Sharma et al. 2017. *Int. J. Vehicle Structures & Systems*, 9(5), 321-329
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.9.5.10

International Journal of
Vehicle Structures & Systems
Available online at www.maftree.org/eja

Modernization of Railway Track with Composite Sleepers

Rakesh Chandmal Sharma[a], Srihari Palli[b], Sunil Kumar Sharma[c], Mritunjoy Roy[d]

[a,d]*Mech. Engg. Dept., Maharishi Markandeshwar (Deemed to be University) Mullana, India*
[a]*Corresponding Author, Email:drrcsharma@mmumullana.org*
[b]*Mech. Engg. Dept., AITAM, Tekkali, Andhra Pradesh, India*
[c]*Dept. of Mech. Engg, Amity School of Engineering and Technology, Amity University Uttar Pradesh, Noida, India*

ABSTRACT:

Railway sleeper is an important component of railway network. Its clamping is also a critical issue in order to avoid any slippage and to maintain the alignment or cross level. Earlier, railway network used wooden sleepers worldwide. Further steel sleepers in parallel with wooden sleepers have been employed. Both are replaced with concrete sleepers with the advancements. With the modernization, the idea of railway sleepers with fibre composite materials has been introduced which is accepted worldwide due to its unique features over any other type of sleeper. This paper discuss about different composite material sleepers and review the important features associated with them i.e. composition, properties, advantages and limitations.

KEYWORDS:

Railway sleeper; Wooden sleeper; Steel sleeper; Concrete sleeper; Composite sleeper; FFU synthetic sleeper

CITATION:

R.C. Sharma, S. Palli, S.K. Sharma and M. Roy. 2017. Modernization of Railway Track with Composite Sleepers, *Int. J. Vehicle Structures & Systems*, 9(5), 321-329. http://dx.doi.org/10.4273/ijvss.9.5.10.

1. Introduction

Railway sleeper is one important element of the entire rail network. Its function is to support the rails, prevent any slippage of rails, maintain the proper alignment and to transfer the load of vehicle to ballast. Sleeper also prevent the longitudinal & lateral movement of the rails, maintain a proper gauge and resist the cutting or erosive action of bearing plates & ballast material. In earlier days wooden sleeper were mainly used and they were linked with few difficulties such as rots, spiling, spike pull and environmental decay. Railway organisation used timber or wooden sleepers for nearly two centuries and due to the problems discussed above millions of old timber sleepers in the world need to be replaced [1]. With the development in technologies steel based sleepers were also employed on bridges at busy traffic with the advantage of low maintenance requirement. With ever-growing advancements in technologies wooden sleepers were replaced by concrete sleepers [2]. However at certain places like bridges wooden sleepers are preferred over any other sleeper due to better damping properties.

In the maintenance of existing timber lines, turnout sleepers (switch ties) and transoms (bridge ties) wooden sleepers are still used. Approximately 2 billion wooden sleepers are still in use in railway network at present worldwide. Concrete sleepers provide high gauge holding characteristics [2]. Besides so many other advantages the popularity of concrete sleepers is limited due to their size and stiffness specifically limits their use to places where complete sleeper replacement is to be employed or new track is to be constructed [2]. In recent years reinforced polymer composite sleepers have appeared as a potential substitute as they are far less subjective to environmental decay as compared to any other sleeper [3]. Composite sleepers have low maintenance cost and have life span about 50 years. Composite sleepers are free from insect & moisture damage, resistant to chemical damage, have excellent damping and shock absorption properties, provide better performance on curves. Composite sleepers have no future disposal issues associated with them and can be easily recycled into new composite sleepers [3]. However reinforced polymer sleepers are accepted with the limitation as their price is 5-10 times higher than that of a wooden timber.

2. Hazardous features with wooden sleeper preservative Creosote

Wooden railway sleepers soaked in Creosote which is a wood preservative are used in railway tracks in Europe. “Creosote” is a material which contains toxic harmful chemical compounds like polycyclic aromatic hydrocarbons (PAHs) [3, 5]. These compounds are a danger to human health as they are carcinogenic. Creosote is therefore categorised as potentially carcinogenic. Many of the research investigates that wooden sleepers in Europe exceed the critical creosote limit set by the European Union and their disposal should be treated as hazardous waste. Around 8.5 million creosote sleepers along 15,000 km of railway line in Sweden are installed in typical railway tracks. While sleepers remain embedded in railway tracks, the creosote is considered to be environmentally safe. However, upon removal, if the total creosote content is greater than the limit set by the European Union (EU), of 1000 ppm dry weight (1 g per kg dry weight), the sleepers should be classified as hazardous waste and disposed of according to the regulations of EU [5].

As the costs associated with hazardous waste storage and disposal are higher than for ordinary waste, there is a tendency among financial stakeholders to underestimate the creosote content in sleepers. When sleepers are burnt as ordinary waste, some carcinogenic compounds are released and have a substantial impact on human life. The other main disadvantage of wooden sleeper is its sensitivity to biodegradable and mechanical failures. Fungal decay, moisture decay, pest attacks and splitting at the ends of the wood are the major issues which limits its application. Splitting is due to very large transverse shear loading exerted to the sleepers. Wooden sleepers may be categorized into hardwood and softwood sleepers. Softwood sleepers are less resistance to gauge spreading and spike hole enlargement. Softwood sleepers are also not effective in load transmission to ballast, however they are good at damping thus provide a good ride comfort [6-7].

