Sustainable Sleepers – Composite and low carbon sleepers
TME Conference
25th May 2023

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‘What is driving the change?

Increased asset life

Regulation – Creosote ban July 2021

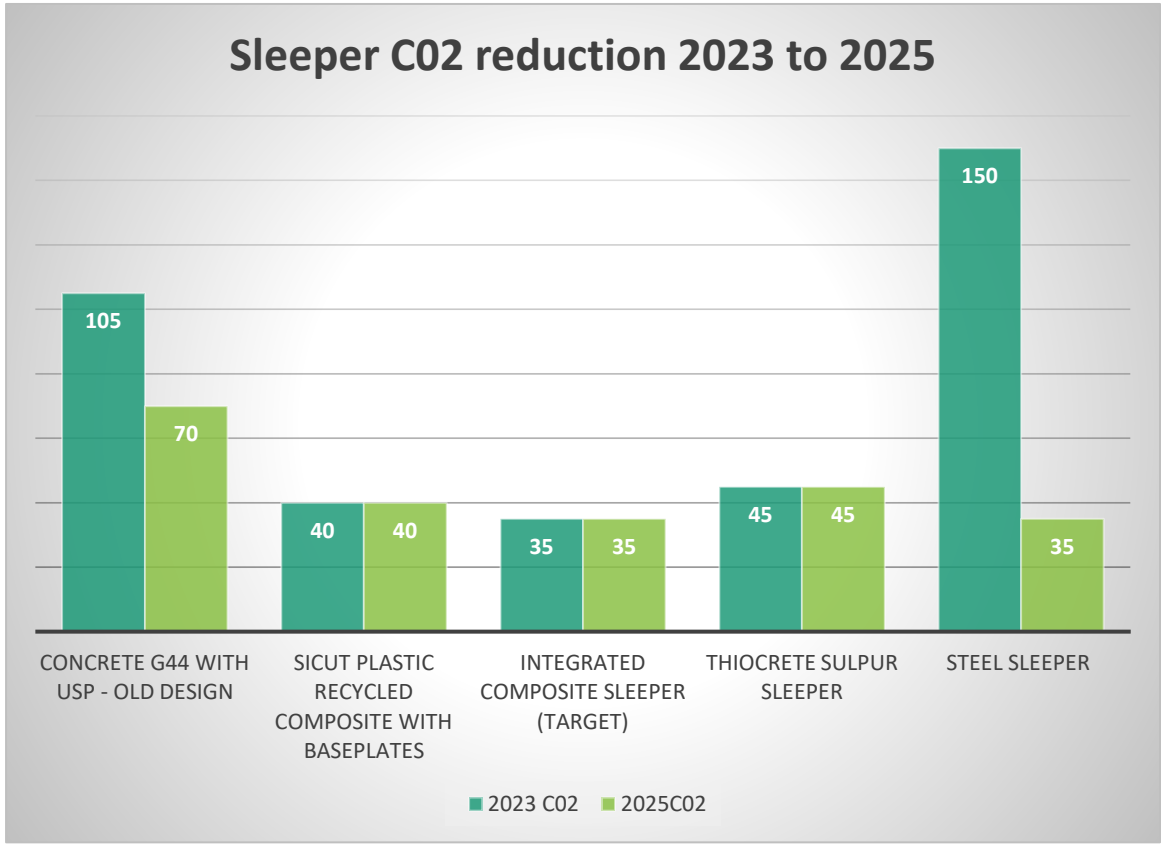
Improved sustainability

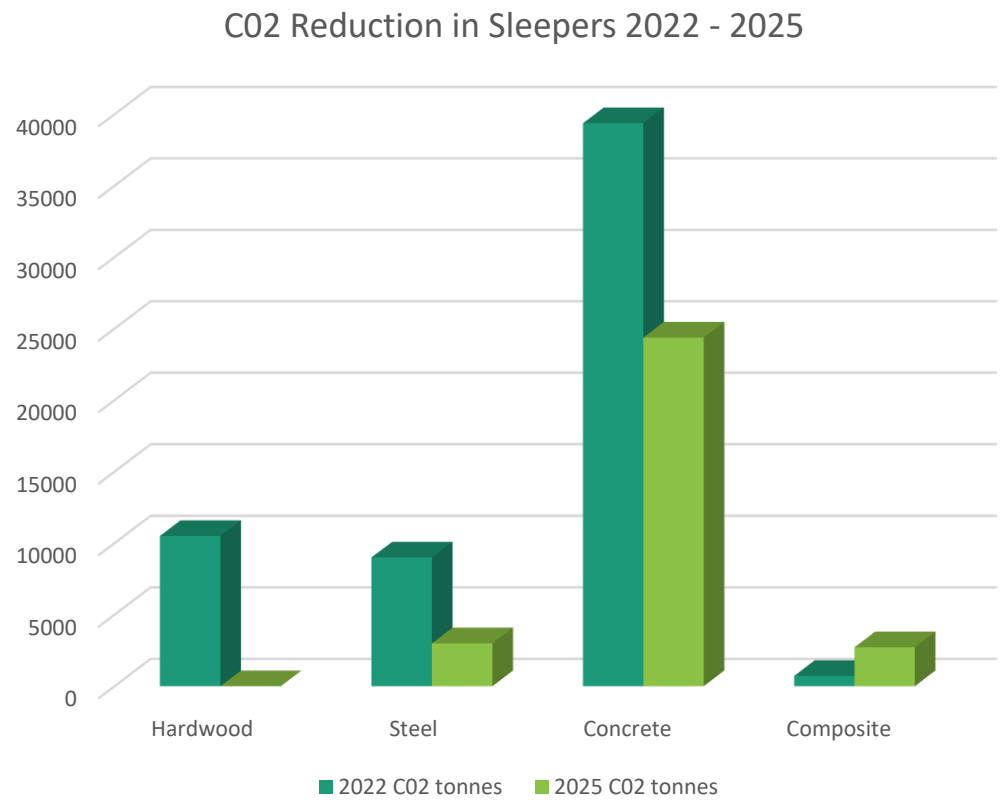
Reduced Whole Life Cost

SERVING THE NATION WITH THE CLEANEST, GREENEST MASS TRANSPORT

PRIORITIES	A LOW-EMISSION RAILWAY	A RELIABLE RAILWAY SERVICE THAT IS RESILIENT TO CLIMATE CHANGE	IMPROVED BIODIVERSITY OF PLANTS AND WILDLIFE	MINIMAL WASTE AND THE USE OF MATERIALS
AMBITIONS	We will achieve net zero carbon emissions by 2050 (and 2045 in Scotland) and deliver continual improvements to air quality so that our passengers, neighbours, and employees breathe healthier air	We will prepare the railway infrastructure to minimise the impacts of climate change by 2050.	We will continue to look after nature and protect, maintain and enhance biodiversity across the railway.	We will reuse, repurpose or redeploy all surplus resources, minimise use of resources, design out waste and embed waste life-cycle/circular economy thinking into the rail industry by 2035.

