

USE OF SUSTAINABLE WOOD MATERIAL FOR SLEEPERS PRODUCTION: A REVIEW

MUTHUMALA C.K.

State Timber Corporation, Battaramulla Sri Lanka

PATABANDI K.P.L.N.

Department of Geography and Environmental Management, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka

VIDYARATNE H.

State Timber Corporation, Battaramulla Sri Lanka

MARIKAR F.M.M.T.*

Staff Development Centre, General Sir John Kotelawala Defence University, Sri Lanka

E-mail: faiz@kdu.ac.lk

Abstract:

Railway sleepers play a vital role in ensuring the stability and functionality of railway infrastructure. While concrete sleepers have been the standard choice, there is increasing global interest in exploring sustainable alternatives, such as wooden sleepers. This review highlights the environmental, economic, social, ecological, and operational advantages of wooden sleepers, with a focus on their role in climate change mitigation. In the context of Sri Lanka, a tropical country with well-managed commercial forests, the use of sustainably harvested timber offers a viable solution to reduce carbon emissions. Wooden sleepers act as carbon sinks, contributing to a carbon-positive economy and supporting broader sustainable development goals. The article emphasizes the importance of maximizing the use of timber in infrastructure projects as a strategic approach to address environmental concerns while promoting local forestry industries. By evaluating the performance and long-term benefits of wooden sleepers, this review advocates for a shift in railway policy and planning to incorporate greener alternatives, aligning infrastructure development with ecological stewardship and climate resilience.

Key words: *Wooden railway sleepers, Sustainable infrastructure, Carbon-positive economy, Climate change mitigation, and Sustainable forestry.*

INTRODUCTION

An essential part of the railway track system are railway sleepers. According to Ellis (2001), they are the sleepers that rails rest on. According to Zarembski (1993), the most common sleeper type in a railway turnout is timber. Turnout sleepers are sleepers that are specifically placed on a turnout (Andersson and Dahlberg 1998). Fig. 1 depicts the main components of the rail track system.

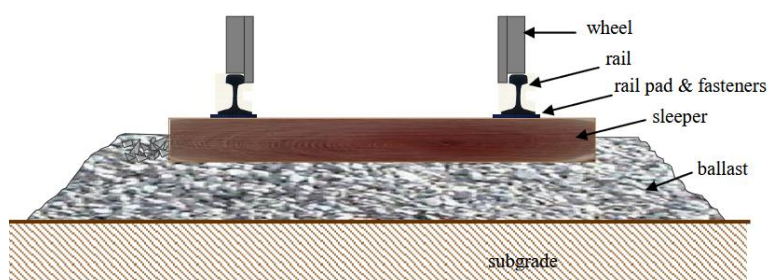


Fig. 1.
Components of a typical railway track system.

Demand of the wooden sleepers in the world

Up until now, hardwood has been the most popular material for sleepers, and the vast network of hardwood sleeper tracks still needs maintenance. Over 2.5 billion timber sleepers have been installed in railway tracks worldwide as of right now (Ets Rothlisberger 2008). Overall, timber sleepers support at least 75% of the world's track (Adams 1991). More than 8,000,000 timber sleepers are used in the Australian state of Queensland (Miller 2007).

*Corresponding author

The railway sector is among the most demanding when it comes to finding a suitable alternative to hardwood timber. For instance, Australian railways require over 1.5 million timber sleepers annually for maintenance purposes (Van Erp et al. 2006). Despite efforts by Queensland Rail (QR) to phase out timber sleepers, it still purchases nearly 80,000 each year, including around 5,000 turnout sleepers for ongoing maintenance and upgrades, due to the lack of a feasible replacement (Miller 2007). In the United States, about 2% of the 700 million timber sleepers are replaced annually (Lampo 2002). Meanwhile, India imports approximately 7 million timber sleepers every year to address its railway maintenance needs (Van Erp et al. 2006). In contrast, Germany's rail system alone required the replacement of 11 million timber sleepers (Woidasky 2008), excluding figures from other European countries and China, where timber sleepers are still predominantly used. Additionally, Australia's railway sector allocates around 25-35% of its annual budget solely to track maintenance (Yun and Ferreira 2003). Wooden sleepers have become the major source for railway ties in Sri Lanka over a century, which are produced by hardwood species mainly from Forest plantations in Sri Lanka (Amarasinghe & Muthumala 2020).