3. Utilization issues with recycled concrete railway sleepers

Concrete sleepers have estimated life of about 35 years. When concrete railway sleepers are removed from the track line, they are unusable [6]. They can't be used to build any foundations, due to their block feature. Its shape makes it impossible for bricklaying and because of the heavy weight and small size they can't be used in road construction. To obtain a useful recycled product, the recovery of the material by crushing is generally used. The crumbling of concrete sleepers is not as difficult as the problem to skilfully separate concrete from steel reinforcement and remove it with the other of structural elements is there. Concrete sleepers are very heavy weight which required specialized machinery during laying and installation and moreover their production cost are almost double that of hardwood sleepers. The investigation to the timber and concrete sleepers, reveal that the concrete sleepers higher sleepers have high stiffness characteristics and the design requires higher depth than the existing timber sleepers.

4. Limitations with steel sleepers

A steel sleeper weighs less than timber sleeper which provides an ease in installation as well as having a life of around 50 years. However, steel sleepers are being used only on more lightly travelled tracks and are regarded as suitable only where speeds are 160 km/h or less [4]. Steel sleepers require extra care during installation and tamping due to their inverted through profile which makes them difficult to satisfactorily pack with ballast. Observations of rail deflections under imposed vehicle track loading have shown that the steel sleepers settle a greater amount than the timber sleepers, indicating that the steel and adjacent timber sleepers are not carrying an even proportion of the imposed wheel loading. Furthermore, steel sleepers are expensive and are used only in minimal number because of the fear of corrosion. Another problem with steel sleepers is fatigue cracking in the fastening holes caused by moving trains [4].

5. General composition of fibre composite sleeper

General Constituents of a fibre composite sleeper are shredded High Density Polyethylene (HDPE), rubber form whole post-consumer tires, Crumbled Rubber from retreaders, other waste materials, chemical additives, fibre and fillers [4, 8]. HDPE (High Density Polyethylene) Polymer composite sleeper assimilate a polymer material recycled HDPE as a chief component with fibre as reinforcement or fillers. Hence, sleepers do not require use of toxic preservatives and do not have water absorption problem which cause loss of strength. Crumbled Rubber introduces elastic property in the sleeper and will reduce crack problem in sleeper. Crumbled Rubber reduces maintenance costs and also increases lifespan of sleeper. Fibre acts as reinforcement for sleepers. Fibre is both strong and stiff in tension and compression. Fillers i.e. CaCO3, Mica have excellent mechanical and thermal properties. Fillers are flexible and elastic. They are also moisture proof having high tensile and flexural strength. If above materials are combined on basis of properties a superior quality of material is achieved which can be used as railway sleeper.

Table 1: Comparison of wooden, steel and composite bridge sleepers

Parameter	Wooden	Steel	Composite
Durability (years)	8-10	15-20	40-50
Weight (kg)	100-171	110	54
Replacement of sleepers	Easy	Difficult	Easy
Handling	Not so easy	Difficult	Easy
Suitability for track circuited area	Suitable	Problematic	Suitable
Cost per sleeper with fittings	Rs. 3500/-	Rs. 9500/-	Rs. 19240/-
Life cycle cost (Rs./year)	402/-	575/-	385/-

6. Composite sleepers: A better alternative

Recent developments in fibre composites now suggest their use as alternative material for railway sleepers [3, 8-10]. These developments can be subdivided into new railway sleepers produced by combining other materials with fibre composites and the strengthening of existing sleeper materials with fibre composite wraps. Indian Railways specially adopted these materials for use in bridge sleepers [11-12]. Table 1 describes a comparison between fibre reinforced plastic sleepers with wooden and steel ones for bridge track applications. Their composites consisted of E-glass woven fabric as the reinforcement and polyester as the resin. Polyester resin was also mixed with accelerator, hardener, fire retardant, and UV Stabilizer.

7. Available composite sleepers commercially used worldwide

Sleeper manufacturing companies use different compositions and manufacturing process for making composite sleeper depending upon the desirable properties, cost involved, application, maximum load at the track, density of traffic etc. and give them a commercial name. It is worthwhile here to discuss various composite sleepers worldwide used. A number of companies are selling railway sleepers manufactured using recycled plastic materials and fibre composites. These sleepers are said to have high strength, be more durable and to weigh similar to timber sleepers while otherwise exhibiting properties similar to their wooden counterparts in terms of damping impact loads, lateral stability and sound absorption [14].

7.1. TieTek sleepers

The US Company Tietek LLC in Houston along with Union Pacific Railroad prepared a composite railway sleeper from recycled plastic bottles and bags, fibre reinforce glass, crumbed rubber i.e. scrapped vehicle tyres and structural mineral fillers i.e. calcium carbonate, mica etc. [13-15]. It was composed of 85% recycled materials and designed to replace traditional timber sleepers. Around 2 million wooden sleepers were replaced by Tietek sleepers within a span of two decades throughout the world. Tietek sleeper (Fig. 1) provides lower noise and vibration levels, better lateral stability, a longer life span (40 years) than a timber sleeper, good resistance to rail-seat abrasion, spike pull, damage by moisture, insects and fungi and low electrical conductivity [13-15].