Kg CO2e for Common Sleeper Types





Total annual saving of 29500 tonnes of C02 in 2025 = 49.5% reduction

Sleeper Type	Hardwood	Steel	Concrete	Composite	Totals	Reduction
2022 Volume	50000	60000	375000	18000	503000	
2022 C02 tonnes	10500	9000	39375	720	59595	
2025 Volume	0	60000	375000	68000	503000	Same volume
2025 C02 tonnes	0	3000	24375	2720	30095	29500
						49.5%

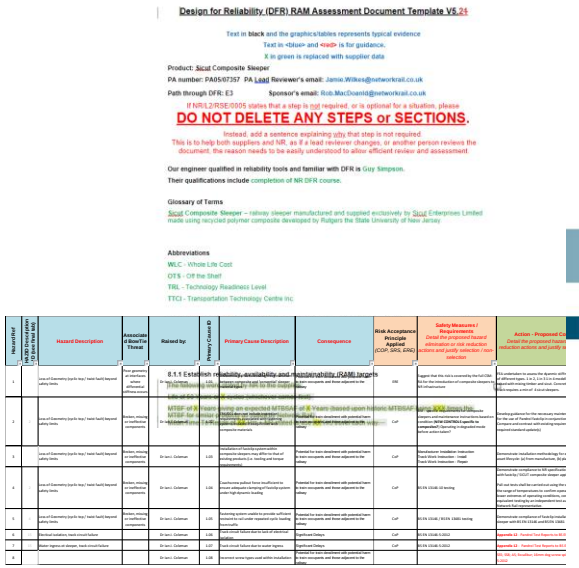
Product Approval – Why it takes time…

- Design for Reliability
  - Design, manufacturing, installation FMEAs
  - Product is designed fit for purpose.
  - *40 page document, each requirement evaluated*

- Common Safety Method
  - Understanding the operational risk to infrastructure through the introduction of novel componentry
  - *100+ risks, each requires mitigation*

- Operational trial requirements
  - Understanding of failure modes
  - Handling, installation, compatibility with automation?
  - Evaluating the ‘unknown-unknowns’
  - *What are the safe operation conditions in early life?*

- Controlling the risk at a national level
  - Once PA is approved, data becomes challenging to monitor
  - Reversibility of the change is lost
  - *Realistic aims without stifling opportunity*


Design for Reliability (DFR) RAM Assessment Document Template V5.2

Text in black and the graphics/tables represents typical evidence
Text in <blue> and <red> is for guidance.
X in green is replaced with supplier data

Product: Sicut Composite Sleeper
PA number: PA05/07357 PA Lead Reviewer's email: Jamie.Wilkes@networkrail.co.uk
Path through DFR: E3 Sponsor's email: Rob.MacDonald@networkrail.co.uk

If NR/L2/RSE/0005 states that a step is not required, or is optional for a situation, please
DO NOT DELETE ANY STEPS or SECTIONS.
Instead, add a sentence explaining why that step is not required.
This is to help both suppliers and NR, as if a lead reviewer changes, or another person reviews the document, the reason needs to be easily understood to allow efficient review and assessment.

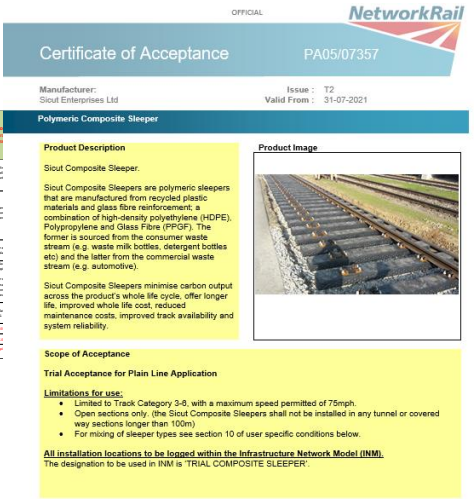
Our engineer qualified in reliability tools and familiar with DFR is Guy Simpson.
Their qualifications include completion of NR DFR course.

Glossary of Terms

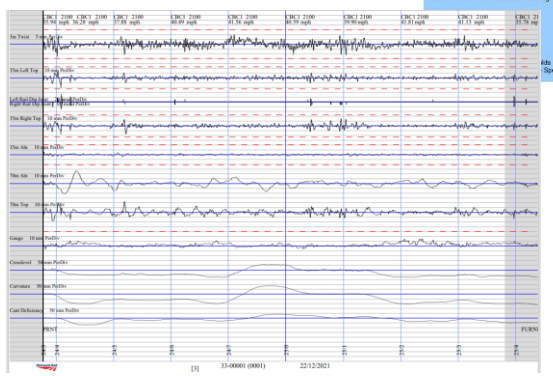
Sicut Composite Sleeper – railway sleeper manufactured and supplied exclusively by Sicut Enterprises Limited made using recycled polymer composite developed by Rutgers the State University of New Jersey

Abbreviations
WLC - Whole Life Cost
OTS - Off the Shelf
TRL - Technology Readiness Level
TTCI - Transportation Technology Centre Inc

8.1.1 Establish reliability, availability and maintainability (RAM) targets


OFFICIAL
NetworkRail
Certificate of Acceptance PA05/07357
Manufacturer: Sicut Enterprises Ltd
Issue : T2
Valid From : 31-07-2021
Polymeric Composite Sleeper
Product Description
Sicut Composite Sleeper.
Sicut Composite Sleepers are polymeric sleepers that are manufactured from recycled plastic materials and glass fibre reinforcement; a combination of high-density polyethylene (HDPE), Polypropylene and Glass Fibre (PPGF). The former is sourced from the consumer waste stream (e.g. waste milk bottles, detergent bottles etc) and the latter from the commercial waste stream (e.g. automotive).
Sicut Composite Sleepers minimise carbon output across the product's whole life cycle, offer longer life, improved whole life cost, reduced maintenance costs, improved track availability and system reliability.
Product Image
Scope of Acceptance
Trial Acceptance for Plain Line Application
Limitations for use:
- Limited to Track Category 3-6, with a maximum speed permitted of 75mph.
- Open sections only. (the Sicut Composite Sleepers shall not be installed in any tunnel or covered way sections longer than 100m)
- For mixing of sleeper types see section 10 of user specific conditions below.