Advantages of the Wooden Sleepers

Timber sleepers have long been recognized for their proven effectiveness and reliability in railway applications (Zarembski 1993). One of their key strengths lies in their adaptability and suitability for all types of railway tracks. They are easy to handle, install, and replace, requiring no complex machinery or specialized tools. This allows for quick, localized repairs without the need for additional labor or heavy equipment. Such convenience is especially valuable on high-speed or high-traffic rail lines, where maintenance time is limited and the use of large work crews is often impractical (Ets Rothlisberger 2008). Moreover, timber sleepers demonstrate excellent fatigue resistance, tolerating repeated flexing with minimal wear (Smith 2006). They are capable of absorbing heavy vibration impacts—such as those during derailments—with limited damage, whereas materials like concrete may crack or shatter under similar conditions. Additionally, timber sleepers naturally provide electrical insulation, which is crucial for track signaling systems, a feature not always offered by alternatives like plastics or fiber composites (Zarembski 1993).

Wooden Sleepers as a Green Material

Wood is one of the most renewable natural resources with significant potential to help combat climate change. Large volumes of wood residues produced during processing activities can play a role in reducing climate impacts (Bernad 2014). Human-induced climate change remains one of the most pressing and complex challenges of the 21st century. While the exploitation of forests and wood products continues, it does not eliminate the urgent need to reduce greenhouse gas emissions at their source. Trees naturally absorb carbon dioxide from the atmosphere throughout their life cycle, storing it within their biomass, as illustrated in Table 1 (Hannah et al. 2004). Research indicates that approximately 1.5 kilograms of CO₂ are absorbed from the atmosphere for every kilogram of wood produced (ASCE 2010). Therefore, utilizing wood as a carbon sink is seen as a promising strategy for climate change mitigation, although it is important to note that CO₂ is released back into the atmosphere when wood is used as a fuel source (Philippe 2013, Muthumala et al. 2020).

Table 1

CO ₂ released and stored by various building material during their construction		
Material	Carbon released (kg/m ³)	Carbon stored (kg/m ³)
Rough sawn timber	15	250
Steel	5320	0
Concrete	120	0
Aluminum	22000	0
Plastic	22	0

Source; Ferguson et al. 1996

Disadvantages of the Wooden Sleepers

The primary drawback of timber sleepers is their vulnerability to both mechanical and biological degradation, which can ultimately result in failure (Qiao et al. 1998). Common modes of timber sleeper failure are illustrated in Fig. 2. Among these, fungal decay is the leading cause of failure in Queensland, as depicted in the figure (Hagaman and McAlpine 1991). Splitting at the ends of timber sleepers is also widespread, largely due to the intense transverse shear forces exerted on them in railway operations

(Hibbeler 2004). In some cases, termite infestations have led to significant damage to timber sleepers, as shown in Fig. 2 (Miller 2007). Nevertheless, the most pressing issue currently facing the railway sector is the limited availability of high-grade timber suitable for sleeper production.



(a) Fungal decay

(b) Splitting at ends

(c) Termite attack

Fig. 2.

Common types of timber sleeper failure (Source: Manalo 2011).

Preservation of the sleepers

Creosote-treated timber sleepers have traditionally been the primary choice in the railway industry for protecting wood against degrading agents (Pruszinski 1999). To achieve long-term durability, softwood timber from plantations intended for sleepers must undergo preservative treatment (McCarthy and Cookson 2008). Because of the large dimensions required for sleepers and the relatively small diameter of plantation-grown logs, most sleepers inevitably contain some heartwood. However, heartwood presents a significant challenge for treatment due to its low permeability. In response to this issue, Vinden et al. (2010) investigated the use of microwave technology to enhance preservative penetration in Radiata pine railway sleepers. Pinewood sleepers (*Pinus caribaea*) absorb more Creosote preservatives rather than other hardwood timber species in Sri Lanka.