Fig. 1: TieTek sleepers

7.2. Polywood and polysum sleepers

The Polywood Inc. manufactures structural plastic lumber from post-consumer and post-industrial recycled plastics and has patented technologies for this production. The company Produce ties “co-continuous” immiscible post-consumer HDPE and PS scrap, which was initially developed at Rutgers University, which negates the need for glass reinforcement in high load-bearing applications [11, 13 and 16]. Polywood sleepers have composition of mainly two items i.e. Polystyrene (PS) and High Density Polyethylene (HDPE). Its percentage is in the ratio of approximately 35% PS to 65% HDPE. The Demer Corp. spent approximately 4 years on research and development of the railroad ties, which are made from 60% recycled-gypsum filler and 40% post-consumer high density and low density polyethylene and polypropylene. In 1996, the first Polywood sleepers were installed in a five degree curve in AAR/TTCI test track in Colorado.

Polywood sleepers have been installed in the US for over 14 years, and have been extensively used in class 1 rail road and transit lines, including, Norfolk Southern, Union Pacific rail road, Chicago transit, New York City transit, New Jersey transit, Long Island rail road, Washington Metro, South-eastern Pennsylvania transport authority and Toronto transit authority. Polywood is a light weight material which provides a significant reduction in transportation, handling and time costs with the added benefit of no maintenance. This coupled with the reduction in greenhouse gases and Co_2 emissions and providing a solution to the plastic waste problem has resulted in an alternative sleeper product which challenges and beats the life cycle cost of wood and concrete. A comparison of mechanical properties for Tietek and Polywood Sleeper is listed in Table 2.

Table 2: Comparison of mechanical properties for TieTek and polywood sleeper

Mechanical property	TieTek sleeper	Polywood sleeper
Density	57-66 lbs/cft	53-56 lbs/cft
Coefficient of thermal expansion	0.000075 inch/inch per °F	0.00005 inch/inch per °F
Modulus of elasticity (compression)	175-250 ksi	170000 psi
Flexural strength	2000- 2500 psi	3000 psi
Mechanical fasteners screw spike withdrawal	5000 lbs	15000 lbs.

The polysum technologies LLC registered its first patent for a thermoplastic railroad cross tie. The company’s thermoplastic railroad tie is available in two configurations: the tuff-tie and the hi-load tie. Polysum’s tuff-tie made from HDPE with 50% virgin gypsum. To produce the ties, a co-rotating twin-screw extruder feeds 3,300 pounds per hour of gypsum-filled HDPR to an accumulator, which sends melt into an e-foot long mould [11, 13 and 16]. Axion international, who produced first thermoplastic composite bridges in the world, used their reinforced structural plastic composite, which they also name as thermoplastic, in making crossties too. Their HDPE-based recycled material is reinforced with polypropylene coated glass fibres. FFU synthetic sleepers FFU (Fibre Reinforced Foamed Urethane) synthetic sleepers are manufactured using a pultrusion-extrusion process. Continuous glass fibre strands are soaked in special polyurethane and a composite of the materials is developed curing at an increased temperature.

The whole process is controlled by a drawing tool which pulls the synthetic sleeper profile out of the curing tool. This assures a high quality of ISO certified sleeper with unvarying material properties. Due to its closed cell structure FFU synthetic sleepers have minimal electrical conductivity, density and machinability equal to wood, high chemical resistance to oils, lubricants and pollutants, minimal maintenance cost, are dimensionally stable and accurate, can be 100% recycled and do not absorb moisture [17-19]. The properties of FFU synthetic sleepers are listed in Table 3. FFU synthetic sleepers can be used on railway bridges technically and commercially in exactly the same way as natural wood. In addition, installing FFU sleepers on railway bridges assures significant additional engineering design benefits in bridge construction through long product life, constant static system, consistency of gradient and ease in use of conventional fastening systems, dimensional stability and ease with use of identical tools, excellent technical properties and lower maintenance costs.

Table 3: Properties of FFU synthetic sleepers

Properties	Unit	Value with life		
		New	10 years	15 years
Density	kg/m^3	740	740	740
Bending resistance	Pa	142	125	131
Bending modulus	Pa	8100	8000	8160
Compressive resistance	Pa	58	66	63
Shear resistance	Pa	10	9.5	9.6
Hardness	Pa	28	25	27
Impact bending resistance at 20° C	J/cm^2	41	-	-
Impact bending resistance at 20° C	J/cm^2	41	-	-
Electric insulation resistance (dry)	Ω	1.6×10^{13}	2.1×10^{12}	3.6×10^{12}
Electric insulation resistance (wet)	Ω	1.4×10^{8}	5.9×10^{10}	1.9×10^{9}
water absorption	mg/cm^2	3.3	-	-
Rail spike extraction force	kN	28	28	23
Rail screw extraction force	kN	65	-	-

In case bore holes are misplaced or drilled in an accurate size during on site-work on the FFU synthetic sleepers technology offers two different quick and easy repair methods without affecting the quality of the material. With the first method (Fig. 2), the defective bore hole is re-profiled, cleaned and then filled with liquid synthetic resin. After a curing time of about 30 minutes, a new bore holes is drilled in the correct position a few millimetres away, and originally required screw connection is made. With the 2nd method (Fig. 3), the defective bore is cleaned and filled with liquid synthetic resin. A FFU synthetic wood dowel is then inserted. With this method curing takes nearly 4 hours until a new bore hole can be drilled at the repaired spot.

