Evaluation of alternative railway track sleepers including recycled plastic

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# Abstract

Several railway track sleepers have been developed over the last few years. The development of new sleepers is meant to establish the best alternative sleeper for the construction of railway track. Though studies have been conducted and several sleepers developed, studies indicate that timber and steel are steel the widely and commonly used materials for the manufacturing of railway sleepers. The recent development of composite sleepers such as recycled plastic sleepers and fiber are as a result of research being done to establish the best alternative sleeper which can be used for the construction of railway track. However, since the development of recycled plastic sleepers, most companies prefer to use it instead of traditional sleepers. This paper, therefore, evaluates various existing railway sleepers based on their durability, flexibility, stiffness, and availability in order to determine the best material for the manufacturing of railway sleepers. In order to establish alternative sleeper timber, concrete, steel, and recycled plastic sleepers were evaluated based on the performance. The evaluation establishes that recycled plastic sleepers are the alternative sleepers suitable for the construction of railway track sleepers to timber and steel. Looking into the cost-efficient and availability, it is established that timber still the most cost-efficient sleeper despite several hurdles related to environmental laws which have limited cutting down of trees.

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# CHAPTER ONE: INTRODUCTION

## Background information

The traditional resources which were used for the manufacturing of railway track sleepers are timber, concretes and steel. Though recycled plastics and steel are commonly used recently for the construction of railways track sleepers, timber was the earliest material preferred by Railway line constructors and engineers worldwide and they have been used for over decades (Remennikov, et.all, 2015, p. 156). According to Remennikov, et.all (2015, p. 158), more than 2.5 billion components of timber have been used to construct railway track sleepers and are currently buried worldwide. Timber was the preferred materials for many constructors for several years until it becomes scarce and could not be the current properties demanded by railway line engineers and constructors. Most railway line constructors preferred timber because of its adaptability and have excellent dynamic, sound-insulating and electric properties. During the 1880s, timber became very scarce and therefore, the railway constructor sorted the alternative and therefore, the steel sleeper was introduced as the best alternative material to timber (Hino, 2018, p. 24). However, over the last decades, railway constructors have decided to use cement-based concrete as the best alternative rather than steel and timber sleepers. The block sleepers were introduced in the 1940s and nowadays used across the world for the construction of high speed and heavy haul rail track. The changing dynamic has altered the viability and necessity of some of the sleepers. Therefore, most railway tracks are currently being constructed using recycled plastic sleepers as the best alternative.

This, therefore, brings the question of why railway construction companies normally used a variety of materials for the construction of railway track sleeper instead of a particular one. The answer is very simple none of materials steel, timber and concrete has satisfactory meets the requirements of a sleeper. As stated by Remennikov, Ferdous, Manalo, Gerard, Aravinthan, & Kaewunruen (2015,p. 160) the alternative to timber discovered still indicates that there is high demand for the sleeper. A recent study indicates that traditional sleepers have not met the demand of sleeper because most of them have failed to resist biological, mechanical and chemical degradation (Manalo, Aravinthan, Karunasena, & Ticoalu, 2010, p. 604). Timber has several problems related to rotting, splitting, and insect attack and more serious it has become very scarce due to environmental related laws which have limited cutting down of trees worldwide. The scarcity of timber, rotting, splitting and attack by insect introduced a new challenge to the construction industry. Steel has also other challenges related to corrosion, fatigue cracking, and high electrical conductivity. It is also discovered that steel is difficult to pack within the ballast and therefore, this made steel inferior material for the construction of railway track sleeper. On the other hand the expected alternative materials for rail sleeper, concrete sleepers suffer a great disadvantage because it is heavy and having a high cost compared to timber and steel though it has greater durability. The concretes are also difficult to handle and require extensive and expensive materials or equipment for the installation.

Moreover, steel and concrete sleepers need special fasteners for them to be able to operate efficiently. Both cannot be used to replace timber immediately they still need to be placed in the track because of the incompatible nature of the timber and concrete (Bolin & Smith, 2013, p. 21). However, there have been also a lot of problem with environmentalists regarding cutting down of trees for the production of timber making the traditional materials very unacceptable. According to Kaewunruen, Ruilin, & Ishida (2017, p. 23), cutting down trees for the production of timbers emits a lot of fo carbon dioxide to the atmosphere during the production stage. This had made the traditional materials very difficult to be accepted and therefore, timber became very scarce and expensive for the construction of track sleepers. The effect of cutting down trees for the production of timber motivated researchers from various countries from around the world, to develop and examine the best new and effective alternative sleeper technology which can be used in the construction of railway track. Currently, the worldwide market for complex technology is quickly increasing because of the several advantages it provides the industry. Kaewunruen, Ruilin, and Ishida (2017, p. 15) pointed that the new technology for the construction of railway track has a high strength to weight ratio, moisture and insect resistance, corrosion resistance and thermal and electrical resistance as well. These qualities make the new technology one of the best materials for the construction of railway sleeper track. These materials used in the railway line sleepers can be engineered to meet certain requirements for railways sleepers. It is, therefore, believed that composite railway sleepers can make the best alternative for the widely used sleepers timber, concretes, and steel for the construction of heavy haul rail network and mainline. The composite sleepers have shown that they are the materials for the future generation of sleepers. With advantage technology, the composite sleepers are the best because of their environmentally friendly nature and compatibility with the existing materials which are being used for the construction of railway line track.

In Australia most railway construction have companies have shifted to steel sleepers as the alternative sleeper. Kaewunruen, Ruilin, and Ishida (2017, p. 32) noted that over 90% of railway constructors still use steel for the construction of railway track despite the challenges such as corrosion which is common with steel sleepers. According to Yun & Ferreira (2003, p. 38), research is still being conducted using various composite materials to derived on the best alternative sleepers. The market of steel sleeper is high but in North American most constructors are using timber sleepers as the alternative for the construction of a railway track. Kaewunruen, Ruilin, and Ishida (2017, p. 36) pointed out that despite several studies which have been conducted regarding sleepers, most railway construction companies have not decided on the best alternative sleeper for railway track construction.