All installation locations to be logged within the Infrastructure Network Model (INM).
The designation to be used in INM is 'TRIAL COMPOSITE SLEEPER'.
Network Rail Acceptance Panel (NRAP) hereby authorises the product above for use and trial use on railway infrastructure for which Network Rail is the Infrastructure Manager under the ROGS regulations.
Authorised by:
Gareth Evans
Network Technical Head Track



Current ‘State of the Nation’ - HDPE

- In use since 2021, driven by the creosote ban in softwood.
- Currently contracted to Sicut.
- 2 products are approved – 135mm and 155mm deep sleeper.
  - 135mm – 90mph / Cat 2
  - 155mm – 110mph + / Cat1, Cat1a (?)
- Suitable for most plain line, ballasted applications.
- Different failure modes to wood (covered later).
- Screwspikes only, no rail spikes!
  - Further discussion on BR1 baseplates to come…
- Finalising approvals for High Output / track relaying machines

HDPE Composite Sleepers – Previous Concerns

- **Fire Risk**
- Extensive fire testing undertaken by Sicut at fire testing facilities
- In almost all categories (and in all key categories) the HDPE outperformed existing timber
- The overall category (in accordance with fire classification was D_{fl} – the same as timber.
- Smoke density and ignitability is far lower than timber.
- After much debate with fire engineers, it was agreed to use a hierarchy-type system for sleeper fire risk in tunnels
- Concrete > Composite > Timber
- FFU (alternative composite) does have a classification of B_{fl} but there is still some additional measurements required on the smoke toxicity which needs to be closed out before assuming the material is more suitable.

Image 3 - Sample after 1 minute flame application

Image 4 - After removal of the flame source – sample self-extinguished

HDPE Composite Sleepers – Previous Concerns

- **Narrow Gauge (Thermal Coefficient of Expansion)**
- HDPE does have a higher coefficient of expansion than concrete, wood and FFU.
- Within operational ranges, this is still very small (fine for sleepers, bearers TBC)
- The primary concern was from Sherrington viaduct, where the sleepers were incorrectly plated off-site. NCR raised with Sicut and subsequently closed out with new process.
- Other sites have been manually measured, and NMT/TIGER data has been used to confirm no obvious or alarming change through seasonal cycle.
- Plating tables to be required in NR/L2/TRK/039, and coefficient of expansion limits set.

Sicut Sleeper Gauge Variation Range

Reference table of evidence for Haz-id log and 039 standard gauge variability vs sleeper temperature.

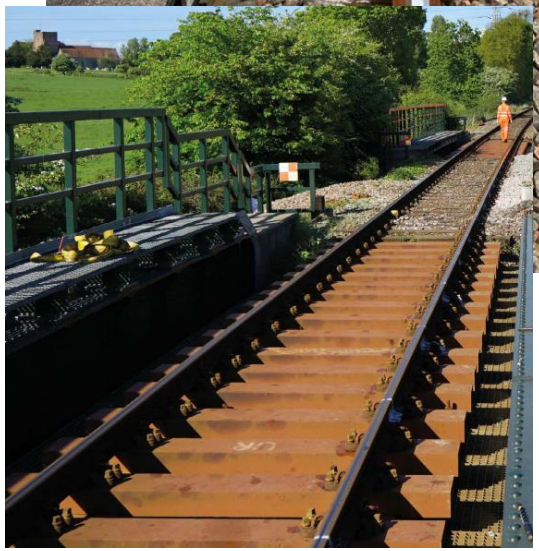
Sleeper Gauge Variability	Sleeper Temperature Range lower and upper limits						COE (Coef of expansion)	
	-27 to -6	-5 to 14	15 - 25	26 - 32	33-45	46 to 60	Nominal value	value used
Median temperature range (degrees Celcius)	-17	10	20	29	38	53	mm/m/degC	mm/m/degC
Temp difference (temp - 20 degrees Celcius)	-37	-10	0	9	18	33		
Plating down and gauging (m)	1.433	1.435	1.436	1.437	1.437	1.438	0.055	0.05
Sleeper prefab inspection (m)	1.433	1.435	1.436	1.437	1.437	1.438	0.055	0.05
Sleeper transport prior to instal (m)	1.433	1.435	1.436	1.437	1.437	1.438	0.055	0.05
Sleeper storage (m)	1.433	1.435	1.436	1.437	1.437	1.438	0.055	0.05
Installed and restrained sleeper (m)	1.435	1.436	1.436	1.436	1.437	1.437	0.025	0.025
Installed and restrained sleeper at low gauging temp 1433	1.432	1.433	1.433	1.433	1.434	1.434	0.025	0.025
Installed and restrained sleeper at high gauging temp 1438	1.437	1.438	1.438	1.438	1.439	1.439	0.025	0.025

Current ‘State of the Nation’ – FFU (LBS)

- In use on UK infrastructure since 2014.
- Full Product Acceptance was granted in early 2021.
  - Sekisui hold the longitudinal timber contract (inc. ‘bridge’ sleepers)
  - Newark Flat Crossing
- Common questions…
  - Bridge sleepers?
  - Transitions?
  - Direct fix?
  - Ballasted bridges?
  - Cross-use with HDPE?