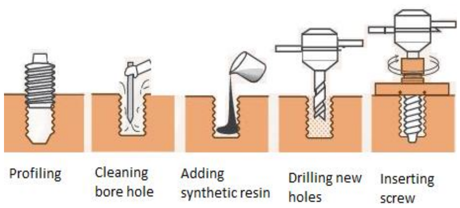

Fig. 2: First repair method of FFU synthetic sleeper

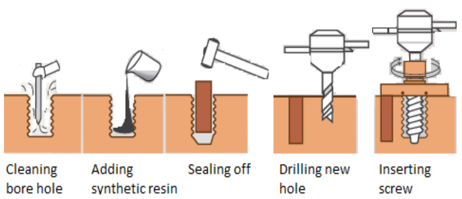

Fig. 3: Second repair method of FFU synthetic sleeper

In 1978, the Japanese company Sekisui Chemical Co. Ltd. developed a synthetic wood called ESLON Neo Lumber FFU (Fibre reinforced Foamed Urethane) for the manufacture of railway sleepers in which thermosetting rigid urethane resin foam is reinforced with long glass fibres. As the characteristic properties of the synthetic material FFU can be classified as being between those of wood and plastic, it possesses the advantages of both materials [17] and unlike traditional timber sleepers, does not need to be impregnated with environmentally harmful chemicals. The key features are: light weight; good resistance to water absorption; heat and corrosion; easy drill ability; and more than 50 years of design life. An investigation of the acoustic and dynamic characteristics of a FFU turnout sleeper showed that its performance is equivalent to that of a timber sleeper. To date, this sleeper has been installed Fig. 4 in more than 925kms of track (approximately 1.5 million sleepers) with its main application in turnouts, open steel girder structures and tunnels [18]. Apart from in Japan, Sekisui FFU sleepers have been installed in Germany, Austria and recently, in Australia. Their applicability is also now investigated for a long span rail bridge in Chongqing city, China [19].

Fig. 4: ESLON neo lumber (FFU) composite sleeper

Fig. 5: Polyurethane (FFU) composite sleeper

Sumika Bayer Urethane Co. Ltd have developed composite sleepers FFU (Fibre reinforced Foamed Urethane) made from grade 60 reinforced with long glass fibres [11]. These sleepers resemble with wood and have all positive features of the natural product with those of a modern composite material. These sleepers have low linear coefficient of thermal expansion, low thermal conductivity values, high compressive and tensile strength [11]. Polyurethane sleepers have been installed for the tracks for the Japanese high-speed train Shinkansen, for the tracks for the Zollamt Bridge and for the tracks for Vienna in Europe (Fig. 5).

7.3. Axion ecotrax sleeper

Axion, a US green technology company developed composite sleepers made from recycled consumer plastic i.e. plastic coffee cups, plastic bags, milk jugs and laundry detergent bottles and industrial plastic waste with the brand name Ecotrax [16]. In 1994 this manufacturing technology was developed by the Polywood Plastic Composite Company. In 2007, its processing function was taken over by Axion [16]. Since its introduction, a variety of sleepers have been produced for different applications Fig. 6 including switches, road crossing, bridges, passenger and heavy duty track. This sleeper provides excellent resistance to rot, fungus, insects and moisture, provides better resistance to plate wear and has a longer life span of around 50 years. This sleeper is installed in Europe, Australia, New Zealand, Canada and Southeast Asia [16].

Fig. 6: Axion ecotrax sleeper

7.4. IntegriCo sleeper

IntegriCo Composites Inc. manufactured a unique processing technology for manufacturing composite sleepers from landfill-bound 100% recycled plastic materials Fig. 7 and produces different types of sleepers depending on the required application. IntegriCo sleeper provides good resistance to moisture, insects, plate-cut, caustic environment and have an expected life about span 50 years. Since 2005 more than 1 million IntegriCo sleepers have been installed in North America and are currently introduced in Mexico, Canada and India [20].

Fig. 7: IntegriCo composite sleeper

7.5. Fibre-reinforced polymer (FRP) sleeper

The ban on felling trees in India Permali Wallace Pty. Ltd. to developed an alternative to a timber sleeper. An FRP composite uses fibre reinforcement and a resin matrix [21-24]. FRP sleepers have light weight, longer service life of about 45 years, good resistance to corrosion, high electrical insulation, lower life cycle cost and innovative design [21-24]. Since 1998, several FRP sleepers have been installed in different locations in India [25, 26] for trial purposes (Fig. 8).

Fig. 8: FRP sleeper

7.6. I-plas sleeper

I-Plas, Halifax-based British manufacturing company has developed a new railway sleeper from 100% recycled composites using domestic and industrial wastes such as plastic bags, drink bottles and old car bumpers. The main objective is to replace timber sleepers with this eco-friendly composite sleeper Fig. 9 [27]. I-Plas sleeper provides a better performance against rotting, twisting, degradation, are resistant to fire; have low maintenance cost and 30-year service life [28].