The demand for replacing deteriorated timber sleepers has exceeded supply, making it difficult to meet current needs. Consequently, many railway industries are actively seeking alternative materials to replace the aging timber sleepers in their existing tracks.

Disposal methods of replaced sleepers

Morris (2008) emphasized the need for clear guidelines on the storage and disposal of old creosote-treated sleepers to minimize potential health risks. Globally, it is generally considered acceptable to dispose of preservative-treated timber sleepers in landfills. However, the growing volume of such sleepers poses environmental concerns, and many existing landfills may not be able to accommodate them without negative impacts. In Australia, the New South Wales Environmental Protection Agency (2004) requires that treated timber waste be disposed of in specially engineered landfills equipped with active leachate management systems.

Usage of Softwood timber for producing the sleepers

Hardwood timber sleepers offer greater resistance to gauge widening and spike hole wear compared to their softwood counterparts (AREMA 2003). Additionally, mixing softwood and hardwood sleepers on the same railway track is discouraged, as softwood sleepers are less effective at distributing loads to the ballast. Despite this, researchers at Queensland University of Technology in Australia are exploring ways to make softwood suitable for railway sleeper use, given its renewable nature and availability from plantation sources (Hersch 2008). While several tests have confirmed the technical viability of softwood sleepers, it is important to note that these evaluations were conducted on lighter-duty secondary rail lines. In Sri Lanka, the Railway department and the State Timber Corporation are collaborating to do some trials for using the Pine sleepers in railway tracks.

Disadvantages of Concrete sleepers

One of the main drawbacks of concrete sleepers is their substantial weight, which requires specialized equipment for both installation and handling. While they can be spaced further apart—resulting in a slightly lower quantity needed—they also demand more ballast and heavier rails compared to timber sleepers (Smith 2006). The initial cost of concrete sleepers is nearly double that of hardwood timber sleepers. Kohoutek (1991) confirmed that concrete sleepers exhibit different performance characteristics than timber ones. Their high stiffness and greater depth make them incompatible with track sections that still contain timber sleepers. Additionally, concrete sleepers are prone to rail seat deterioration due to insufficient cushioning and the

nature of the concrete itself (Cope and Ellis 2001). Tests on low-profile concrete sleepers also revealed poor performance, mainly because of their rigidity and limited damping capacity, which necessitates the use of high-grade rails and ballast to prevent structural damage (Baggot et al. 2006).

Steel Railway Sleepers

Australia has gained international recognition for its advancements in steel railway sleeper design and performance. Monash University's Institute of Railway Technology is actively working to enhance the performance of steel sleepers while also aiming to lower production costs (BHP 2008). Currently, over 13% of the railway sleepers in Australia are made from steel. These sleepers are lightweight-comparable to timber sleepers-making them easy to handle, and they have a service life exceeding 50 years. However, steel sleepers are typically used on lower-traffic rail lines and are considered suitable only for operations with speeds up to 160km/h (Railway Track and Structures 2008). Additionally, when installing and tamping traditional steel sleepers, extra care is required due to their inverted trough-shaped profile, which complicates proper ballast compaction (Manalo 2011).

Steel Sleepers

Australia has earned international recognition for its expertise in steel railway sleeper design and performance technology. Monash University's Institute of Railway Technology is actively working to ensure the high performance of steel sleepers while aiming to reduce associated costs (BHP 2008). Currently, over 13% of railway sleepers in Australia are made from steel. However, their relatively high cost limits their use to moderate levels (Qiao et al. 1998).

Fibre composite alternatives

Recent developments in fibre composite technology suggest their promising use as alternative materials for railway sleepers. These innovations fall into two main categories: reinforcing traditional sleeper materials using fibre composite wraps, and manufacturing entirely new sleepers by integrating composites with other materials (Manalo 2011).