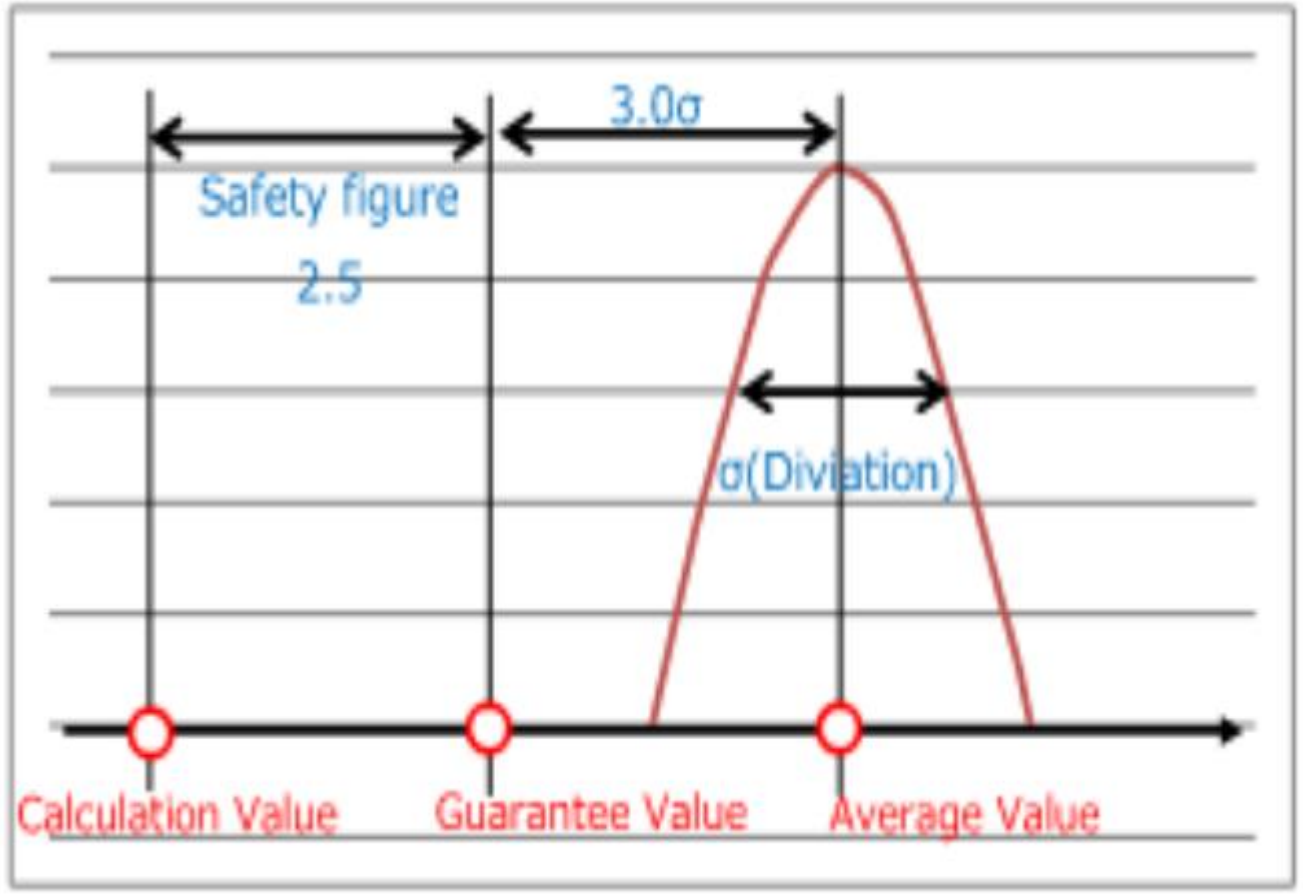
Current ‘State of the Nation’ – FFU (Sleepers)

- In late 2021, Eastern region approached TA to approve the use of FFU on higher Category track.
  - FFU not contracted to deliver sleepers, but proven track record at high speed with Shinkansen.
  - Sicut sleepers had not yet been used over 100mph and therefore needed more rigorous testing to approve at Cat1A.
- A small-section trial was agreed for FFU, subject to PA approval.
  - No ‘free issue’ use of FFU whilst Sicut is in contract.
  - Supports the route and NR with an aging asset which should last longer as a result.
  - Continuation of innovation and development of 2 different material types.
  - There may be additional benefits from FFU which HDPE cannot achieve, and vice versa.
- Still under trial (installations through 2023), but installation and initial route reaction appears positive.



Current ‘State of the Nation’ – FFU (Alternative uses)

- Baker Hicks ur
  vs. traditional
- Report demor
- Dispensation
  trial the produ
  loading.
- Derogation to
- Other TRK/40
  slip protectior
  patterns cons



Trial Acceptance
This certificate of acceptance is only valid for the fo
Forge Farm Level Crossing - ELR: SCU1 34m71ch
Snargate Level Crossing – ELR: APL 65m73ch

1. Surface to be prepared by the supplier to comply with anti-slip requirements laid out in NR/L2/TRK/4040.
2. The design must comply with the dimensions/ material referenced in the Product Configuration.
3. No abutting unsupported ends are allowed.

IMPORTANT NOTE: The level crossing system does not comply with the current requirement in NR/L2/TRK/4040 for HB45 loading requirements.

The FFU Level Crossing Surface System is only suitable for 30 units of HB loading, in accordance with ‘minor road’ requirements. Contact the PA Lead Reviewer for more information if required.

ses that 75mm thick
g replacements. This
has been achieved with the NR derogation permitting the traffic loading to be lowered to 30 units of HB and the Sekisui dispensation permitting the Guaranteed value as the limiting bending stress value. The analyses also show that FFU 74 is an adequate material to be used for the bearers onto both concrete and timber sleepers.

Network Rail's Controls Framework

- **NR/L2/TRK/039** will cover the technical requirements and performance specifications for composite materials.
  - Published December 2022
- Covers supplier requirements for FFU and 'plastic' HDPE sleepers.
- TWI 3C039 and 3C040 – Published in June 2022.

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Track Work Information **3C039**
How to inspect, maintain and replace FFU synthetic longitudinal bearer systems