Fig. 9: I-plas sleeper

7.7. Tufflex sleeper

In 2004, a South African company developed a composite sleeper made from a special mix of recycled polypropylene and high and low density polyethylene materials for an underground railway line and narrow gauge railway track Fig. 10. Tufflex sleeper promised to have a longer service life than timber and concrete sleepers when used in underground mines where high fluctuations of pH and high levels of water and humidity are challenging factors associated with using wooden sleepers. Recently, Tufflex plastic installed sleepers in underground lines of the Anglo Gold Ashanti and Gold Fields mines in Africa and their in-service performances are now being investigated [29].

Fig. 10: Tufflex sleeper

7.8. Natural rubber sleeper

The use of natural rubber in rubber-asphalt mixtures for road surfaces, bridge bearings, plates for vibration absorbers and blocks for the seismic protection of tall buildings inspired a group of researchers in Thailand to manufacture railway sleepers using it in 2005 (Fig. 11). Mechanical properties of natural rubber were improved using an ebonite system whereby the cross-link density of natural rubber was increased. Modified natural rubber provided better compressive modulus and hardness than scrap rubber [30].

Fig. 11: Natural rubber sleeper

7.9. KLP sleeper

The ban of using harmful creosote oil to preserve timber sleepers motivated a company in the Netherlands to introduce 100% recycled plastic sleepers under the brand name KLP (Kunstst of Lank horst Product) for main track, switch and bridge applications (transoms). The manufacturer optimised the volumes of materials for its main track product which requires 35% less plastic than a traditionally shaped rectangular solid sleeper. This is a good initiative for minimising the cost of both the sleeper manufacture and transportation. This plastic sleeper have a long life of nearly 50 years, durability, ease of installation and environmental friendliness and due to their innovative design, it is promised to have a better lateral resistance. Since they were first developed in 2006, KLP sleepers Fig. 12 have been installed in more than 20 turnout applications in the Netherlands and Germany [31]. The KLP plastic sleepers are ideal for selective replacement of timber sleepers as well as for use in areas where timber or concrete sleepers are not the most beneficial choice for your track.

Fig. 12: KLP sleeper

7.10. Mixed plastic waste (MPW) sleeper

Since beginning in 2008, the rail waste project in Germany has developed alternative railway sleepers from a combination of mixed plastic wastes, glass fibre wastes and auxiliary agents with a thermoplastic polymer matrix using an extrusion process. It is expected that this sleeper has much better weather resistance than timber, a lower consumption of primary materials due to the use of waste plastic and better acoustic damping properties than metal and concrete [32]. However it has found many voids Fig. 13 which may be beneficial in terms of weight reduction but not good from structural point of view.

Fig. 13: MPW sleeper

7.11. Wood core sleeper

In 2011, a plastic composite wood-core sleeper was introduced by the Texas based US company named Southwest RV and marine wood core sleeper composed of polyethylene-based plastic mixture, which provide an excellent resistance from insect attack, moisture and UV degradation, with reinforced rectangular wooden beam [33] inside which carries the loads (Fig. 14).

Fig. 14: Wood core sleeper

7.12. Glue laminated sandwich sleeper

Glue laminated sandwich sleeper is developed using glass fibre composite skins and modified phenolic core material [34, 35]. The results promised that the glue-laminated composite sandwich beams have the strength and the stiffness suitable for turnout sleeper. In glue-laminated sandwich beams, it was investigated that the fibre wraps had minimal effect on the bending stiffness and strength but has a more significant effect on the shear strength. The behaviour of glue-laminated sandwich beams was investigated for replacing traditional timber sleepers in turnout application. The sandwich beam technology Fig. 15 claimed far better mechanical properties than most of the available composite railway sleepers and is comparable with the existing timber turnout sleepers. This sleeper provides excellent resistance to hold the screw in position which is one of the most common problems of existing plastic composite product [36-38].

Fig. 15: Glue laminated sleeper

7.13. Geopolymer concrete sleeper

The Geopolymer concrete sleeper is now considered an alternative environmentally friendly railway sleeper as Geopolymer concrete reduces landfill weights because it is developed from industrial by product called fly ash. Australia's leading concrete sleeper supplier, Rocla, developed Geopolymer pressurised concrete sleepers for mainline rail tracks since 2002 [39]. In 2010, Uehara [40] developed a Geopolymer concrete sleeper and conducted a series of tests on it, with the results stratifying the Japanese standard they used, JIS E 1202. In 2011, Palomo and Fernandez-Jiménez [41] developed alkali activated fly ash mono-block pressurised concrete sleepers for an industrial trial and their experimental results met the requirements of both the Spanish and European codes. Ferdous et al [42] investigated the feasibility of a Geopolymer concrete-filled pultruded composite sleeper Fig. 16 and their initial results showed satisfactory performances compared with those of timber and existing composite sleepers. Recently in 2014, the durability of eco-friendly pre-stressed concrete sleeper made from steel slabs have been investigated through field inspection and it has promised as an alternative to conventional pre-stressed concrete sleeper with the additional advantage of low environmental impact [2].

