Myth vs Reality - High Performance Resin Bonded Rubber

Technical report exploring the top 10 most common misconceptions around working with high performance Resin Bonded Rubber

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Introduction

As a designer and manufacturer of fastening systems, welding, electrification solutions, track equipment and Resilient Rubber Systems, Pandrol is in a unique position to understand and influence the environmental impact of rail infrastructure.

Our products and services are designed to maximise efficiency of track installation and operation and to address safety and environmental factors. In recent years, we have used our expertise in track resilience to develop a range of environmentally sustainable systems to improve the lifecycle of railway infrastructure, reduce track maintenance costs, and mitigate noise and vibration.

We are extremely proud to be the first manufacturer in our field to provide, fully compliant with the most stringent Railways specifications, resin bonded rubber Sustainable Resilient Systems (SRS) solutions that have been assessed and certified in an Environmental Product Declaration (EPD) – a measure of our products' impressively low environmental and carbon footprint and contribution to minimising the environmental impact of railway infrastructure.

This technical report provides an overview of our SRS product range, highlighting its composition and performance from both environmental and technical perspectives. It also addresses some of the common misconceptions that remain around the use of resin bonded rubber, or in general recycled rubber which, as an organisation, we are determined to dispel. Pandrol has a deep-seated commitment to helping both our customers and the planet, and we see the increased use of recycled material as key to increasing the sustainability of track infrastructure.

> Our Resin Bonded Rubber SRS solutions have all passed the same demanding technical performance tests as alternative products. Now we have confirmation that they also come with exceptional green credentials.
>
> The EPDs provide irrefutable evidence that our recycled SRS products are the right choice when it comes to quality, performance and sustainability.

Thomas Lorent, Head of Product Line Sustainable Resilient Systems for Pandrol

Executive Summary

Pandrol's Sustainable Resilient Systems products have been increasing the efficiency and sustainability of urban, mainline, heavy haul and high-speed railways globally for over 20 years.

All our SRS products:

- ✓ increase track quality
- ✓ reduce noise and vibration
- ✓ reduce installation and maintenance costs
- ✓ extend the life of the track.

They are developed by Pandrol's research and development specialists based in Belgium and across the world and are tested by prestigious institutes to international railway standards EN 16730, EN 13146/1348, EN 50122-2 and DIN 45673.

SRS PRODUCTS AVAILABLE

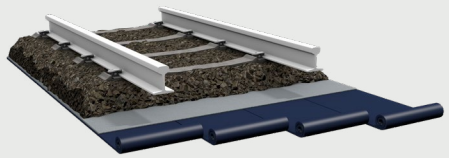

Figure 1: Under Ballast Mats

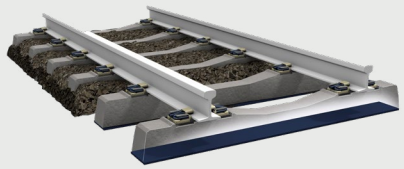

Figure 2: Under Sleeper Pads

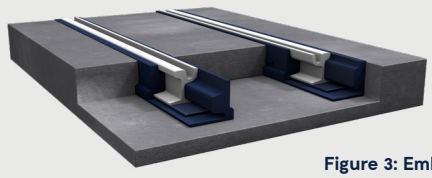

Figure 3: Embedded Rail Systems (with and without fastening)

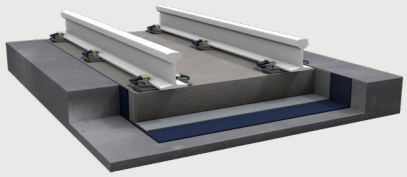

Figure 4: Floating Slab Mats/Pads

MATERIAL MATTERS

Pandrol's Resin Bonded Rubber SRS products are made using recycled rubber granule technology that provides a better technical performance and significantly lower environmental footprint than the materials used for similar solutions on the market (for example, microcellular polyurethane or other polymers made from virgin raw material).

Recycled rubber granules bonded with resin provide exceptional physical performance:

- · ideal elasticity
- · minimal material settlement or creep under service loads
- · durability in excess of typical track lifetime
- · higher chemical resistance
- · maintenance of the track's full drainage function
- · no hydrolysis or biodegradation.

In addition, the compression moulding process used to manufacture resin-bonded rubber mats, pads and encapsulations is much more stable and controllable than the foaming process used in microcellular polyurethane or foamed plastic manufacturing.