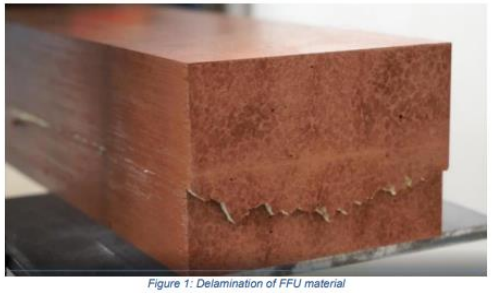
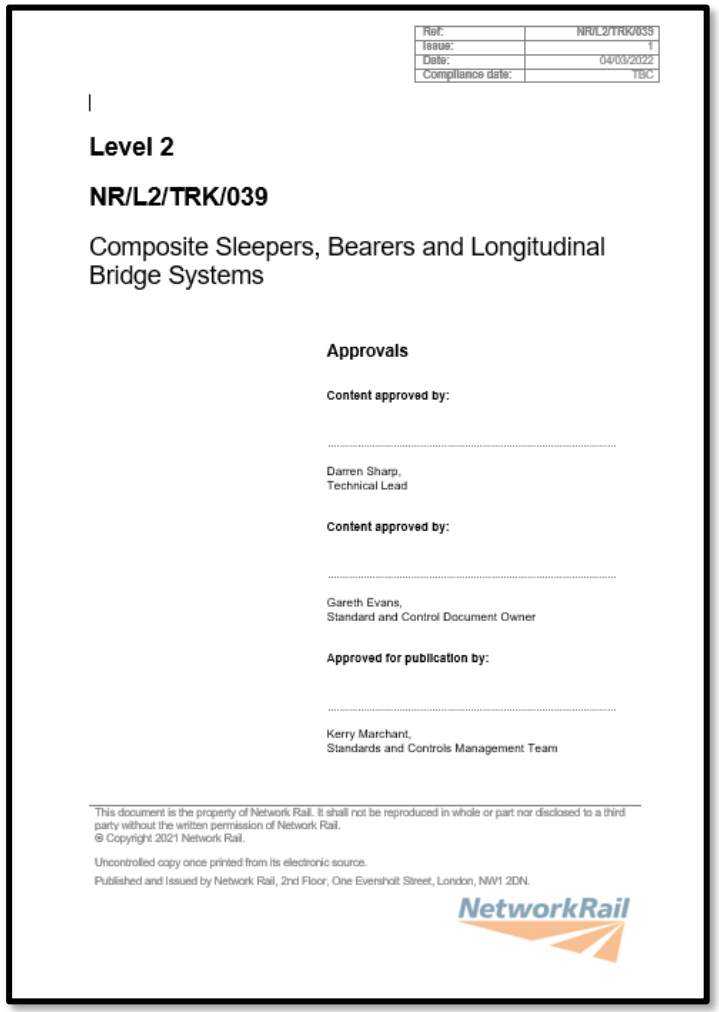


Figure 1: Delamination of FFU material

Track Work Information 3C040
How to store, handle, install and maintain Sicut Composite Plain Line Sleepers

Figure 9 - Example of plastic swarf following drilling.



Ref:	NR/L2/TRK/039
Issue:	1
Date:	04/03/2022
Compliance date:	TBC

Level 2

NR/L2/TRK/039

Composite Sleepers, Bearers and Longitudinal Bridge Systems

Approvals

Content approved by:

Darren Sharp,
Technical Lead

Content approved by:

Gareth Evans,
Standard and Control Document Owner

Approved for publication by:

Kerry Marchant,
Standards and Controls Management Team

Published and Issued by Network Rail, 2nd Floor, One Eversholt Street, London, NW1 2DN.

NR/L2/TRK/039 – Sustainability & Eco-design

12 Recycling/Disposal – Circular Economy and Eco-design

The sleeper or bearer shall be recyclable into a sleeper or bearer at 'end of service life'.

The Supplier shall document the end of service life including the process and costs associated with product recycling/disposal

The Supplier shall provide information on the appropriate maintenance for the product or any measures which can be taken to extend the product life

The Supplier should work to continuously improve the environmental factors of their products.

The following environmental considerations shall be considered:

a) use of chemicals not harmful to health or the environment (including percentage of mass)

b) use of recycled materials (including percentage of mass)

c) environmental impact of the manufacturing process including CO_2 content at point of supply

d) end-of-life recycling and re-use

e) transport costs from raw material production sites through to final site-of-use

f) residual waste from cutting and drilling and its effect on the environment, animal and human health.

The product shall not contain Persistent Organic Pollutants (POPs) and evidence shall be provided of how non-POP content in manufacture is assured.

The Supplier shall provide an independently verified environmental product declaration (EPD) to enable Network Rail to quantify the environmental impact within the infrastructure

TWI 3C039 – Key messages

- FFU will perform very similarly to wood
  - Pilot hole sizes are the same (assuming AS).
- Main failure modes (very uncommon):
  - Cellular collapse/ indentation of baseplate
  - Material splitting or cracking
  - Delamination of material

Cutting should be done at slow speed so not to melt the material.

- Specific FFU paint and Quickfiller (Spikefast alternative)
  - Catalogue numbers are on the TWI.

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Track Work Information **3C039**
How to inspect, maintain and replace FFU synthetic longitudinal bearer systems

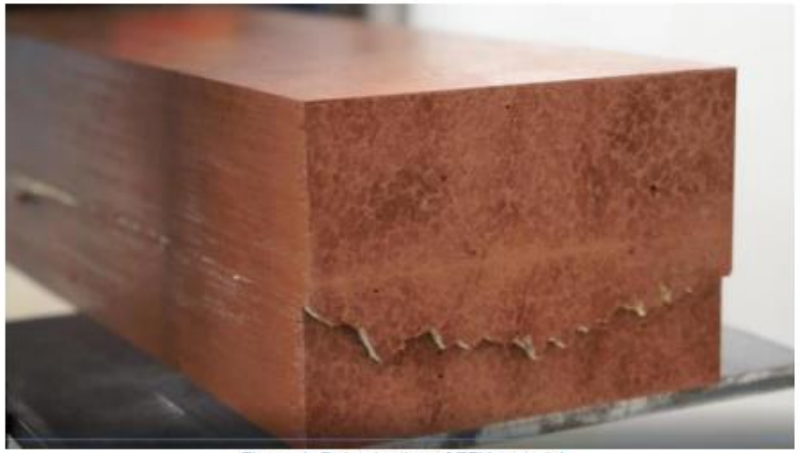


Figure 1: Delamination of FFU material

- If cutting or drilling - overalls, FFP3 rated masks and goggles should be worn as a minimum.
  - Vacuums can also be used to help capture the material as it is cut.

TWI 3C040 – Key messages

- Main failure modes (very uncommon):
  - Bending/ warping
  - Plastic deformation
  - Baseplate indentations
  - Material splitting/ cracking