## Problem statement

The technological advancement and the recent environmental challenges have made the traditional materials for the construction of railway sleepers obsolete. In early days, railway track sleepers were being manufactured using timber, then companies shifted to steel and concrete. Currently, several companies have adopted composite sleepers including recycled plastic as the alternative for timber and steel for the manufacturing of railway track sleepers. However, there is still a huge gap since almost each of sleepers is faced with various challenges and therefore, affecting the railway industry. Studies indicate that timber is almost being wiped out of the railway track, the same will soon happen to steel and then concrete because of lack of a particular sleeper preferred by the majority of railway track constructors as the best sleepers. The sleepers made of timber are experienced splitting, rotting and therefore, the timber is less durable. The steel is faced with corrosion, high electrical conductivity and the cost of implementation is high the same to concrete sleepers. Though concrete has not been faced with several challenges compared to timber and steel, it has proved to be costly in implementation and therefore, it is facing a lot of doubts as to the best alternative. With the trend, it is important to evaluate the sleepers being used by most construction firms. This would help decide on the best alternative railway track sleepers for the construction o railway line.

The growth in the railway industry requires high efficient materials for the construction of sleepers and therefore, with the challenges facing the traditional railway track sleepers such as timber, and steel, it is high time for the best efficient alternative to be derived. The railway industry has also improved and for the last decade, the high-speed train has been discovered. Several laws have also been enacted to protect the environment against degradation and therefore, the traditional materials used to manufacture railway track sleepers are no longer viable.

## Purpose of the Study

The purpose of this study is to evaluate the recent developed composite railway sleepers, limitation and also provide necessary solutions that can be used to overcome the challenges created in the process of their utilization and acceptance. In order to understand vividly some of the railway track sleepers being used for the construction of railway track, this paper analyses each of the track sleepers including timber, recycled plastic, concrete, and steel. The study compared the four known railway track sleepers timber, steel, concretes and recycled plastic sleepers which are recently discovered as the best alternative railway track sleepers and most railway companies have adopted worldwide including several Australia companies. The study analyses the advantages and disadvantages of recycled plastic sleepers as the best alternative track sleeper and therefore, it illustrates its usefulness as well. Furthermore, the study focusses on the alternative sleepers which can be implemented without violating any law and can meet the demand of the market.

## Research questions

The research questions were based on the stiffness, durability, and strength of the sleepers and therefore, the research question was " among the existing railway sleepers which is the best alternative railway sleeper based on strength, stiffness, cost, durability, and adaptability?

## Objective and Goals

The core goal of the study is to examine railway track sleepers and provide the best alternative which can be efficient for the construction of railway track. Several railway track sleepers have been developed before but almost each of them has defaults which have made railway construction experts continue searching for the best alternative sleepers. Therefore, the objective of the study is to evaluate the existing materials used for the construction of railway track sleepers and advise on the best alternative sleeper based on stiffness, durability, cost-efficient and eco-environment friendly that can be used in the modern world for the construction of railway track sleepers worldwide.

# CHAPTER TWO: LITERATURE REVIEW

## 2.1. Overview of the existing materials for railway track sleepers

There have been several types of research and related studies on railway sleepers used worldwide in the construction of railway1 sleepers. The widely known sleepers are timber and steel, which have been used for decades. According to Jain, Khandelwal, Mehrotra, & Gupta (2016, p. 21), the research and innovation in the railway industry have never stopped. In the last few decades, other materials have been inverted to reinforce the traditional and widely sleepers made of timber and steel. It is, therefore, evident that several new and advanced sleepers have been developed from different parts of the world as the best alternative of timber and steel. A study by Sharma, Sunil, Srihari, & Kumar (2017, p. 325) illustrated that for the last decades, steel concretes and recently recycled plastic sleepers have been developed to replace traditional sleeper, timber, and steel. Apart from concrete and steel, recycled plastic and fiber made sleepers are developed to impersonate timber or to incorporate the behavior of timber which has proven to be an essential requirement for the maintenance of the track. Though a lot of doubts have been raised on the durability of the timber, studies indicate that it was used for decades before, resulting to invest in the alternative sleepers (Bolin & Smith, 2013). It was used from the 1860s to the later 1990 by several companies to construct railway track sleepers.

Bolin and Smith (2013, p. 158) pointed out that a lot of investigations which have been done in an attempt to decide on the best, durable, cost-effective and strong materials for the construction of railway track sleepers. Some early studies concluded that existing resources such as steel, concrete, and timber could be the best approaches to address the deficit in the industry (Bolin & Smith, 2013, p. 154). However, other approaches have also been made to incorporate the existing materials with other materials such as fiber and recycled plastic sleepers. Further attempts have been made as well to replace the entire existing sleepers using alternative materials such as recycled plastic and polymer concrete. Recently a lot of focuses have been on the recycled plastic sleepers as the alternative materials for the manufacturing of railway track sleepers. This literature review, therefore, provides a detail presentation of the studies which had been conducted on various sleepers. It analyzed sleepers used for the construction of railway track such as timber, concretes, steel and recycled plastics.

## 2.2. Timber Sleepers

Timber sleepers have been a widely used traditional material for the construction of railway track sleepers. Studies indicate that previously timber was readily available and therefore, it could be produced for the construction of railway track sleepers (Ferdous & Manalo, 2014, p. 31). A study conducted by Sadeghi and Barati from the School of Railway Engineering, Iran University of Science and technology on the comparison of various materials used for the manufacturing of railway track sleepers, indicates that timber has been used widely due to its availability but its lifespan is short (2012, p. 15). According to Sadeghi and Barati (2012, p. 21), timber sleepers have been used since the 1880s and were considered the best railway sleeper at that time but it has a lifespan of 20 to 30 years. In the early days, 90%of railway track sleepers were wooden (Sadeghi & Barati, 2012). Most railway constructors preferred timber as the alternative materials for the manufacturing of sleepers for the construction of railway track. It means that wooden railway sleepers were visible across the world and this was because the timber was readily available and the there were no strict laws regarding cutting down of trees which have put a lot of restrictions on the usage of timber (Sadeghi & Barati, 2012).