Table 2

Comparison of existing materials for Railway Sleepers

Properties	Hardwood	Softwood	Concrete	Steel
Adaptability	Easy	Difficult	Difficult	Difficult
Workabiligy	Easy	Easy	Difficult	Difficult
Handling and installation	Easy	Easy	Difficult	Difficult
Durability	Low	Low	High	Low
Maintenance	High	High	Low	High
Replacement	Easy	Easy	Difficult	Difficult
Availability	Low	High	High	High
Cost	High	Low	Very high	Very high
Fasteners	Good	Poor	Very good	Poor
Sleepr ballast interaction	Very good	Good	Very good	Poor
Electric conductivity	Low	Low	High	Very high
Impact	High	High	Low	Medium
Weight ^a , kg	60-70	60-70	285	70-80
Service life, years	20-30	20	50	50

^aBased on the weight of a standard mainline sleepers (Source: Manalo 2011)

Comparison of existing materials for Railway Sleepers

The manufacturing of steel sleepers and concrete is among the major contributors to atmospheric carbon emissions, as both processes consume significantly more energy. According to a 2006 report by the Australian Greenhouse Office, the carbon dioxide emissions from producing steel and concrete are approximately 200 and 10 times greater, respectively, than those from producing hardwood timber. A summary of the advantages and disadvantages of the various materials currently used for railway sleepers is presented in Table 2.

Properties of Wooden Sleepers

One effective way to reduce railway maintenance costs is by replacing only the timber sleepers that are damaged or deteriorated. For this purpose, alternative materials that closely match timber sleepers in terms of strength and performance are most suitable. Since the material and geometric characteristics significantly influence the design and functionality of railway sleepers, any replacement should closely replicate the dimensions, depth, and weight of the existing hardwood sleepers. Timber sleepers used in Australian railways must adhere to stringent standards for stiffness, strength, and durability. However, with increasing difficulty in sourcing high-quality hardwood with large cross-sections-and the reality that today's hardwood is generally of lower quality than in the past-numerous studies have been undertaken to evaluate the bending strength and modulus of the timber currently used for sleepers.

Wooden Sleepers supply through State Timber Corporation

State Timber Corporation (STC) is the sole supplier of wooden treated sleepers for Sri Lankan railway Department and STC geared itself to maintain three impregnation plants in Sri Lanka. Production of Sleepers of previous two decades are shown in Fig. 3.

Demand

It is evident that the demand for wooden sleepers by the Department of Railways has significantly declined over time. Despite their advantages-being easy to work with, simple to handle and replace, and requiring no complex installation tools-the use of timber sleepers has dropped. In the Sri Lankan context, the State Timber Corporation manufactures timber sleepers from sustainably managed forests, but the overall supply has steadily decreased.