- Can be purchased plated off-site if required

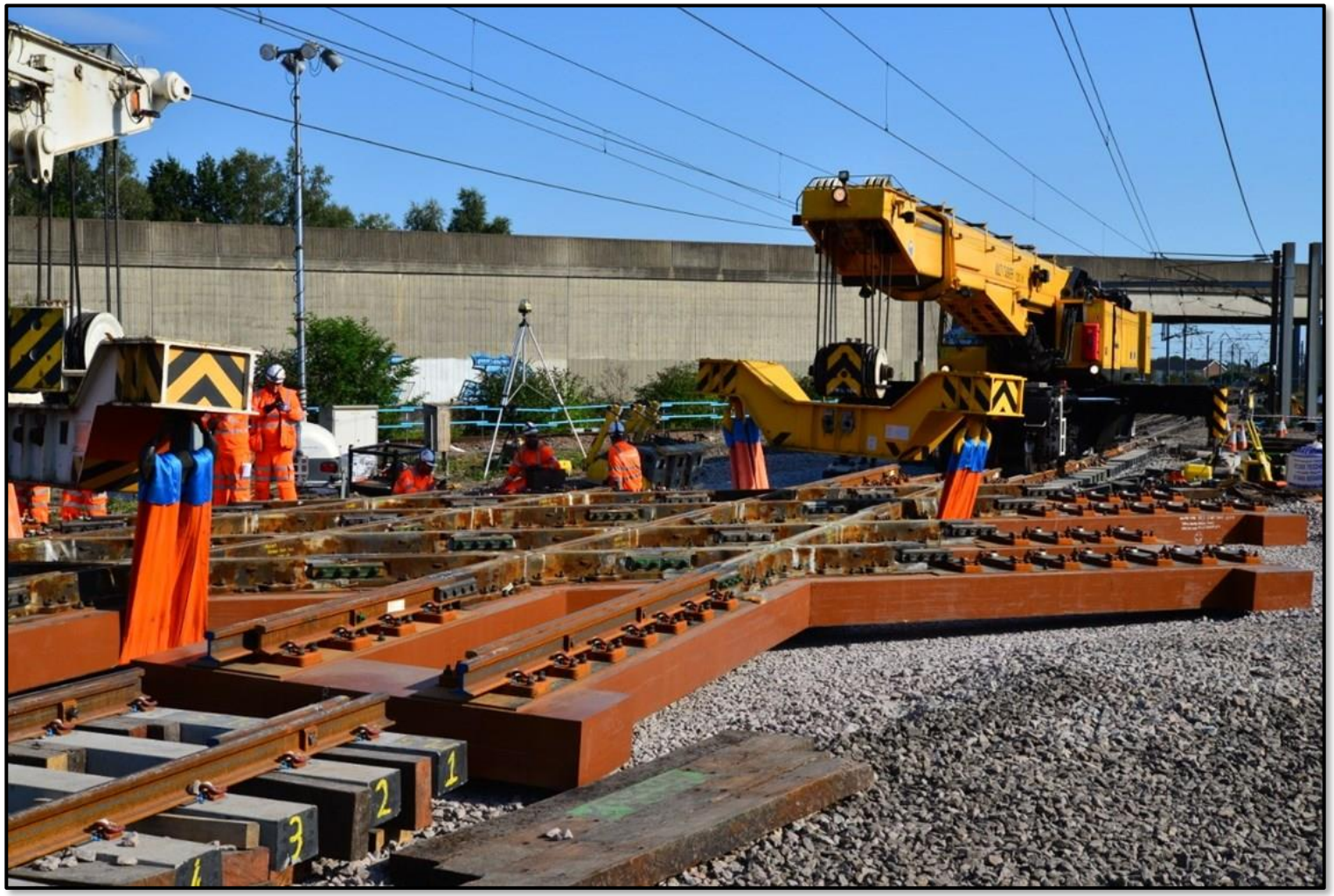
- Swarf from drilling should be collected where possible
- Cutting should be done at slow speed so not to melt the material.
- Spikefast can be used to repair holes

- Counterboring of pilot holes is important to prevent the material ballooning at the baseplate surface if using wide shank bolts (such as AS screws).

Track Work Information 3C040
How to store, handle, install and maintain Sicut Composite Plain Line Sleepers

Current ‘State of the Nation’ – Switches & Crossings

Still under early consideration, strategy will be confirmed this month.



Current ‘State of the Nation’ – Wood

- Hardwood does not reflect Network Rail’s long term sustainability strategy.
- Transfer from hardwood to 100% composite at current HDPE sleeper rates would only cost regions approx. 1.16% more on renewals and refurbishments.
- £4,305 saving per sleeper on WLC vs. hardwood based on current rates on a 25 vs. 50 year service life.
- Unfactored for potentially reduced inspection or maintenance (RBM).
- Justification is being presented to ELT to help determine the decision.

- Any phase out will be planned over an extended duration and consulted with all regions as part of the existing sleeper strategy group.
- Focus at present is on plain line, renewal options for LBSs and S&C still need to be discussed.

Integrated Composite Sleeper Project (Nick Matthews)

Sustainability: Integrated Composite Sleeper Project

SOUTH RAIL SYSTEMS ALLIANCE

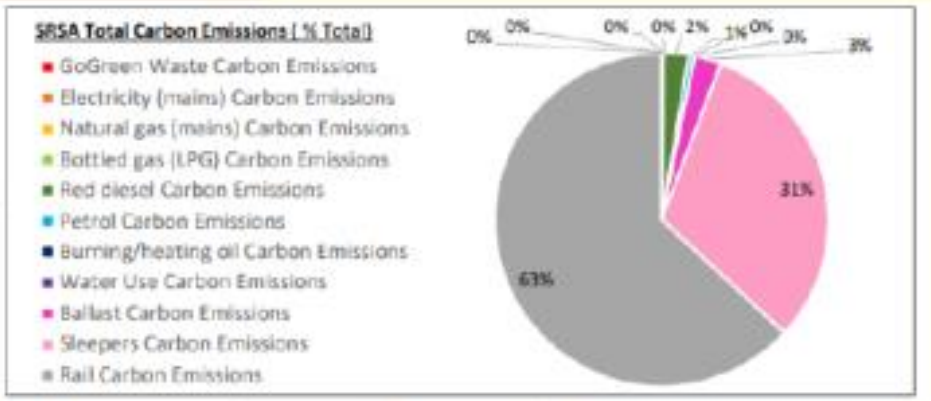
Integrated Composite Sleeper R&D

- Composite sleepers with Fastclip Shoulders "cast" into composite sleepers in the same way concrete sleepers are produced and supplied.
- Project aim is to develop a composite version of G44 / EG47 for mass production.