However, wooden railway sleepers are used mostly on railroad tracks for low, medium and high tonnage because it could easily provide support for the weight of up to 32 tons per axle. It also offers an operating speed of up to 120 km/hr. According to Manalo, Aravinthan, Karunasena, & Ticoalu (2010, p. 23), wooden sleepers offered the best resistance to the derailment and it is easy to install using any kind of machine with through the use of manual hands. The study also established that wooden sleepers easily adapt to different kind of rails and it can fit into any radius which includes broadening of the gauge in the curves of any radius (Kaewunruen, Ruilin, & Ishida, 2017, p. 35). According to Yun & Ferreira (2003, p. 23), timber sleepers have been approved as one of the reliable and effective sleepers in performance in any railway environment. A study conducted by Yun & Ferreira (2003, p. 25) pointed out that though timbers are used in the same way, they are different in their flexibility. Timber can be adjusted in all types of railway track and therefore, it is viable, easy to replace, easy-going and require no complicated assembly of types of equipment. In figure 1 above, bolts and other adjustment parts are viable and can be done manually. Research has also indicated that timber sleepers are highly attractive to high-density lines where track line is restrained and limited to introduce large scale production (Ticoalu, Aravinthan, & Karunasena, 2015, p. 156).

***Figure 1: Old wooden railway sleepers (Yu and Ferreira, 2003. P. 12)***

As indicated in figure 1 above, timber sleepers are placed halfway on the ground and therefore, it exposed the timber sleepers to moisture. As a result, timber has been widely criticized for its high rate of degradation and therefore, biological and mechanical degradation are some of its major failures or drawbacks. As shown in figure 2 below, timber sleepers rot, split and making them less durable compared to other sleepers used for the construction of railway track sleepers. The cracking, splitting and degradation have made timber not to be the best material for sleepers. However, the most problem facing railway is a lack of quality timber which can be used to manufacture railway sleepers. Timber has been discovered that it easily caused hazard due to the chemical used for the preservation of timber. Researchers have also pointed out that a lot of questions have been raised by environmentalist which made the usage of timber to be affected. From the early 1990s, laws, and policies have been enacted across the globe to limit cutting down of trees. Ferdous and Manalo (2014, p. 25) pointed out that this made timber not to be a viable alternative material for the construction of railway track. The use of chemical for the preservation of timber causes a hazard to the environment. Therefore, these are some of the reasons timber sleepers are generally criticized forcing engineers to continue with innovation and development until the best railway sleepers are discovered. A study by Kaewunruen, Ruilin, & Ishida (2017, p. 21) concluded that the durability, efficiency, and environmental degradation issues make timber to be inappropriate material for the manufacturing of railway sleepers. According to Remennikov, Ferdous, Manalo, Gerard, Aravinthan, & Kaewunruen (2015, p. 123,) the drawbacks made timber sleepers unreliable for the sustainability of the future railway tracks and therefore, this made railway trail constructors and other related experts and researchers in railway constructions to have continuous research to establish the best alternative railway track sleepers.

*Diagram 2: Timber sleepers with splits (Ferdous & Manalo, 2014, p. 12)*

## 2.3. Steel Sleeper

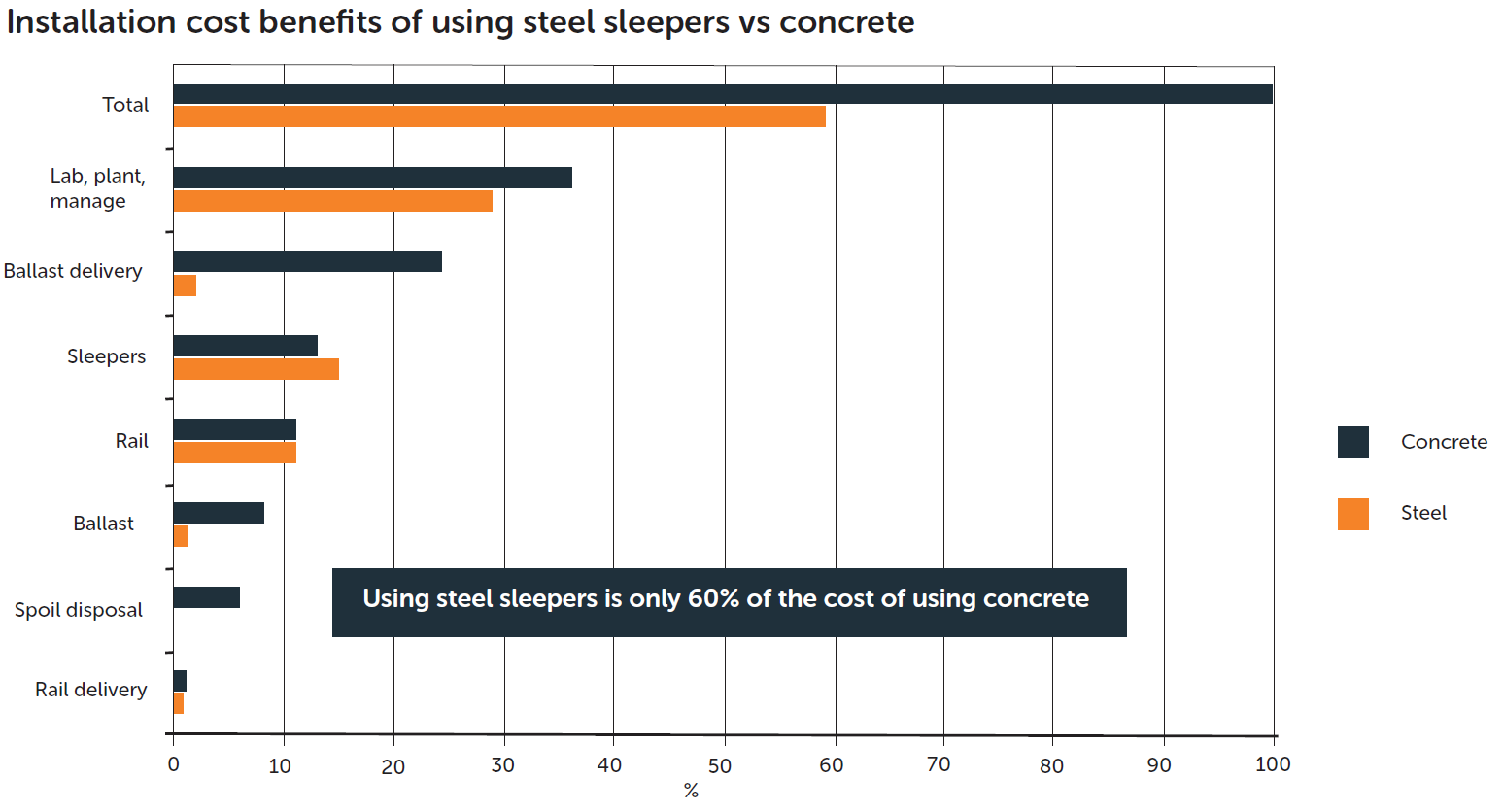
Steel sleeper was inverted as an alternative to the wooden sleeper and it has been used in the railway construction for decades. According to Hino (2018, p. 21), steel sleepers are used where wooden sleepers cannot be used and therefore, steel sleepers are used as an alternative to wooden sleepers in the construction of railway track. With a lifespan of 50 years, steel sleepers emerged as the best alternative to replace timber sleepers in the railway industry (Manalo, Aravinthan, Karunasena, & Ticoalu, 2010, p. 21). A study conducted by Hino on the uncertainties of different types of sleepers concluded that steel sleepers provide higher mechanical strength and very light and not difficult to handle compared to timber (2018, p. 35). Further studies established that steel sleepers can be operated manually making the maintenance of steel sleepers to be less expensive compared to timber sleepers. However, the usage of railway constructed using steel sleepers are always limited to tracks used for light travel (Bolin & Smith, 2013). According to Bolin and Smith (2013, p.35), since steel sleepers can be recycled several times, it offers the best alternative sleeper to timber for the manufacturing of railway track sleepers. The use of steel for the construction of the railway track has economic value to companies and other stakeholders. Compared to timber sleepers, steel sleepers have a longer lifespan and maintenance, repair and sustainability are easier and efficient making steel to a preferred sleeper for the construction of railway track in recent history.