This low investment cost material with high return on technical performance, along with lower installation/ maintenance costs, results in significant savings for network operators.

When coupled with the environmental benefits – two to three times less CO_2 is produced during manufacturing and the products are fully recyclable – the argument to switch to recycled rubber is compelling.

10 myths about recycled rubber...

MYTH 01

Recycled rubber is not stable – the material will deteriorate over time

When tested in the same way as new elastomer, recycled rubber meets international standards. Pandrol has products in-track that are still performing after a quarter of a century!

MYTH 02

Recycled rubber isn't uniform and behaves unpredictably. Its manufacturing process is unstable.

The rubber granules we use are controlled according to a tight geometric composition and density tolerance to ensure consistency. Our products behave exactly how we expect them to every time, complying with the strict production quality control required by networks around the world.

Moreover, the foaming process used to make microcellular polyurethane is actually more unstable! We have not encountered any variation or tolerance issues when working with recycled rubber.

MYTH 03

Recycled rubber products crack over time, like used tyres

The main cause of old tyres cracking is ultraviolet light, nowadays tyres are treated against that! Because SRS products are installed below and within the track, this is not an issue. When tested against railway ozone testing in compression conditions, Pandrol's products have shown no cracks.

MYTH 04

Old tyres lose their elastic properties

The tyres we recycle are typically less than three years old. All are tested for fatigue and ageing, and are fit for purpose on track for several decades.

MYTH 05

Recycled rubber is prone to settlement/creep

Pandrol's recycled rubber has been extensively tested and found to have a superior resistance to long-term settlement/creep, offering more durability than microcellular polyurethane solutions. This is due to the rubber supporting the load via solid and highly elastic rubber granules working in compression rather than on cells full of gas, leaking with time.

MYTH 06

Microcellular polyurethane outperforms recycled rubber in terms of stiffness

Our recycled rubber products deliver constant vibration attenuation regardless of the ever-changing load above the track. In contrast, microcellular polyurethane solutions are only suitable for the maximum load, and have not compensated for the changing passenger numbers throughout the day.

MYTH 07

Recycled rubber is vulnerable to chemicals

Coming from road tyres, the recycled rubber granules used in Pandrol's SRS products are extremely resistant to chemicals. This has been confirmed by rigorous testing.

MYTH 08

Recycled rubber is prone to water absorption and has poor stiffness when wet

Pandrol's SRS products are 100% water permeable. This allows the track to drain, avoiding blockages.

MYTH 09

Recycled rubber products are not able to achieve industry standards

Our recycled rubber products are subject to the same rigorous, independently verified tests as all rail infrastructure products as proven by their performance over the years in service in rail networks around the globe.

MYTH 10

Recycled rubber products are not accepted by major networks

Our customers clearly disagree! What's more, as a growing proportion of the world's networks aim for net zero carbon infrastructure, using Pandrol SRS products can halve the carbon footprint of track construction.

Climate change and rail

Pandrol's Sustainable Resilient Systems products have been increasing the efficiency and sustainability of urban, mainline, heavy haul and high-speed railways globally for over 20 years.

Today, rail infrastructure owners and operators recognise the need to act immediately to meet UIC climate declaration objectives towards zero net carbon by 2050. The challenge is to minimise the CO_2 footprint of construction, installation, operation, maintenance and renewal railway projects across the entire lifecycle, while sustaining the highest performance standards and competitive costs.

Public and private tenders in the rail sector are rigorously evaluating the environmental criteria – especially CO_2 equivalent – that are verified and certified by independent Environmental Product Declarations (EPD)[1]. The environmental dimension has become as important as the traditional parameters of technical performance and cost.

Advancing circular economy through the use of recycled products is an obvious way to accelerate achievement of a net zero carbon railway. This report addresses this issue with hard facts, tackling a number of common myths in the industry concerning the performance and durability of resin-bonded rubber solutions for railway engineering. It demonstrates that such circular economy rubber products consistently deliver equivalent or better technical and functional performance at equivalent or lower cost when compared with competing products made of petroleum-based plastic materials.

Proven and certified technology

For over two decades, Pandrol's Sustainable Resilient System (SRS) products have been in service with leading railways on all six inhabited continents. Across urban, mainline, heavy haul and high-speed segments[2], they have been shown to increase track quality and lifetime, reduce noise and vibration, and reduce installation and maintenance costs.