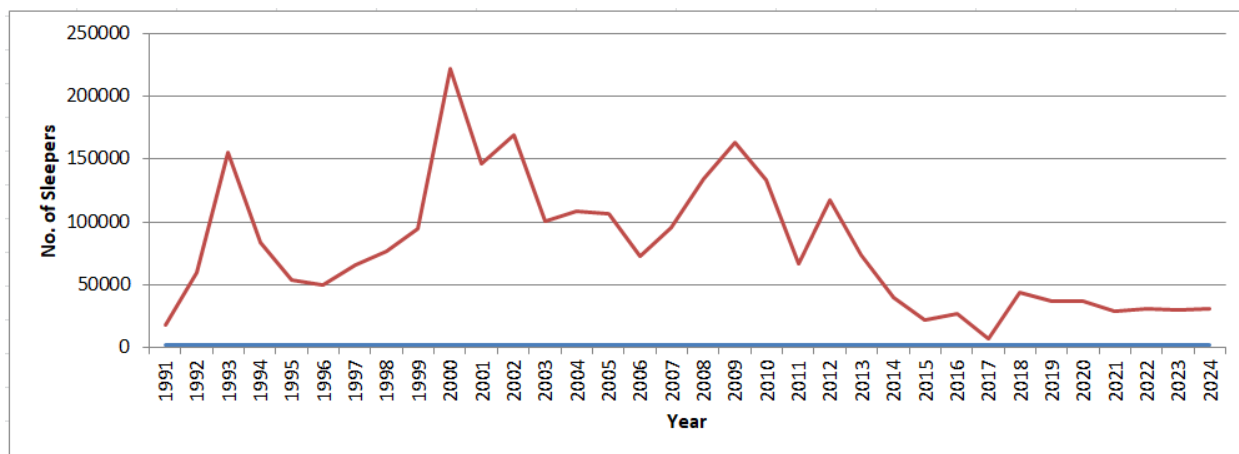


Fig. 3.
Sleepers production of STC in past 2 decades (STC Highlights).

Cresote for wood sleepers

In Sri Lanka, the use of creosote for wood sleepers is no longer permitted due to its toxicity and environmental risks; however, durability can still be improved through environmentally friendly alternatives such as heat-treatment (e.g., Thermowood), bio-based impregnation with furfuryl alcohol (NobelWood), and the use of natural extractives like tannins or hinokitiol, which enhance resistance to decay and termites without harmful residues. Other feasible options include low-toxicity preservatives such as copper naphthenate or PTI formulations combined with wax stabilizers, as well as traditional eco-methods like surface charring (Shou sugi ban) or protective coatings with linseed oil and pine tar. By integrating these approaches with locally available timber (such as plantation pine), Sri Lanka can make wooden sleepers more attractive, reliable, and sustainable while reducing dependence on imports and avoiding environmentally damaging chemicals.

CONCLUSION

The versatility of timber sleepers is one of their main advantages, and they have a long history of delivering dependable and efficient performance in railway environments. Wood is regarded as an efficient way to slow down climate change because it is a renewable resource that absorbs CO₂ from the atmosphere and stores it as carbon. In a sustainable future, they can be equipped with any kind of railway track.

REFERENCES

- Amarasinghe WVTD, Muthumala CK (2020) The Effect of Incising on Coal-Tar Creosote Treated Wooden Sleepers to Increase Retention, *Proceedings of the 25th International Forestry and Environment Symposium 2020*, USJP, pp. 72.
- Andersson C, Dahlberg T (1998) Wheel/rail impacts at a railway turnout crossing. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, 212(2):123-134.
- AREMA (2003) Basic track components. Viewed 22 May 2008, http://www.arena.org/eseries/scriptcontent/custom/e_arena/Practical_Guide/PChapter3.pdf.
- ASCE (2010) Sustainability Guidelines for the Structural Engineer. <https://materialspalette.org/wood/> (Accessed: 30, May 2019).
- Baggott M, McGrath M, Wong J (2006) Maintenance cost benchmarking for the Victorian Freight Network, Worley Parsons Services Pty Ltd, Australia.
- Bernard E (2014) Maximizing wood residue utilization and reducing its production rate to combat climate change. *Res. arti. International Journal of Plant and Forestry Science*, 1(2):1-12.
- Ellis DC (2001) Track Terminology, British Railway Track, The Permanent Way, Institution, England.
- Ets Rothlisberger (2008) History and development of wooden sleeper. Viewed: 20 October 2008, <<http://www.corbat-holding.ch/documents/showFile.asp> >
- Ferguson I, La Fontain B, Vinden P, Bren L, Hateley R, Harmesec B (1996) Environmental properties of timber, Research paper commissioned by the FWPRDC.
- Hagaman BR, McAlphine RJ (1991) ROA timber sleeper development project. *Proceedings of the Eight International Rail Track Conference*, Rail Track Association of Australia, pp. 233-237.
- Hannah R, Saleemul H, Aino I, MacGregor J, Macqueen D, Mayers J, Murray L, Tipper M (2004) Using wood products to mitigate climate change: A review of evidence and key issues for sustainable development, International Institute for Environment and Development and The Edinburgh Centre for Carbon Management.
- Hearsch J (2008) Rail CRC research helps save old-growth forests. Viewed: 27 October 2008. http://www.railinnovation.com.au/news/softwood_sleepers.html
- Hibbeler RC (2004) *Statics and mechanics of materials*, SI edition, Prentice Hall, Singapore.
- HP Institute of Railway Industry - Monash University (2008) Advancing the railway industry through technology. Viewed 02 October 2008, www.eng.monash.edu.au/railway
- Kohoutek R, Campbell KD (1989) Analysis of spot replacement sleepers. *The Fourth International Heavy Haul Railway Conference*, Institution of Engineers, Brisbane, Australia, pp. 316-321.
- Lampo R (2002) Recycled plastic composite railroad crossties. Viewed: 06 November 2008, http://www.cif.org/Nom2002/Nom13_02.pdf
- Manalo A (2011) PhD thesis on Behaviour of Fibre Composite Sandwich Structures: A case study on railway sleeper application, Centre of Excellence in Engineered Fibre Composites Faculty of Engineering and Surveying University of Southern Queensland Toowoomba, Queensland, Australia.
- McCarthy K, Cookson L (2008) Natural durability of five Eucalypt species suitable for low rainfall areas - Sugar gum, spotted gum, red ironbark, yellow gum and swamp yate. Rural Industries Research and Development Corporation Publication No 08/162, Project No CSF-61A, Australia, pp. 16.
- Miller R (2007) Rail and tramway sleepers: Product recognition, identification and presentation, viewed 29 May 2008, http://www.cqfa.com.au/documents/1181619278_sleepers_fact_sheet.pdf
- Morris T (2008) Poisonous railway sleepers pose health risk, The Greens Tasmania, Media release, viewed: 08 October 2008, <http://www.abc.net.au/news/stories/2008/10/02/2380183.htm?site=news>
- Muthumala CK, Sudhira De Silva, Arunakumara KKIU, Alwis PLAG (2020) Finger-joint technique to mitigate climate change, *NeelaHaritha* Vol.3, 2020, Climate Change Secretariat, Ministry of Environment, Sri Lanka. pp. 147-152.