Fig. 16: Geopolymer sleeper

8. Advantages of composite sleepers

There are so many advantages of composite sleepers. Some of them are listed below:

- Composite sleepers being made of non-bio-degradable material, its durability is more than that of wooden sleepers. Life of wooden sleepers is nearly 10 to 25 years depending upon its type, quality, traffic density and its location of use. The life of composite sleepers is nearly 40 to 50 years.
- Composite sleepers are as equally flexible as compared to wooden sleepers. All types of flexibilities available with wooden sleepers like notching, grooving, repairing of the spike killed area, edging, drilling holes etc. are available with composite sleepers.
- Property of the wooden sleeper is not uniform due to presence of knot and other defects available in the timbers. Cost of the wooden sleeper also increases which is disproportional with respect to increase in size. As compared to this, unit cost as well as property of composite sleepers is uniform in respect to shape and size (including length).
- No toxic preservative is involved in composite sleepers like use of Creosote in wooden sleepers. This is a sensitive issue in USA where environmentalists are very much conscious about proper disposal of toxic materials.
- Composite sleepers have excellent shock absorption characteristics. Sound and vibrations are well exhausted.
- Composite sleepers have good rail holding ability, better operational efficiency, better maintainability, excellent specific strength and modulus, giving high performance per given weight, leading to fuel savings.
- Composites typically are anisotropic materials governed by 2nd order tensor, with 21 materials property constants such as Young's modulus, Shear modulus, Poisson's ratio, etc. Laminate patterns could be designed to give a certain mechanical properties in different directions.
- Excellent resistance to corrosion, chemical attack and outdoor atmosphere. If offers greater resistance to greases and oils. It has low weight, fire resistance and low electrical conductivity.
- The constituent material of the composite sleepers is thermo-plastic based. As such, its recycling is possible. Composite sleepers consume the waste plastic which otherwise is posing its disposal problem. As such, it is fantastic case of reuse of waste resources. Use of plastic in sleepers will reduce disposal problems of plastic on land that causes choking of sewerage system. More use of composite sleepers will ensure less destruction to the forests.

The properties of few composite sleepers discussed in this article are summarised in Table 4.

9. Limitations with composite sleeper

Limitations of composite sleepers are as follows:

- Composite sleeper loses its strength and stiffness after recycling which is the main hurdle for its widespread application in installation of railway track. Most of the alternative sleeper technologies are developed for replacing existing timber but their strength and stiffness are not compatible with timber. For example, hardwood timber sleeper has a modulus of rupture of 60MPa while the recycled plastic sleeper exhibits only around 25MPa.
- The extra high cost of the most composite sleeper is responsible for their slow worldwide acceptance. The cost of a composite sleeper is approx. 5 to 10 times higher than that of a wooden sleeper [43].
- Natural rubber composite sleepers are not able to maintain the rail track gauge due to their low capacity and very stiff and inelastic characteristics of holding rail fastenings.
- With composite sleeper, loosening of fastener with time makes the truck unstable due to stress relaxation which leads to derailment failure of track system.
- The voids formation during manufacturing of plastic sleeper creates problems to transfer stresses from one part to others, generate stress concentration and later leads to the local failure before their design life.
- Under sustained loads, the composite sleeper may be subjected to permanent deformation due to creep [44-46]. The rate of creep depends on the magnitude and duration of stress and temperature at which the load is applied. The effect of creep leads to stress relaxation and consequently the fastening system tends to lose particularly in the curve track that has an adverse effect on gauge holding.
- The lack of knowledge on the long term performances of composite sleeper technologies are also restricts their application in rail track.

Table 4: Properties of composite sleepers

Properties (Unit)/Types of sleeper	Timber	FFU	TieTek	Axion	IntergriCo	Wood core	Glue laminated
Density, (kg/m^3)	1085	670-820	1153	849-897	1121	993	-
Modulus of elasticity, (MPa)	16000	8100	>1724	1724	1655	1517	5190
Modulus of rupture, (MPa)	65	142	>18.6	20.6	18.6	17.2	103
Compressive MOE, (MPa)	-	-	269	176.5	262	241	-
Rail-seat compression, (MPa)	60	58	16.5	20.6	15.9	15.2	-
Screw pullout force, (kN)	40	65	35.6	31.6	73.4	-	63.8
Thermal expansion, (cm/cm/°C)	-	-	1.35×10^{-4}	0.74×10^{-4}	1.26×10^{-4}	0.2×10^{-4}	-
Electrical impedance (wet), (Ω)	-	140×10^{6}	500×10^{6}	-	-	-	-
Flammability	-	-	No@20s	-	-	-	-
Impact bending strength, (MPa)	-	41	-	-	-	-	-

10. Discussions

The major challenges in using composite railway sleepers are their limited strength, limited stiffness, high cost which is not compatible with timber in most cases. A significant research needs to be performed either on the existing composite sleepers or a new composite sleeper from another material in order to increase the strength and stiffness of recycled plastic sleepers. However, a significant amount of research is required to develop the techniques how the fibres will work with thermoplastic polymer. On the other hand, the cost of composite sleeper technologies can be reduced by optimising the use of materials. When the train passes over the rail, the wheel loads are generally distributed at the rail seat region. Therefore, rail seat region is the most critical section and other parts of sleeper do not require the same strength. The material cost is significant in case of composite and any reduction of the volume of materials can contribute to the cost minimisation.