A study conducted by Bolin and Smith concluded that the commercial value of steel made it be the best alternative sleeper (2013, p. 47). As a result, 60% of railway tracks are being constructed using steel sleepers instead of timber (Bolin & Smith, 2013, p. 25). Though there are other sleepers such as recycled plastic and concrete, studies indicate that steel sleepers are highly preferred by most railway constructors (Bolin & Smith, 2013, p. 15). This is because steel sleepers provide excellent gauge restraint and increase lateral resistance needed to secure its geometric. Steel sleepers also last longer than timber which has made it the most reliable and widely used sleeper for the construction of railway track in different parts of the world during the 21st century.

Though steel sleepers have been widely preferred by railway constructors, it has several drawbacks which have made many researchers and constructors look for the best alternative sleeper. Some of the drawbacks of steel sleepers are rampant corrosion, heavy and difficult in implementation of the sleeper. A study by Remennikov, Ferdous, Manalo, Gerard, Aravinthan, & Kaewunruen (2015, p. 32) indicated that installation of steel require special equipment because of the usage of ballast to re-enforce the sleepers for them to be durable. The lack of enough timber in the country and the economic factors has led to the use of steel as the best alternative material for the construction of railway sleepers. Steel sleepers are more durable, it incurs lesser damage during transportation and handling. Steel sleepers cannot be attacked by vermin and not susceptible for fire and it the value of its scrap is high and therefore, it is more acceptable in the railway industry for the construction of railway track. Despite several advantages, steel sleepers are faced with several challenges related to transferability. According to Yun & Ferreira (2003, p. 25), steel sleepers can only be used for the specific rail it was manufactured for and cannot be used for any other. Maintenance of the gauge is very difficult because the tie bar usually gets bent when being untied or fastened. Steel sleepers are not suitable for circuit track and it requires a large number of fittings. Most railway constructors have pointed that steel sleepers are the best the construction of railway track because it is realigning the gauge firmly making it difficult to uproot or whether out.

***Diagram 3: Steel Sleepers on the railway track***

## 2.4. Cost-benefit of using steel sleepers versus concrete

Depending on the type of project being implemented, there is a lot of cost-saving when using steel sleepers over concretes. The volume of ballast and other materials needed for the implementation of steel is less compared to concrete. A study conducted by British Steel shows that the use of steel cost only 60%of the cost required for the implementation of concretes (Loizos & Konstantinos, 2010, p. 38). This makes steel less expensive compared to concrete and even to timber which required a lot of ballast during the implementation as well. Australia has developed one of the best steel technologies which are being used for the construction of a railway track. The Institution of Railway technology at Monash University has been working to reduce the cost and make sure that the performance of steel sleepers improved (Loizos & Konstantinos, 2010, p. 21). According to Hino (2018, p. 21), steel accounts for over 13%v of the total railway sleepers being used in Australia for the construction of railway track. This is because of the low cost of implementation of the steel compared to concrete and timber sleepers.

## 2.5. Concrete Sleepers

The concrete sleepers became high recognized sleepers for the railway truck in the early days and it is being for the construction of a railway track. It was inverted as the alternative to steel sleepers because of its efficiency and reliability in high-speed line. A study conducted by Manalo ( 2010, p. 21) concluded that its economic consequences and long life and low maintenance cost required made it be the alternative railway truck sleepers. According to Manalo (2010, p. 28), even after several modern and technological sleepers have been developed, concrete sleepers are still widely used for the construction of railway life for high-speed trains. Monobloc prestressed is the commonly used concrete sleeper for the construction of railway track. Sharma, Sunil, Srihari, & Kumar (2017, p. 32) pointed out that Monobloc is widely used because it is easy to handle compared to a triple block and other types of concrete sleepers. However, the study conducted by Sharma, Sunil, Srihari, & Kumar (2017, p. 45) concluded that concrete sleepers are used as the alternative sleeper for the construction of railway truck because it distributes the load longitudinally and therefore, it reduces the need to have ballast for maintenance.