Pandrol's SRS products are designed and optimised on circular economy principles to deliver uncompromising quality, cost competitiveness, ease of installation, minimal ecological footprint, and lifetime performance. The entire range of solutions is certified by globally recognised institutions and complies with standards such as EN 13481 for fasteners, EN16730 for under sleeper pads, DIN 45673 for mats and mass spring systems, and many more[3].

The process begins with the production of uniform high-quality rubber granules originating from end-of-life rubber tyres. When combined in precisely controlled proportions with high performance bonding resin (based on polyurethane or PU binder), the result is resin-bonded rubber.

RESIN-BONDED RUBBER (RBR):

- is an engineered recycled rubber of uniform characteristics
- is made up of granular composites, with inner spaces in the material that allow for bulking out
- is compressible and soft
- allows the flow of water and air through the material whilst still maintaining durability
- has an ideal elasticity
- experiences minimal material settlement under service loads
- has durability in excess of typical track lifetime.

Each element of the structure of RBR contributes meaningfully to the material's overall performance.

1/ Rubber granules – support vertical track load and provide durability, chemical resistance and damping

2/ Bonding resin / PU binder – connects granules and gives tensile, lateral and vertical strength

3/ Air (between granules) – allows bulking out of rubber, optimising resilience and providing water permeability

Figure 5: Structure of Pandrol's RBR

Pandrol's Sustainable Resilient Systems are developed by the company's team of research and development specialists in Belgium. They are tested by prestigious institutes to international railway standards EN 16730, EN 13146/13481 and DIN 45673.

Recycled rubber myths and facts

MYTH 01

Recycled rubber is not stable – the material will deteriorate over time

THE FACTS:

Resin-bonded rubber is composed of sustainably sourced rubber granules bonded together to form an engineered, stable and fully tested material.

Rubber has been widely used as a raw material in numerous industries for nearly two centuries, since Mr Goodyear accidentally discovered vulcanisation. The material's high performance, durability under extreme environmental conditions and cost-effectiveness have made it indispensable since, including in performance-critical industries such as aviation and aerospace[4].

Pandrol's recycled rubber is made from end-of-life tyres from cars, buses, trucks, agricultural equipment and mining equipment. All ageing and fatigue tests are completed as for a new product – the material is subjected to the same international standard performance requirements and long-cycle fatigue testing as any competing track materials (e.g. SNCF's Vibrogir; EN 16480 or DIN 45673 ageing, climatic and fatigue testing).

Measurements taken over a decade at Lisbon's famous Rossio tunnel, where trains pass below the city, showed a stable decay rate. High-level, long-lasting vibration mitigation was needed. Pandrol's RBR mats were installed and vibration measurements were taken on a logarithmic scale base 7, 70 and 700 days after installation. These measurements proved a low decay rate (i.e. a limited reduction in performance with time) and, more importantly, gave a robust extrapolation for a longer time span that allows to predict long-term performance of RBR[5].

Pandrol's Sustainable Resilient Systems have references since 1997 still in track and performing to the full satisfaction of customers[6].

MYTH 02

Recycled rubber isn't uniform and behaves unpredictably. Its manufacturing process is unstable.

THE FACTS:

Pandrol selects and controls the recycled rubber granules used in its track products according to a tight geometric tolerance, and there is a well-established size distribution. These are then bonded with premium-grade PU binder in a process analogous to mixing sands and aggregates in accurate ratio to produce concrete.

The result is a uniform final material with guaranteed homogeneous behaviour. This has been demonstrated by our quality control process, which has typically shown +/-20% variation in stiffness (representative of function).

Microcellular polyurethane (or PU foam) and other elastomers used in track also exhibit local heterogeneous characteristics whilst achieving homogeneous track performance (subject to more sensitive production control process when compared with recycled rubber equivalent products).

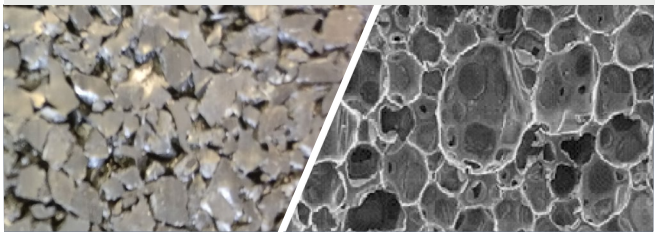

Figure 6: High-quality RBR (top) compared to microcellular polyurethane (bottom). Both exhibit locally heterogeneous structure, whilst having homogeneous track behaviour.

