composite is frequently regarded as the weak link because it experiences physical damage and chemical deterioration when exposed to the environment and stressed applications [20-21].

In the case of plastic materials, UV has an impact on both the chemical structure and the mechanical properties, which causes embrittlement, discoloration, and a general reduction in the material's physical and electrical properties a phenomenon that can drastically shorten a sleeper's useful life [22-23].

3.5 Raised Temperature

High environmental temperatures are frequently applied to railway parts, especially during the summer. A polymeric sleeper can exhibit two distinct mechanical behaviors both below and above its glass transition temperature (Tg). A polymeric material has a high modulus and acts like a glassy material while the temperature is considerably below its Tg, but when the temperature is above its Tg, the modulus rapidly decreases and the material takes on a rubbery appearance. When determining it using the DMA approach, obtained the variations of Tg for polymer epoxy grouts varies between 60 and 90 C [24]. Moisture can also have an impact on a polymeric composite's Tg, which decreases when water is absorbed [25].

4. Future Perspectives

The main drawbacks of Type-1 composite railway sleepers are their insufficient stiffness, strength, and dynamic qualities, which are frequently incompatible with those of wood. Although Type-2 and Type-3 sleepers have solved the shortcomings of Type-1 sleepers' poor structural performance, their exorbitant costs as compared to materials for regular sleepers continue to be a significant obstacle. Additionally, the absence of design rules and understanding regarding their long-term performances limit their extensive applications and utilizations. Table 1 provides a comparison of the effectiveness of three distinct types of composite sleepers. More thorough research is required to solve the shortcomings of the current composite sleepers. The following strategies are suggested to get around composite sleepers' existing drawbacks.

Properties	Type-1	Type-2	Type-3
Price	Low	High	High
Shear strength	Low	Medium	Good
Stiffness	Low	Good	Good
Anchorage capability	Low	Good	Good
Cutting& Drilling	Easy	Easy	Moderate

Table 4. Comparison between different kinds of composite sleeper

4.1 Improvement in Performance of Structure

Timber and recycled plastic sleepers (Type-1) behave structurally incompatible. Due to the incorporation of long reinforcement fibers, the Sekisui FFU synthetic composite sleeper (Type-2) offers greater strength and stiffness than Type-1 composite sleepers, although it is currently relatively expensive and its use is mostly restricted to turnout applications. It is advised that fiber reinforcements be utilized to increase the strength and stiffness of the recycled plastic sleepers (Type-1) because they are much less robust and rigid than conventional wood sleepers. However, in order to determine the methods by which the fibers will interact with thermoplastic polymer, more research is needed.

4.2 Evaluations in Terms of Performance

The performance of the composite material is influenced by its durability and capacity to handle environmental loads such as UV radiation, high pH, extreme hot and low temperatures, moisture, and others, in addition to operating load requirements. The performance histories of these novel materials in the railway industry are rather brief compared to those of more traditional sleeper materials like hardwood, concrete, and steel because composite railway sleepers are a relatively new technology. To improve the market and boost confidence in adopting these alternative materials, short- and long-term research into the behavior of composite sleepers is crucial. Additionally, it's important to continuously evaluate performance to make sure they can support the loads needed for installation and maintenance.

4.3 Recommendations of Designs and Standards

The standard for existing sleeper materials is utilized to create a composite railway sleeper because there is currently no widely accepted standard for composite sleepers (especially Type-3). While adopting JIS Z2101 and DIN EN standard, AREMA (2013) specifies the minimum physical and mechanical performance standards for an engineered composite sleeper (Type-1) and FFU (Type-2); however, these are only applicable to standard gauge railway tracks [26-27].

It is important to establish design suggestions for composite railway sleepers so that their full potential can be utilized to reach an acceptable degree of structural reliability. The adoption of these innovative sleeper technologies as an alternative to conventional railway sleeper materials will be further encouraged by the development of national and international standards factors that reduce capacity the design standard for prestressed concrete sleeper AS 1085.14 is based on the allowable stress design idea, which has been shown via significant study to produce less effective and economical results than the limit state design method. For composite railway sleepers, limit state design equations must be created with values for partial load factors and capacity reduction factors [28].

5. Conclusion

Researchers, engineers, and end users are considering composite material sleepers as an alternative to timber, concrete, and steel sleepers because of their high maintenance costs and environmental issues. Many have recently been created in various parts of the world, but their market acceptance has been incredibly gradual. The main barriers to the widespread use of recycled plastic sleepers are their low strength and stiffness, low anchorage ability of holding screws, formation of voids in the sleeper's body, permanent deformation due to creep and temperature variations, and inadequate lateral resistance. This study offered some potential solutions to the difficulties currently associated with employing composite sleepers. Fiber reinforcement can increase the strength and stiffness of recycled plastic sleepers, and cost-effective high-fibre sleepers can be produced by maximizing the use of raw materials and streamlining the manufacturing process. The cost-saving benefits of sleeper optimization are enhanced by the increased lateral stability of rail track. For composite sleepers to be widely accepted by structural designers and end users, design guidelines must be established.