Concrete sleepers have gone through various developments to establish a better and durable concrete sleeper which is advantageous for the railway industry (Manalo, 2010, p. 34). As stated by Sharma, Sunil, Srihari, & Kumar (2017, p. 32) concrete sleepers were designed to be used together timber sleeper for the construction of the railway track. Mostly concretes are used to replace timber sleepers which have reached the end of their lifetime. The concrete sleepers are used most on the mainline truck because it has a specific pattern which needs to be followed. Several studies have pointed out that the main drawback of concrete sleepers is the weight. Concrete sleepers are heavy and therefore, they require to complicate machine to handle them during the installation process. Sharma, Sunil, Srihari, & Kumar (2017, p. 29) noted that the initial cost of concrete sleepers was low but the fact it currently being used with timber sleeper has made the cost to increase significantly. Studies have also discovered that concrete sleepers are stiff and therefore, the design used requires greater depth compared to timber sleepers. Concrete sleepers are also very sensitive to the corrosion of the rail seat and this result to the lack of resilient rail pad and the concrete. The concrete sleepers have registered poor results because of its inflexible nature. Some of the concrete sleepers are also little damping and therefore, requires good standard ballast and rail to avoid getting damaged. In diagram 4, the usage of concrete sleeper is illustrated and based on the image; concrete sleepers provide a straight and straight align work (Ghorbani & Erden, 2015, P. 21). This makes the installation and maintenance of the concrete sleeper to be easy and cost-efficient. The replacement of concrete sleepers was, therefore, necessary due to drawbacks viewed as essential in the railway construction industry. Therefore, despite their advantageous, many constructors rarely used concrete for the construction of the railway track. It is also stated by Ghorbani and Erden (2015, p.32) that concrete sleepers ha high stiffness and require heavy machines for the installation. Therefore, with much easier sleepers to use, concrete sleepers have generally been left by several railway constructors as the alternative sleeper for the construction of railway track.

Diagram 4: Concrete Sleepers

## 2.6. Recycled Plastic Sleepers

Remennikov, et.all (2015, p. 152) pointed out that in the last few years, several recycle plastic sleepers have been developed as an alternative sleeper for the construction of railway track. These technologies have been approved as the best alternative to timber sleeper. Apart from concrete and steel sleepers, these sleepers can be modified to mimic the behavior of timber, which is some of the essential requirement for the maintenance of timber sleepers. The recycled plastic and other composite sleepers are more accepted as an alternative sleeper because of their environmentally friendly nature of the material. According to Remennikov, et.all (2015, p. 155), recycled plastic sleepers are more sustainable from the environmentalists perspective and maintenance of the railway track built from the recycled plastic sleepers is cheap compared to the rest of traditional sleepers. As illustrated in diagram 5 below, railway track constructed using recycled plastic sleepers looks neater and maintenance is cheap and easy. From the diagram (5), the bolts and other fastening components are placed strategically to allow the maintenance to be done efficiently. Remennikov, et.all (2015, p. 152), noted that the design for recycled plastic sleepers is done for longevity but not to reduce the total cost of ownership or construction of the railway track.

Diagram 5: Recycled railway sleeper.

The longevity is also to ensure that stiffness is maintained specially when used for interspersing the timber sleepers. As stated by Shinde (2016, p. 18), the concept of recycled plastic sleepers was to maintain. The recycled plastic sleepers have also a longer lifespan of above 50 years and therefore, the recycled plastic sleepers can be easily used to replace timber, and steel sleepers from the railway track. The recycled plastic sleepers are designed and manufactured using high quality, ductile materials with enclosed steel reinforcement bars to provide high strength properties and excellent damping features. Compared with other existing railway track sleepers, the recycled plastic sleeper is the best alternative material for the construction of railway track. It provides the best structural design and has higher durability needed by railway engineers for the construction of railway track in this 21st century (Shinde, 2016, p. 23).

## 2.7. The need for alternative sleepers

A study conducted by Shewale, Patil, Kothawade, Joshi, & Deore (2018, p. 32) concluded that many railway construction firms have been using concretes and steel for the construction of railway track for decades. The use of timber and concrete was due to the ability of the materials because, in the early days, timber was readily available and was very affordable as well. But the cost of maintenance of both timber and concrete sleepers are high. According to Shewale, Patil, Kothawade, Joshi, and Deore (2018, p. 35), it made researchers and railway line constructors continue to look for the best alternative sleepers. The concrete sleeper did not prove to be the best viable alternative to timber and therefore, few railway line construction companies are still using timber for the construction of railway track sleepers. According to Shewale, Patil, Kothawade, Joshi, & Deore (2018, p. 32), in Queensland Rail in Australia a closely 80,000 timber is used for track maintenance despite the high increase of the effectiveness and reliability of steel and other sleepers such as recycled plastics. Shewale, Patil, Kothawade, Joshi, & Deore (2018, p. 12) pointed that the reason for the utilization of timber for the maintenance of railway track is because of the convenient and financial viability for short term replacement of sleepers.

The fact that most constructions firms worldwide are still purchasing several timbers for the maintenance of railway track is enough evidence of the viability and efficiency of timber in the construction of railway track. Though many studies have been done on the alternative sleepers, the traditional sleepers such as timber, concrete, and steel are being preferred by many construction firms and commonly used for the construction of railway track. The analysis of some of the recent constructed railway lines worldwide indicates that most firms steel use steel as the choice rather than composite. In Sub Sahara Africa where several railway tracks have been constructed by Chinese companies. Steel sleepers are widely used to construct the railway track instead of the composite sleepers. According to Shewale, Patil, Kothawade, Joshi, & Deore (2018, p. 8) most of these new constructions of railway line utilizes steel sleepers instead of concrete or other alternatives. In 1400 km railway line, the Chinese Company used steel reinforce with concrete for the construction of the Mombasa to Nairobi railway line. It is evident that despite research other studies which have been done to come up with composite sleepers. Steel and concrete sleepers are still used as the alternative for the construction of the railway by several railway construction companies worldwide. Most companies using steel and concretes for the construction of railway track focus on the durability of the track. Steel and concrete are expensive in terms of installations and maintenance, adaptability and availability. The provision of longer duration makes them more viable and the best choice for some of the constructors in the railway industry.

However, the type of sleeper utilize for the construction of railway track depends on the purpose of the rail. According to Sharma, Sunil, Srihari, & Kumar (2017, p. 12), in cases where the railway line is constructed for heavy usage or commercial for heavy rails, most companies prefer to use steel sleepers or recycles plastic sleepers. The steel sleepers are also used for the construction of railway track for high-speed rails. As illustrated by a study conducted by Shewale, Patil, Kothawade, Joshi, & Deore steel and composite sleepers are widely used for the construction of some of the latest railway line or track which are being done recently (2017,p. 25). According to Shewale, Patil, Kothawade, Joshi, & Deore (2017, p. 32), most railway track being constructed currently is constructed using recycled plastic and steel for efficient operation and reliability of the railway track. The analysis of several pieces of literature from different railway engineers indicates that timber sleepers have been used for years and thousands of timbers are still being for the construction of railway track.