11. Conclusion

Polymeric composites may a good alternative for current railway sleepers as they have properties such as corrosion and chemical resistance, environmental durability and high specific strength. They will create ecological benefits due to their recyclability, causing decrease of plastics in landfills and reduction in forest degradation. A number of composite sleeper technologies have been developed in different parts of the world but their uptake in the market is extremely slow. The primary obstacles of their widespread application are their low strength and stiffness, high price, low capacity of holding screw, formation of voids into the body of sleeper and permanent deformation due to creep and temperature variations. Moreover, the long term performances and durability of composite sleeper are not fully investigated yet. The introduction of long fibre reinforcements will improve the strength and stiffness of recycled plastic sleepers. Similarly, the optimal use of materials and improve manufacturing techniques will help minimise the overall costs.

The potentiality of using sandwich composite panel for manufacturing composite sleeper is anticipated to provide an efficient structural element. Current trials of polymeric composites as railway sleepers have some successful stories, which ended up with commercial patented products as seen in Axion international, while some trials were not found satisfactory as stated in reports of Indian railways. While traditional materials have all well-established continuous production lines, cost of production on industrial scale is still a question for polymeric composite sleepers. Hybrid structures to be obtained by combination of composites and traditional materials also exhibited satisfactory properties, which make them also an alternative. Developments up to date suggest further research on such alternative materials with regard to their advantages compared to existing railway sleepers.

REFERENCES:

[1] R. Mitchell, M.G. Baggott and J. Birks. 1987. Steel sleepers: An engineering approach to improved productivity, *Conf. on Railway Engg.*, Perth, Australia.

[2] T. Koh and S. Hwang. 2015. Field evaluation and durability analysis of an eco-friendly pressurised concrete sleeper, *J. Materials in Civil Engg.*, 27(7).

[3] A. Manalo, T. Aravinthan, W. Karunasena and A. Ticoalu. 2010. A review of alternative materials for replacing existing timber sleepers, *Compos. Struct.*, 92, 603-611. https://doi.org/10.1016/j.compstruct.2009.08.046.

[4] C. Jain, S. Khandelwal, S. Mehrotra and R. Gupta. 2016. A review paper on use of composite material for railway sleepers in railway track, *SSRG Int. J. Civil Engg.*, 3(5), 104-108.

[5] DG environment news alert service. 2008. Treating old railway sleepers as hazardous waste, *European Commission*.

[6] B. Kinga and S. Jacek. 2015. The issue of wooden and concrete railway sleeper's utilisation, *Production Engg. Archives*, 9(4), 33-37.

[7] A. Ticoalu, T. Aravinthan and W. Karunasena. 2008. An investigation on the stiffness of timber sleepers for the design of fibre composite sleepers, *Proc. 20th Australasian Conf. Mechanics of Structures and Materials*, Toowoomba, Australia.

[8] G.V. Erp and M. Mckay. 2013. Recent Australian developments in fibre composite railway sleepers, *Elec. J. Structural Engg.*, 13(1), 62-66.

[9] A.C. Manalo, G. Maranan and G.V. Erp. 2014. Evaluation of the physical and mechanic properties of a composite railway turnout sleeper, *Proc. 23rd Australasian Conf. Mechanics of Structures and Materials*, 1, 539-544.

[10] A. Sahay and S. Phogoat. 2015. Composite railway sleepers in the Indian sub-continent, *Int. J. Emerging Trends in Electrical and Electronics*, 11(2), 133-137.

[11] A. Ghorbani and S. Erden. 2013. Polymeric composite railway sleepers, *Proc. 2nd Int. Symp. Railway System Engg.*, 9-11.

[12] R.A. Daniel. 2003. Environmental considerations to structural material selection for a bridge, *Proc. European Bridge Engg. Conf. Lightweight Bridge Decks*, 1.

[13] R.K. Gupta. *Composite Sleepers: An Environment Friendly Alternate Sleeper for Track and Bridges*, RDSO, Manak Nagar, Lucknow.

[14] TieTek. 2014. *Increase productive track time and reduce costs with TieTek composite ties*, www.tietek.net.

[15] W. Vantuono. 2010. TieTek LLC is up for grabs, bids are due, *Railway Age*.

[16] Axion. 2014. *Axion EcoTrax composite railroad ties*, www.axionintl.com.

[17] *Synthetic Sleepers Made from Fibre Reinforced Foamed Urethane*, Japanese Standard Association, JIS E 1203, 007.

[18] *FFU Synthetic Railway Sleepers*, Sekisui Chemical GmbH, www.sekisui.de.

[19] G. Koller. 2009. The use of sleepers made of FFU synthetic wood in Europe, *RTR-Railway J.*, 2.

[20] *IntegriCo Composites*, www.integrico.com.

[21] C.P. Antonopoulos and T.C. Triantafillou. 2003. Experimental investigation of FRP-strengthened RC beam-column joints, *J. Composites for Construction*,

ASCE, 7(1), 39-49. https://doi.org/10.1061/(ASCE)1090-0268(2003)7:1(39).

[22] H.C. Wu, G. Fu, R.F. Gibson, A. Yan, K. Warnemuende and V. Anumandla. 2006. Durability of FRP composite bridge deck materials under freeze-thaw and low temperature conditions, *J. Bridge Engg.*, 11(4), 443-451. https://doi.org/10.1061/(ASCE)1084-0702(2006)11 :4(443).