In over a quarter of a century, Pandrol has not encountered any unusual variability or tolerance issues when sourcing recycled rubber granules or manufacturing resin-bonded rubber in-house. We have successfully defined and consistently maintained criteria on incoming raw material, as well as production parameters, to guarantee a stable output.

Granule size is characterised by particle size distribution (PSD), which is controlled and kept constant. Pandrol's vigilant quality process secures consistently high product quality at every stage of production:

- checking inputs – the granules' PSD, origin and binder characteristics
- verifying recipe material and moulding conditions (percentage mix, temperature, pressure, dimensions) during production
- measuring product dimensions and functional performance (stiffness, strength) post-production.

Mixing the rubber granules and binder compound, as well as curing and compression moulding, take place in strictly controlled temperature and humidity conditions to eliminate climate as a source of variability. We have defined and are able to reproduce an intrinsically stable process, in which a given mass of raw material is set in a given mould volume. This guarantees a uniform product in its characteristics and lifetime in-track performance.

This stable manufacturing process enables Pandrol to provide a full range of products that all share the same high level of stability and performance.

The foaming process used to manufacture microcellular polyurethane is much more unstable than the compression moulding process used for RBR. It requires a very high degree of process control to guarantee a homogeneous product.

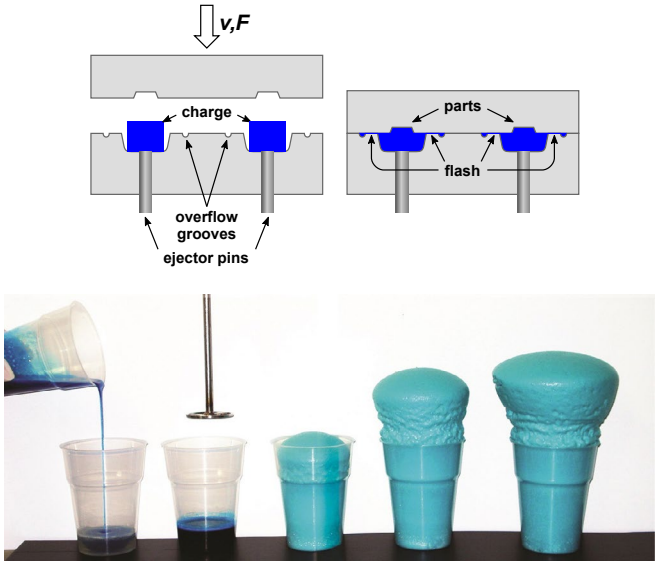

Figure 7: Stable compression moulding (top), compared to unstable foaming process (bottom)

MYTH 03

Recycled rubber products crack over time, like used tyres

THE FACTS:

Pandrol's SRS products demonstrate high resistance to cracks.

The crack phenomenon is strictly linked to the effects of UV or ozone exposure on early tyres[7], which had inferior composition to the newer tyres used in Pandrol products. In addition, UV exposure is not an issue as the SRS products are installed below and within the track. When Pandrol's products are tested against the standard ozone testing in compression condition (representative of track loads), they show no cracks[8].

MYTH 04

Old tyres lose their elastic properties

THE FACTS:

The tyres Pandrol recycles are not old – on average, they have had less than three years' use. The elastic properties of the final products are measured and guaranteed over the track lifetime.

End-of-life tyres are typically removed from vehicles after 30,000km. These tyres are considered end-of-life for vehicles, as their running surface is worn out. However, the rubber within the rest of the tyre construction is still completely serviceable and unworn[9].

During the development phase, all Pandrol products are tested as new products for fatigue and ageing, and pass all tests successfully. This means that our recycled products, made using raw material that is on average three years old, are fit for purpose for several decades on track.

When a chemical process is used in the manufacture of a product, there is a setting up or curing time during the first months of the product's life. However, since the rubber granules used in Pandrol's SRS products are from end-of-life tyres, the material is already in a stable condition.

In contrast, freshly produced elastomers, such as microcellular foams, are not yet fully stabilised and will potentially creep or shrink during their first months in track[10].

MYTH 05

Recycled rubber is prone to settlement/creep

THE FACTS:

Recycled rubber products actually have a superior resistance to long-term settlement than foams, as the loads sit on solid rubber and not plastic cells that inflate with gas.