## 2.8. Improved structural performance

Jain, Khandelwal, Mehrotra, & Gupta (2016, p. 21) concluded that it is important to improve the performance of each component to improve the performance of sleepers. Several studies conducted established that there is some loophole in the materials which are being used for the construction of a railway track. Therefore, the use of both recycled plastic and fiber and even concrete could easily help in addressing the problem. According to Jain, Khandelwal, Mehrotra, & Gupta (2016, p. 32), a lot of improvements have been done to recycled plastic to reinforce it. The unique reinforcement has also been included by several companies to improve the structural performance of sleepers. Therefore, the use of recycled plastic and fiber sleepers is due to the improved structural performance provided by the two composite sleepers. It is, therefore; important to point out that the majority of constructor currently use recycled plastic sleepers for the construction of railway track in most developed nations. The shift in materials is based on environmental issues considered by several countries but mostly because of the durability, stiffness, and strength which is provided by recycled plastic sleepers.

In a study conducted by Bolin & Smith (2013, p. 24) to determine the modulus and hardness of the sleepers, the study established that recycled plastic show high stiffness and inelasticity. Therefore, the high stiffness properties are what makes the recycled plastic one of the best materials for the construction of railway track sleepers. The investigation of natural rubber was engineered and resulted in better compressive modulus and hardness. However, their experimental results show high stiffness and inelasticity. Li (2016) examined the use of bulk re-cycled plastic as a core material for railway sleepers. This means that recycled plastic sleepers are some of the best alternative sleepers which should be used for the construction of railway tracks. In his study, Li concluded that recycled plastic material increases the strength of railway sleepers but may not be competitive in terms of cost-effectiveness (2016, p. 14). Nevertheless, the term cost-effective is a relative index in determining the acceptance of a product. Some of the existing studies Li (2016, p. 21) have confirmed the feasibility of using fiber composites in railway sleepers as the alternative sleepers. Despite several types of resources used for the manufacturing of sleepers, there is still a need to find a reliable and better-performing material which can be used to produce the best and reliable sleepers. The traditional timber sleeper was ideal because timber was a readily available resource that provides flexibility in installation and fastening, and has good resilience property (Zakeri & Abbasi, 2012, p. 34). Therefore, it is preferred that the development of new material for railway sleepers

# CHAPTER THREE: METHODOLOGY

This study was conducted quantitative research method, where the analytical design was used to evaluate various sleepers used in the construction of railway track sleepers. The use of descriptive design method was involved to analyze various literature reviews, articles and other, peer review published by various others regarding the alternative railway track sleepers used in the construction of railway track. The quantitative research was utilized in almost every part of the study to evaluate the alternative track sleepers based on the stiffness and strength. In this case, the evaluation of the sleepers was done based on various pieces of literature or articles and other studies related to railway construction. In order to conduct an efficient evaluation of the existing railway track sleepers, the experiment was conducted using a variety of sleepers which are used for the construction of railway track. Recycled plastic, timber, steel, and concrete were subjected through various laboratory tests to determine the durable and the best alternative sleepers.

## 3.1. Composite (recycled) sleepers

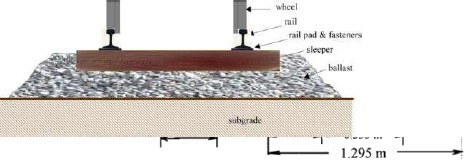
The composite property is a mixture of plastic which is used for producing recycled plastic. The recycled plastic is made from rubber, tires, rubber buffing. The materials are also mixed with a chemical, waste material, filler and various reinforcement agents such as fiberglass. In the mixture of recycled plastic, 20% of the mixtures are rubber (Michael, 2015, p. 21). Therefore, the manufacturing process of the recycled plastic occurs in stages. However, the test was conducted using a machine grid to press on each of the sleepers to determine the strength of each of the sleepers. As illustrated in diagram 5 below each sleeper were suggested to pressure when placed on the ground to determine the durability and flexibility of each sleeper. It is also important to point that each sleeper was tested using different methods based on the environment where the material was placed.

## 3.2. Identification of Strength and stiffness of sleepers

To determine the best alternative sleepers, a test was conducted to determine which sleeper by determine the strength and stiffness of sleepers. For the use of the construction of railway track, timber must meet a certain condition. In Australia, it must meet requirements that meet the condition certain by the government. Since timber can easily be affected by moisture and the environment it is important to test the timber sleepers.

## 3.3. Testing of the timber, recycled plastic, concrete, and steel sleepers

In order to determine the stiffness and strength of the sleepers, pieces of sleepers were arranged for four points bending to obtain load data and deflection. From the data obtained, the elasticity was then calculated to determine the strength and stiffness of each sleeper. It is also important to point out that the beams were then tested to determine the failure. The level for each bend reflected the strength and stiffness of the sleepers. The experiment was conducted in the laboratory under different dynamic. It is essential to state that the testing was also done to concrete and recycled plastic and steel. Each sleeper was subjected to test several times under dynamic condition to establish the behavior of each material of sleeper under different environment. The behavior of sleepers was monitored and recorded and further subjected to further analysis.



***Diagram 6: Process of testing stiffness and strength of concretes***

## 3.4. Test stiffness of the sleepers

Each sleeper was subjected to test by place a sleeper between a grumping tool, then put a lot of pressure to determine the time taken before the sleeper is folded. This test was done in the laboratory under room temperature and pressure which reflect the temperature outside. The test score of each sleeper was then recorded and then analyzed after the conclusion of the test for all the four sleepers. The comparison was then done based on the test core to determine which sleeper has the highest stiffness and strength.

# CHAPTER FOUR: PRELIMINARY DATA

The result of the study indicates that timber, concretes, recycled plastic and steel have different stiffness and strength. On a scale of 1.0 to 10.0, timber, concrete, recycled plastic and steel score different scale of strength and stiffness.