[23] D.K. Stone, D. Koenigsfeld, J. Myers and A. Nanni. 2002. Durability of GFRP rods, laminates and sandwich panels subjected to various environmental conditioning, *Proc. 2nd Int. Conf. Durability of Fiber Reinforced Polymer Composites for Construction*, 29-31.

[24] A. Ghobarah and A. Said. 2001. Seismic rehabilitation of beam-column joints using FRP laminates, *J. Earthquake Engg.*, 5(1), 113-129. https://doi.org/10.1080/136324601 09350388.

[25] *FRP Composite Sleepers for Application on Rail Tracks And Girder Bridges*, 2014. www.permaliwallace.com.

[26] A.C. Manalo, T. Aravinthan, W. Karunasena and M.M. Islam. 2010. Flexural behaviour of structural fibre, composite sandwich beams in flatwise and edgewise positions, *Composite Structures*, 92(4), 984-95. https://doi.org/10.1016/j.compstruct.2009.09.046.

[27] D. Adam. 2009. Network rail to recycle rubbish into sleepers, *The Guardian*.

[28] Network rail to replace wooden sleepers with recycled plastic, *The Telegraph*, 2009.

[29] *Plastic Polymer and Intrusion Products*, Tufflex Plastic Products Pty. Ltd., 2014. www.tufflex.co.za.

[30] D. Dechojarassri. 2005. *Natural Rubber Composites for Railway Sleepers: A Feasibility Study*, Thammasat University, Rangsit Campus, Pathum Thani, Thailand.

[31] *KLP Main Track Sleeper - Sustainable Plastic Railway Solutions*, LHR, 2014. www.lankhorstrail.com.

[32] G. Graebe, J. Woidasky and F. Jv. 2010. *Railway Sleepers from Mixed Plastic Waste*, Rail Waste Project Status Information, Fraunhofer ICT.

[33] *Plastic Composite Wood Core Railroad Ties 270 lbs Near Indestructible*, Southwest RV and Marine, 2014. www.swrvandmarine.com.

[34] M. Allan and A. Thiru. 2012. Behavior of full-scale railway turnout sleepers from glue laminated fiber composite sandwich structures, *J. Compos. Constr.*, 16(6), 724-736. https://doi.org/10.1061/(ASCE)CC.1943-5614.0000307.

[35] A.C. Manalo and T. Aravinthan. 2012. Behaviour of full-scale railway turnout sleepers from glue laminated fibre composite sandwich structures. *ASCE J. Composites for Construction*, 16(6), 724-736. https://doi.org/10.1061 /(ASCE)CC.1943-5614.0000307.

[36] S.S. Pang, G. Li, J.E. Helms and S.I. Ibekwe. 2001. Influence of ultraviolet radiation on the low velocity impact response of laminated beams, *Composites, Part B: Engg.*, 32(6), 521-528. https://doi.org/10.1016/S1359-8368(01)00027-0.

[37] P.M. Schubel, J.J. Luo and I.M. Daniel. 2007. Impact and post impact behavior of composite sandwich panels, *Composites Part A: Applied Sci. and Mfg.*, 38(3), 1051-1057.

[38] D. Cise and R.S. Lakes. 1997. Moisture ingression in honeycomb core sandwich panels, *J. Materials Engg. and Performance*, 6(6), 732-736. https://doi.org/10.1007/ s11665-997-0074-4.

[39] J.T. Gourley and G.B. Johnson. 2005. Developments in geopolymer precast concrete, Geopolymer, green chemistry and sustainable development solutions, *Proc. World Congress Geopolymer*, Saint-Quentin, France.

[40] M. Uehara. 2010. New concrete with low environmental load using the geopolymer method, *Quarterly Report of Railway Technical Research Institute*, 51(1), 1-7. https://doi.org/10.2219/rtriqr.51.1.

[41] A. Palomo and A.F. Jiménez. 2011. Alkaline activation, procedure for transforming fly ash into new materials, Part I: Applications, *Proc. World of Coal Ash Conf.*

[42] W. Ferdous, A. Manalo, A. Khennane and O. Kayali. 2015. Geopolymer concrete-filled pultruded composite beams - Concrete mix design and application, *Cement and Concrete Composites*, 58, 1-13. https://doi.org/10. 1016/j.cemconcomp.2014.12.012.

[43] G.V. Erp, C. Cattell and T. Heldt. 2005. Fibre composite structures in Australia's civil engineering market: an anatomy of innovation, *Progress in Structural Engg. Materials*, 7, 150-160.

[44] R. Lampo, T. Nosker and H. Sullivan. 2003. Development, testing and applications of recycled plastic composite cross ties, *US Army Engineer Research and Development Center*, Illinois, USA.

[45] R. Lampo. 2014. Summary of current state of practice for composite crossties, Proc. *Int. Crosstie & Fastening System Symp.*,

[46] J. Zhao, A.C.H. Chan and M.P.N. Burrow. 2007. Reliability analysis and maintenance decision for railway sleepers using track condition information, *J. Oper. Res. Soc.*, 58, 1047-1055. https://doi.org/10.1057/palgrave. jors.2602251.