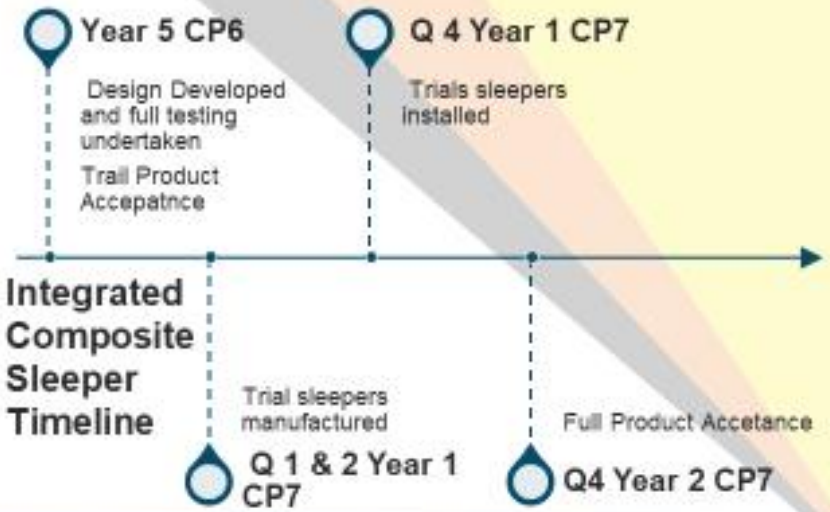
Benefits

- Significant reduction in embedded carbon
- Increase product life (whole life cost)
- Increased production rates
- Potential to reduce CRT risk
- Reduction in cost of composite sleeper vice base plated composite sleeper.

- **Progress/update in Period**
- Contract on course to be signed P13



Pandrol Fastclip



A better railway for a better Britain

Lateral Resistance Testing of Sleepers (Darren Sharp)

- Seed corn funding approved February 2023
- Scope – measure force required to push one sleeper through ballast – single sleeper test.
- Outcomes- Provides a relative comparison between sleeper types to demonstrate sleeper performance. Also to demonstrate how much additional restraint USPs provide and whether they can be used in place of Lateral Resistance Plates
- CRT calculation improvements – demonstrate that composite is better than timber. USP may also be considered to use a higher CRT factor.
- Additional funding gained to expand tests looking at ballast profile and compaction variance affect
- UoSouthampton commencing tests currently.
- The Next Gen USP design will be a revised under sleeper pad designed to enhance lateral resistance.

Sleeper	No USP	USP	LRP +No USP	LRP + USP	Next Gen USP
G44	x	x	x	X	X
Composite	x		x		
Steel	x				
Timber	x		x		
EG47	X				

Table 1 Lab test variables for sleeper lateral resistance tests

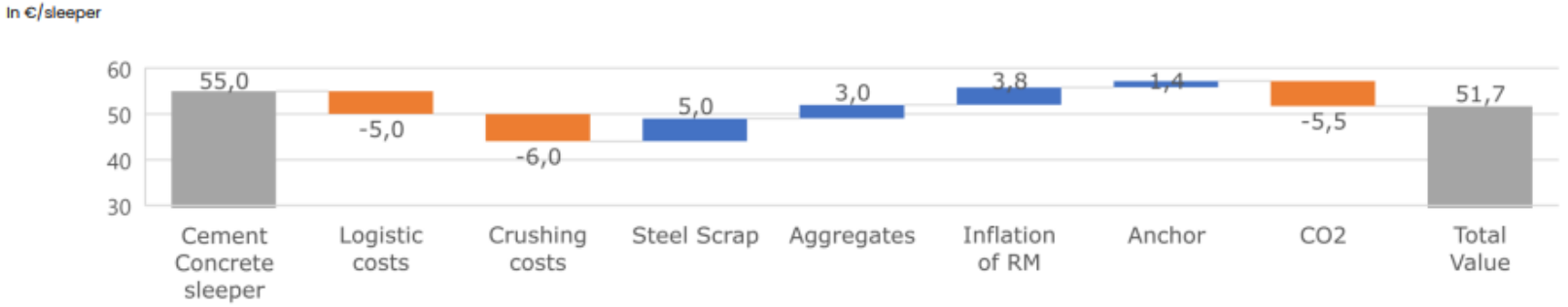
Concrete Sleepers – Reduced CO_2

- Low cement sleepers are looking to reduce CO_2e by approximately 50% per sleeper.
  - CEM 2/ CEM 3 mix designs
- The use of recycled aggregate is also being evaluated, though a proven sleeper has not yet been approved.
- Circular sleepers are now under consideration – sulphur sleepers
  - (De Bonte Innovation)
  - 45kg CO_2e vs. 50kg CO_2e (low carbon concrete)
  - Almost entirely circular
  - Uptake started on other networks (Infrabel, ProRail, SNCF)
  - Needs to be fully evaluated as part of Product Acceptance

Value Comparison including Re-cycling and CO2

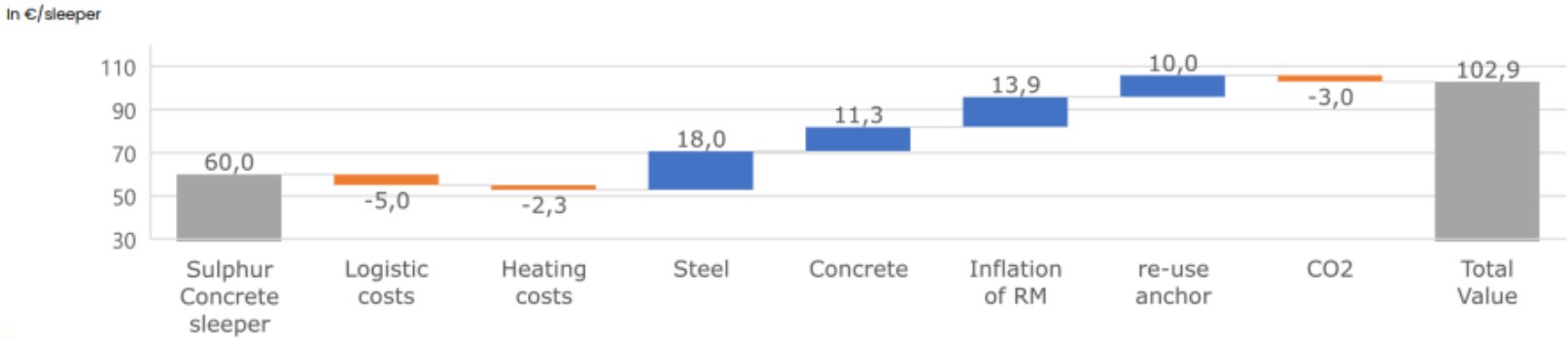
Re-cycling costs | Re-cycling revenues | CO_2 Cost

Cement Concrete Sleeper



By integrating recycling and CO2 costs and revenues, there is a **destruction of value** for the cement concrete sleeper.

Sulphur Concrete Sleeper



By integrating recycling and CO2 costs and revenues, there is **value creation** for the sulfur concrete sleeper.