**4.1. Testing of stiffness and strength of the sleepers**

The result of the test score of the stiffness and strength shows that sleepers have different scores in the same environment and the stiffness and strength also changes based on the environment where the material I exposed. For instance, in hot temperature steel stiffness reduces and wooden increases and in cold temperature, the wood stiffness reduces (Manalo A., 2010, p. 12).

**First test: Stiffness sleepers**

***Graph 1: Sleepers Stiffness test score***

**Second test: Strength of sleepers**

***Graph 2: Sleeper strength test score***

In graph 1, the test of the stiffness of sleepers established that recycled plastic has high stiffness with 9.8 scores compared to the traditional alternative sleepers. Concrete had a score of 9.5, steel 9.6 and timber 8.6. Therefore, based on the stiffness test timber are least stiffed materials which are being used for the manufacturing of the railway track sleepers. However, graph 2, above indicates that recycled plastic has a high strength of 12.5 scores compared to the rest of the sleepers. The concrete scored 8.0, steel 10.5 and timber 8.8 and therefore, timber and concrete have the least strength among the existing materials which are being used for the manufacturing of railway track sleepers. Based on the result of the study, the best alternative sleeper is recycled plastic. This is due to the stiffness and the strength of the recycled plastic. However, timber and concrete sleepers would be the least alternative sleepers for the construction of railway track.

## 2.8. Comparison of alternative railway track sleepers

The evaluation of different railway track sleepers established that sleepers have different properties which make them unique. As illustrated in table 1 below, software which was traditionally used for the construction of railway track sleepers is the best alternative when considering cost, and handling and installations of the sleepers. It is established that hardwood and softwood provide the best easy workable environment compared to steel and concrete. But in terms of durability which many railway line constructors consider, concrete and steel are the best alternative material for the construction of railway track sleepers.

**Table 1: Comparison of the existing railway sleepers**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Properties** | **Hardwood** | **Softwood** | **Concrete** | **Steel** |
| Service life, year | 20-30 years | 20 years | 60 years | 50 years |
| Adaptability | Easy | Difficult | Difficult | Difficult |
| Cost | High | Low | Very high | Very high |
| Workability | Easy | Easy | Difficult | Difficult |
| Handling and installation | Easy | Easy | Difficult | Difficult |
| Durability | Low | Low | High | Low |
| Replacement | Easy | Easy | Difficult | Difficult |
| Availability | Low | High | High | High |

The evaluation of various sleepers indicates that timber sleepers still have several advantages in terms of cost, replacement, availability. The analysis of various materials used for the manufacturing of railway sleepers. A study conducted by Manalo, Aravinthan, Karunasena, & Ticoalu (2010, p. 35) established that the workability of timber, is easy and it is readily available compared to the rest of sleepers which are being used for the construction of railway track. The comparison of sleepers also established that steel and concrete are highly durable and therefore, they are commonly used for the construction of railway track sleepers.

# CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

## 5.1. Recommendation

Several studies have been done to establish the best alternative sleepers. However, studies are still required to be done to get alternative sleeper which can be efficient and effective for the construction of the railway line. It is recommended for a design required for the construction of recycled sleepers to be developed. The design developed should be able to meet the capabilities which can be exploited to achieve a satisfactory level of structural reliability. It is also recommended for the stakeholders to developed necessary standards which can be adopted for the usage of the recycled plastic sleepers. The new technologies are alternative to the existing sleepers. It is, therefore, recommended that a study should be conducted to establish the best alternative using the existing materials or recycled plastic sleepers. Research should also be conducted to establish the most efficient sleepers which are economical which can be used as an alternative of sleepers. The extensive research will ensure that the problems being experienced with the current sleepers are addressed efficiently. It is also important to establish a limit state of design equations which are needed to be established for the recycled plastic sleepers. The recycled plastic sleepers must have values for partial load factors and capacity reduction factor to be enabled to address the problem being experienced. Though recycle plastic sleepers have been identified as the alternative sleeper for the construction of railway track, it recommended that researchers and other stakeholders to continue conducting studies to invent more eco-friendly, cost efficient, durable and reliable railway track sleepers. This is because recycled plastic sleepers are not cost-efficient and maintenance is also high scaling the cost of construction of railway line higher. The discovery of more cost efficient sleepers would save the industry a lot of money and also help in improving the performance of railway track worldwide.

## 5.2. Conclusion

The study established that composite sleeper such as recycled plastic is the best alternative for the timber sleepers. Recycled plastic sleepers are effective load transmit without any reduction. It is established that recycled plastic is high resistance and therefore, it is against degradation from weather influence. The recycled plastic can be recycled and environmentally friendly and despite being preferred by railway constructors, environmentalist preferred it as well. The recycled plastic can be recycled and used for other useful products. The recycled plastic sleeper supports the eco-friendly environment and therefore, it is one of the greatest alternatives to timber and concrete for the construction of a railway track. Studies also discovered that recycled plastic also offer better track stiffness (Berggren, 2009, p. 21). However, because of the vibration which it offers, recycled plastic is a good solution for most of the challenges being experienced with other railway sleepers. The composite sleeper physical and chemical properties compared to traditional sleepers. The recycled plastic sleepers are obtained from recycling materials and therefore, it is a form of waste of materials to high-end application. However, recycled plastic does not have any leaching into the ground wastes. It is also established that recycled plastic has a life span of 50 years and therefore, it is evident that it has more life spans compared to timber concrete and other sleepers. Therefore, it can be concluded that recycled plastic is the best alternative sleepers which can be used efficiently for the construction of a railway track.

The study also obtained the cost of maintenance of timber, concrete, and steel is high and this motivated researchers to conduct a study on the best alternative sleepers. It is also obtained that the challenges experienced by existing sleepers such as timber, concretes and steel made researchers to get alternative. Several sleepers have been developed in different parts of the world but the way the new developed is being utilized in the market has been very slow (Ghorbani, 2015, p. 21). Many of the sleepers are not been used in the market though have been developed. Studies established that fiber sleepers and others have been developed as well, but few companies are using fiber for the construction of railway track. The study also established that the slow uptake in the railway construction market is because of the low stiffness and strength of the recycled plastic. Recycled plastic sleepers also have low anchorage capability of holding screws, permanent deformation due to creep, the formation of voids in the body of the sleeper and the temperature variation. The high cost of fiber makes it impossible for the usage of fiber sleepers and therefore, it is not widely used for the construction of the railway track.