References

1. Crawford, R. H. (2009). Greenhouse gas emissions embodied in reinforced concrete and timber railway sleepers. Environmental science & technology, 43(10), 3885-3890.
2. RailCorp engineering specification, SPC 232: concrete sleepers, 2012.
3. ARTC. Steel sleepers – usage and installation standards TCS 10 Engineering (Track) Australian Rail Track Corporation, 2009.
4. Ets Rothlisberger, S. A. (2008). History and development of the wooden sleeper.
5. Kaewunruen, S. (2010). Sleepers and fastenings. Track design fundamentals, Rail engineering course, Rail corporation.
6. Manalo, A., Aravinthan, T., Karunasena, W., & Ticoalu, A. (2010). A review of alternative materials for replacing existing timber sleepers. Composite Structures, 92(3), 603-611.
7. Ferdous, W., & Manalo, A. (2014). Failures of mainline

railway sleepers and suggested remedies–review of current practice. Engineering Failure Analysis, 44, 17-35.
8. Van Erp, G., Cattell, C., & Heldt, T. (2005). Fibre composite structures in Australia's civil engineering market: an anatomy of innovation. Progress in Structural Engineering and Materials, 7(3), 150-160.
9. GangaRao, H. V., Taly, N., & Vijay, P. V. (2006). Reinforced concrete design with FRP composites. CRC press.
10. Gerard, V. A. N., & Mckay, M. (2013). Recent Australian developments in fibre composite railway sleepers. Electronic Journal of Structural Engineering, 13(1), 62-66.
11. Anne, E. R. (2006). Rubber/plastic composite rail sleepers. UK: The waste & resources action programme.
12. TieTek. Increase productive track time and reduce costs with TieTekTM composite ties. <www.tietek.net> [Access Date: 07.08.14]
13. Takai, H., Sato, Y., & Sato, K. (2006). Japanese twenty five years experiences and standardization of synthetic sleeper. JIS, 100, 2110.
14. Kaewunruen, S. (2015). Acoustic and dynamic characteristics of a complex urban turnout using fibre-reinforced foamed urethane (FFU) bearers. In Noise and Vibration Mitigation for Rail Transportation Systems: Proceedings of the 11th International Workshop on Railway Noise, Uddevalla, Sweden, 9–13 September 2013 (pp. 377-384). Berlin, Heidelberg: Springer Berlin Heidelberg.
15. FFU. FFU synthetic railway sleepers, Sekisui Chemical GmbH, Japan. <http:// www.sekisui.de> [Access Date: 11.08.14].
16. Axion-EcoTrax. Axion EcoTrax composite railroad ties. www.axionintl.com
17. IntegriCo. Integrico composites. <www.integrico.com> [Access Date: 02.08.14].
18. McConnell VP. Rail – an evolving market for FRP components. Reinf Plast 2008, 24-29.
19. Subramanian PS. Induction of a new generation material for the railway infrastructure. In: National Technical Seminar of IPWE(I), 2004.
20. Ridout B. Timber decay in buildings: the conservation approach to treatment. Taylor & Francis; 2013.
21. Chin, J. W., Nguyen, T., & Aouadi, K. (1997). Effects of environmental exposure on fiber-reinforced plastic (FRP) materials used in construction. Composites Technology and Research, 19(4), 205-213.
22. Shah, V. (2020). Handbook of plastics testing and failure analysis. John Wiley & Sons.
23. Lampo, R. (2014, June). Summary of current state of practice for composite crossties. In International crosstie and fastening system symposium. Urbana, IL (USA): University of Illinois.
24. Shamsuddoha, M., Islam, M. M., Aravinthan, T., Manalo, A., & Lau, K. T. (2013). Characterisation of mechanical and thermal properties of epoxy grouts for composite repair of steel pipelines. Materials & Design (1980-2015), 52, 315-327.
25. Selzer, R., & Friedrich, K. (1997). Mechanical properties and failure behaviour of carbon fibre-reinforced polymer composites under the influence of moisture. Composites Part A: Applied Science and Manufacturing, 28(6), 595-604.
26. Takai H, Sato Y, Sato K. Japanese twenty five years experiences and standardization of synthetic sleeper; 2006.
27. Koller G. FFU synthetic sleeper – projects in Europe. Constr Build Mater 2015;92:43–50.
28. Standard Australia, AS 1085.14: Railway track material-prestressed concrete sleeper, Australia; 2012.