Assumptions for Cement Concrete Sleeper:

- Actual value of a concrete sleeper is about €55 per piece
- Scrap : re-use of 10kg of steel at €500/T
- Aggregates : re-use of 300kg of concrete at €10/T
- Inflation RM : inflation of scrap and aggregates at 1% above general inflation
- Anchor : re-use of anchor as scrap (4 x 0,7kg x €500/T)
- CO2 "cost" : 66 kg CO2 per sleeper * 84€ per ton of CO2

Assumptions for Sulphur Concrete Sleeper:

- Actual value of a sulphur concrete sleeper is about €60 per piece
- Heating costs: 15kWh per sleeper at €0,15/kWh
- Steel : re-use of 10kg of steel at €1795/T
- Concrete: re-use of 300kg of concrete at €90/m²
- Inflation of RM : Inflation of raw materials of 1% above general inflation
- Anchor : re-use of anchor as initial value
- CO2 "cost" : 36 kg CO2 per sleeper * 84€ per ton of CO2

Applying circularity to future sleeper designs

- Specific requirements for sleeper supply (*NR/L2/TRK/021, /029, /030, /039*) mandate very ‘rigid’ requirements for particular material types.

- An overarching Technical Specification is currently in development (DS), laying out the minimum design criteria to adhere to when considering future sleeper innovations. This will be applicable to all sleeper types, and coincide with the current track design and construction Standard (NR/L2/TRK/2102).
  - Material types must still adhere to the relevant sub-Standards
  - Creates opportunity for designs and materials not currently approved
  - Could prevent delays in introduction of novel sleeper types

- More flexibility is needed to allow for innovation, and innovative material use.

What is next?


Plan for sourcing projects across range of sleeper materials & innovation projects
Workstream 6
Sourcing plan
Workstream 1
Policy, Standards, WLC & Sleeper Selection Model
Revision to policy & standards to enable improved performance & innovation. Whole life cost review & Decision model for clearer sleeper selection for Regions
Workstream 2
Innovation, Carbon Reduction & Performance Improvement
Plan for reduced Carbon and Innovation for improved sleeper performance
Railway Sleepers Category Strategy
Develop Supplier Management approach, KPIs & SQA requirements and innovation
Workstream 5
Supplier Management Strategy
Workstream 3
Future Demand Model & New Product Planning
Future demand model for sleeper volumes across range of sleeper for CP7 and estimates for CP8. New Product planning
Workstream 4
Operational opportunities
Plan for range of operational opportunities including carbon reduction & stock optimisation
KEY :
Strategic Decision Workstreams
Sourcing
Supplier Management
Operational Change

What is next?

	Workstream	WS Leads	Workstream Key Objectives
WS1	**Policy, Standards, WLC & Sleeper Selection Model**	*TA*	• Revised policy & standards to enable innovations & WS2 delivery • Whole Life Cost review of sleepers • Develop a Sleeper selection model to support Regional decision making
WS2	**Innovation, Carbon Reduction & Performance Improvement**	*TA (+SCO)*	• Innovation roadmap for sleepers with short term & long term objectives • Carbon reduction plan across sleeper range • Performance improvement plan for sleepers (e.g. WLC lateral resistance & life)
WS3	**Future Demand Model & New Product Planning**	*TA (+Regions, SCO)*	• Model across sleeper material types to support SCO plans • Estimates of volumes for CP7 • Inputs for future sourcing projects for existing and new products
WS4	**Operational Opportunities**	*SCO*	• Plan to deliver improvements in operations • Reduce carbon in transport & logistics • Optimise Stock Management process and levels
WS5	**Supplier Management Strategy**	*SCO*	• Develop and implement appropriate supplier performance metrics • Review SQA requirements
WS6	**Sourcing plan**	*C&P (+TA, SCO)*	• Sourcing plans for delivery of range of sleeper requirements • Sourcing plans to deliver innovations for future sleepers

Life Cycle Analysis – Decision Support Tool (Sleepers)

Life Cycle Assessment Criteria for Existing and New Sleeper Range

Sleeper Type / LCA Criteria	Sleeper Unit rate Cost (2021)	Installation Unit rate cost per metre	WLC £ Cost per year/m	Average Life Expectancy (Track system)	Average tonnage per year (EMGTPA)	Average tonnage over lifetime - functional unit (EMGTPA)	Main Track Cat Usage	Lateral Resistance Perf	Ballast and Geometry Deg Rate	Stiffness, Strength and Durability	Fire and Safety Performance	Current CO2E/sleeper kg	Circularity - percentage of sleepers that can be re-purposed	Circularity - Percentage of reusable material (sleeper and baseplate/steel)
Concrete G44 without USP		£1,480		40	30	1200	1a to 4	Medium	Medium	Med	High	80 - 95	TBA	5
Concrete G44 with USP		£1,495		50	30	1500	1a to 4	High	Low	High	High	85 - 100	TBA	5
Concrete EG47 without USP		£1,485		40	30	1200	1 to 4	Medium	Low	Medium	High	75 - 90	TBA	5
Concrete EG47 with USP		£1,496		50	30	1200	1 to 4	High	Low	Medium	High	80 - 95	TBA	5
Steel		£1,150		30	15	450	3 to 6	Low	Medium	Low	High	225	TBA	100
Hardwood with baseplates		£1,530		25	15	375	3 to 6	Low	Medium	Low	Low	190	TBA	10
Plastic Recycled Composite with baseplates		£1,550		50	25	1250	2 to 6	Medium	Low	Medium	Medium	40	TBA	(100)
Integrated composite sleeper (Target)		£1,495		60	30	1800	1a to 4	High	low	TBA	TBA	TBA (<50)	TBA	100
FFU sleeper with baseplates		£1,550		50	30	1500	1a to 4	Medium	?	High	TBA	?	TBA	(100)
Reduced carbon G44/EG47 with USP (Target)		£1,495		60	30	1800	1a to 4	High	low	TBA	High	35 - 55	TBA	?

- Creating a tool which aids decision making in design/ delivery
- Balances upfront cost, whole life cost, performance and sustainability
- More informed decisions
- Enables targeted use in sleeper strategy
- Once up to date and published, this will be onwards briefed to the regions…

POLL!

Based on your own knowledge (and this presentation) what would you like more information on from the Technical Authority going forward?

1. Composite sleepers - maintenance, inspection, replacement
2. Alternative uses for composites (HDPE/FFU)
3. Composites in S&C
4. Phase out of hardwood/ timber
5. Low carbon/ sulphur concrete sleepers
6. What about steel?!

Please choose one, and we'll use this to prioritise material for future briefings.

Thank you for your attention!

everyone home safe every day

Technical Authority

Providing technical leadership