Moreover, the long term performance and durability of recycled plastic sleepers are known. It is, therefore, important to conduct investigate the behavior of recycled plastic under different environment and fatigue loading. This would determine the performance of recycled plastic under different environmental condition. The composite should be tested under moisture, UV radiation, elevated temperature, and high ph. The study would help in understanding or establishing the performance of sleepers under different environmental conditions and therefore, it would provide proper knowledge of the sleepers. Since most of the existing sleepers have been tested and used for generations, the continued research on the best alternative sleeper. It means that timber, concrete, and steel have certain defaults which should be addressed by the alternative sleeper. It is necessary to found the best alternative to address the current challenges being experienced in the railway construction industry. The current design of sleepers is in the form of quasi-static and therefore, the design needs to modify so that sleepers can be able to incorporate dynamic impact or effect to ensure that there is reliability and the track is also safe. The study also indicated that some of the approaches which can be used to overcome the current challenges of recycled sleepers (O'rourke, 2015, P. 23). The stiffness and strength of the composites such as recycled plastic sleepers can be improved by using fiber and recycled plastic. It is, therefore, important to use fiber and recycled plastic to reinforce the performance of sleepers. This could be the best way to produce the best and alternative sleepers for the construction of the railway track. The optimization of the recycled plastic sleeper and other composites could be advantageous in terms of cost reduction. The manufacturing of sleepers should be, therefore, be done using a variety of materials to ensure that the end product is of high quality. However, recycled plastic could be the best alternative sleepers for timbers, steel and concretes.

# Bibliography

Berggren, E. 2009. Railway Track Stiffness Dynamic Measurements and Evaluation for Efficient

Maintenance. *Royal Institute of Technology*, 2-38.

Bolin, C. A., & Smith, S. T. 2013. Life Cycle Assessment of Creosote-Treated Wooden Railroad

Crossties in the US with Comparisons to Concrete and Plastic Composite Railroad Crossties. *Journal of Transportation Technologies*, 149-161.

Ferdous, W., & Manalo, A. 2014. Failures of mainline railway sleepers and suggested remedies –

Review of current practice. *Engineering Failure Analysis, 44* (12), 17-35.

Ghorbani, A. 2015. Polymeric Composite Railway Sleepers. *Journal Of Engineering And*

*Construction*, 2-34.

Ghorbani, A., & Erden, S. 2015. Polymeric Composite Railway Sleepers. *Uluslar arası Raylı*

*Sistemler Mühendisliği Sempozyumu* , 2-37.

Hino, T. 2018. Georisks in railway systems under climate uncertainties by different types of

sleeper/crosstie materials. *The Official Journal of International Association of Lowland Technology*, 2-35.

Jain, C., Khandelwal, S., Mehrotra, S., & Gupta, R. 2016. A Review Paper on the use of Composite

Material for Railway Sleepers in railway track. *SSRG International Journal of Civil, 12* (4), 2-36.

Kaewunruen, S., Ruilin, Y., & Ishida, M. 2017. Composites for Timber-Replacement Bearers in

Railway Switches and Crossings. *https://doi.org/10.3390/infrastructures2040013*, 2-38.

Li, S. 2016. Railway Sleeper Modelling with Deterministic and Non-deterministic Support

Conditions. *Journal of engineering and construction for the railway line, 12* (5), 2-38.

Loizos, A., & Konstantinos, G. 2010. Evaluation of actions on concrete sleepers as design loads

– the influence of fastenings. *International Journal of Pavement Engineering, 11* (3), 2-38.

Manalo, A. 2010. A review of alternative materials for replacing existing timber sleepers.

*International Journal of railway engineering, 23* (4), 2-15.

Manalo, A., Aravinthan, T., Karunasena, W., & Ticoalu, A. (2010). A review of alternative

materials for replacing existing timber sleepers. *Centre of Excellence in Engineered Fibre Composites (CEEFC), Faculty of Engineering and Surveying*, 603–611.

Michael, P. 2015. Experimental investigation into the effect of steel sleeper vertical stiffeners

on railway track lateral resistance. *Journal of Rail and rapid railway*, 2-45.

O'rourke, M. 2015. Technical Aspects Of Fastening System Selection. *Broken Hill Proprietary*

*Co. Ltd.* , 2-34.

Remennikov, A., Ferdous, W., Manalo, A., Gerard, V. E., Aravinthan, T., & Kaewunruen, S.

2015. Composite railway sleepers – Recent developments, challenges, and prospects. *Composite Structures, 134* (32), 158-168.

Sadeghi, J., & Barati, P. 2012. Comparisons of the mechanical properties of timber, steel, and

concrete sleepers. *Journal of structure and infrastructure Engineering, 8* (12), 2-38.

Sharma, R. C., Sunil, S., Srihari, P., & Kumar, R. M. 2017. Modernization of Railway Track

with Composite Sleepers. *International Journal of Vehicle Structures & Systems;* *9* (5), 321-329.

Shewale, R., Patil, G., Kothawade, G., Joshi, K., & Deore, H. 2018. Composite Railway Sleeper.

*International Research Journal of Engineering and Technology, 5* (9), 2-35.

Shinde, A. 2016. A Review Paper on use of Composite Material for Railway Sleepers in railway

track. *SSRG International Journal of Civil*, 2-35.

Ticoalu, A., Aravinthan, T., & Karunasena, W. 2015. An investigation on the stiffness of timber

sleepers for the design of fiber. *Centre of Excellence in Engineered Fibre Composites, Faculty of Engineering and Surveying, 21* (4), 2-38.

Yamada, H., & Ooba, K. 2017. History of Steel Sleepers and the Latest Developments. *Nippon*

*Steel & Sumitomo Metal Technical Report No. 115 July 2017*, 5-38.

Yun, W., & Ferreira, L. 2003. Prediction of the demand of the railway sleepers: A simulation

model for replacement strategies. *International journal of production economics, 12* (6), 12-38.

Zakeri, J. A., & Abbasi, R. 2012. Field investigation on the variation of rail support modulus in

ballasted railway tracks. *Latin Journal of solid and structures*, 2-35.