According to research and lab measurements, recycled rubber products have a superior resistance to settlement than PU foam alternatives. This is because the rubber products support load via solid, highly elastic rubber granules working in compression.

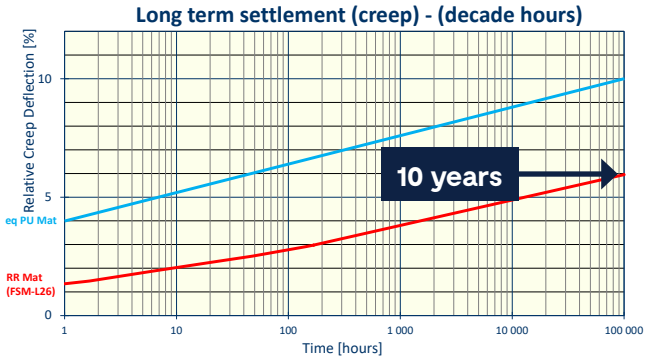

Figure 8: Settlement (Creep) Test: settlement by time on a logarithmic scale. Pandrol's recycled rubber material (in red) clearly outperforms a similar product made of microcellular polyurethane (in blue) by a factor of 3

In addition to this better settlement behaviour, Pandrol's RBR demonstrates excellent performance under constant plus variable load for 12.5 million cycles, with a stiffening of only 10% (international standards typically request 15 to 20% maximum). Pandrol mats pass the most stringent fatigue railway testing, the French SNCF Vibrogir[11].

Microcellular polyurethane material (or PU foam) is of a closed cell or mixed structure. This means that it is less resistant than recycled rubber, with a typical density of just 220 kg/m³ compared to recycled rubber's 710 kg/m³. As a result, more creep occurs over time.

MYTH 06

Microcellular polyurethane outperforms recycled rubber in terms of stiffness

THE FACTS:

Recycled rubber has a similar, constant performance across the whole loading range, whereas microcellular polyurethane only keeps its performance in a narrow loading[12].

The main performance difference between microcellular polyurethane and recycled rubber lies in the load-deflection curve. This curve defines the working properties of the product when loaded in track.

Cellular polyurethane has an S-shaped curve, giving 'optimised' performance at high load. In contrast, recycled rubber has a relatively linear character, providing more constant performance.

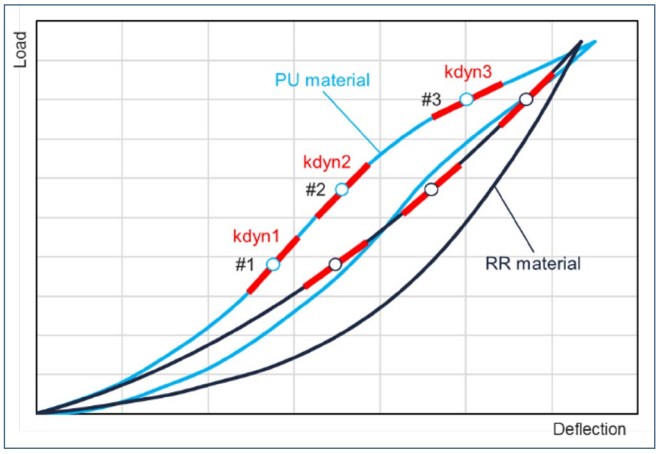

Figure 9: Comparison of load-deflection curves of high-quality RBR and PU foam

In general, the design is controlled under maximum load of the train (between #2 and #3 on the graph). However, this normally only happens at peak times during the day. At night, for example, when vibration limits are more severe, with empty rolling stock the loading falls to #1 and microcellular polyurethane has sub-optimal performance.

Therefore, while performance of the products is comparable during the day, microcellular polyurethane products mitigate less vibration annoyance at night due to unloaded rolling stock[13].