Philippe L (2013) Wood preservation (carbon sequestration) or wood burning (fossil-fuel substitution), which is better for mitigating climate change? , *Annals of Forest Science* (2014) 71:117-124, <https://hal.archives-ouvertes.fr/hal-01098394/document>(Accessed:30 May 2019).

Pruszinski A (1999) Review of the landfill disposal risks and the potential for recovery and recycling of preservative treated timber, Environmental Protection Agency Report, South Australia.

Qiao P, Davalos JF, Zipfel MG (1998) Modelling and optimal design of composite-reinforced wood railroad crosstie. *Composite Structures*, 41:87-96.

Railway Track and Structures (2008) Boost rail infrastructure, Simmons-BoardmanPublishing, Viewed: 02 June 2008, <http://www.nxtbook.com/nxtbooks/sb/rts0108/index.php>

Smith ST (2006) Economics of treated wood used in aquatic applications, Reportprepared for the Western Wood Preservers Institute, viewed 16 August 2009, <http://www.wwpinstitute.org/>

[STC, 1991-2024, STC Highlights, State Timber Corporation, MOE , Sri Lanka.](#)

Van Erp G, Cattell C, Huang D (2006) Fibre composite innovations in Australia's construction industry, CRC for Construction Innovation, Australia.

Vinden P, Torgovnikov G, Hann J (2010) Microwave modification of radiate pine railway sleepers for preservative treatment. *European Journal of Wood and Wood Product*, Springer Berlin/Heidelberg.

Woidasky J (2008) Railwaste – production of railway sleepers by mixed plastic waste, SUSPRISE Joint Call Evaluation Workshop, Berlin, Germany.

Yun WY, Ferreira L (2003) Prediction of the demand of the railway sleepers: A simulation model for the replacement strategies. *International Journal of Production Economics*, pp. 81-82, pp. 589-595.

Zarembski AM (1993) Concrete vs. wood ties: Making the economic choice. Conference on aintaining Railway Track: Determining Cost and Allocating Resources, Arlington, VA.