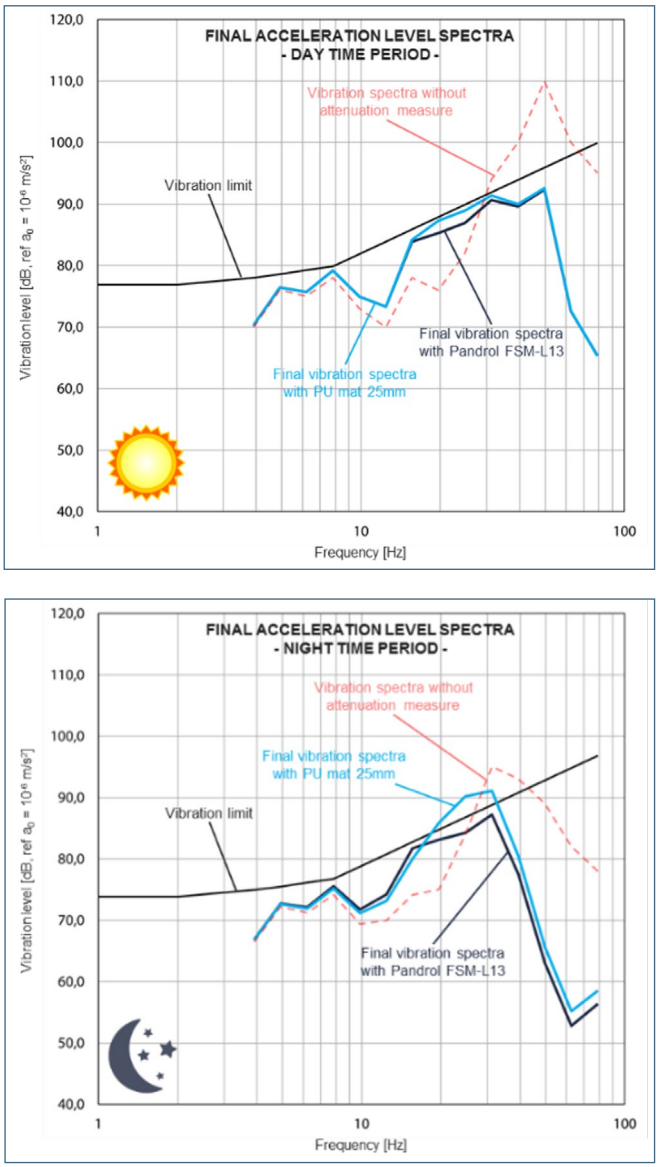

Figure 10: Comparison between performance day and night of recycled rubber mats and microcellular polyurethane

MYTH 07

Recycled rubber is vulnerable to chemicals

THE FACTS:

Recycled rubber is actually very resistant to chemicals, as demonstrated by testing under international standards. Car tyres are designed to be extremely resistant to all chemicals encountered on the road. As a result, the rubber granules Pandrol uses in its RBR products are equally resistant.

As with other properties, Pandrol's SRS products are fully tested as new material. In international lab tests, they have proved to be resistant to salt, lubricants, and chemicals between pH3 and pH12[14].

It is widely recognised that microcellular polyurethane products are prone to crumbling due to hydrolysis, reacting with moisture present in the track[15].

MYTH 08

Recycled rubber is prone to water absorption and has poor stiffness when wet

THE FACTS:

Pandrol's RBR mats are highly water permeable and, as a result, are not prone to stiffening in a well-drained track. They also help to preserve the track's drainage function[16], as water is able to evacuate from the track without becoming clogged.

In addition, Pandrol's SRS products are not sensitive to the presence of water from a chemical or mechanical point of view, as demonstrated by tests comparing stiffness (i.e. performance) before and after immersion[17].

Microcellular polyurethane's foam structure is an issue in terms of water permeability. The material tends to absorb water over time, greatly increasing its stiffness. This effect is extremely difficult, if not impossible, to reverse, and greatly reduces a product's performance during the operation of the line.

Figure 11: Granular structure of Pandrol RBR makes it water permeable

MYTH 09

Recycled rubber products are not able to achieve industry standards

THE FACTS:

Pandrol's recycled rubber products are manufactured using sophisticated technology and quality control. They pass all industry tests.

Our SRS products are developed by our research and development specialists based in Belgium, Spain, The United States and the UK, and are tested by internationally accredited laboratories such as TU Munich, UCLouvain and LADICIM to international standards such as CEN and DIN.

MYTH 10

Recycled rubber products are not accepted by major networks

THE FACTS:

Pandrol's recycled rubber products are used by many major operators, including ADIF, Amtrak, CSX, Rio Tinto, Infrabel, Sydney Light Rail, Metrolinx, Bergen LRT, Metro de Madrid, Shanghai Metro, and Sao Paulo Metro.

As the imperative to achieve net zero carbon railway increases and understanding of the importance of advancing circular economy grows, there is no doubt that using recycled products is set to become an increasing priority for major networks.

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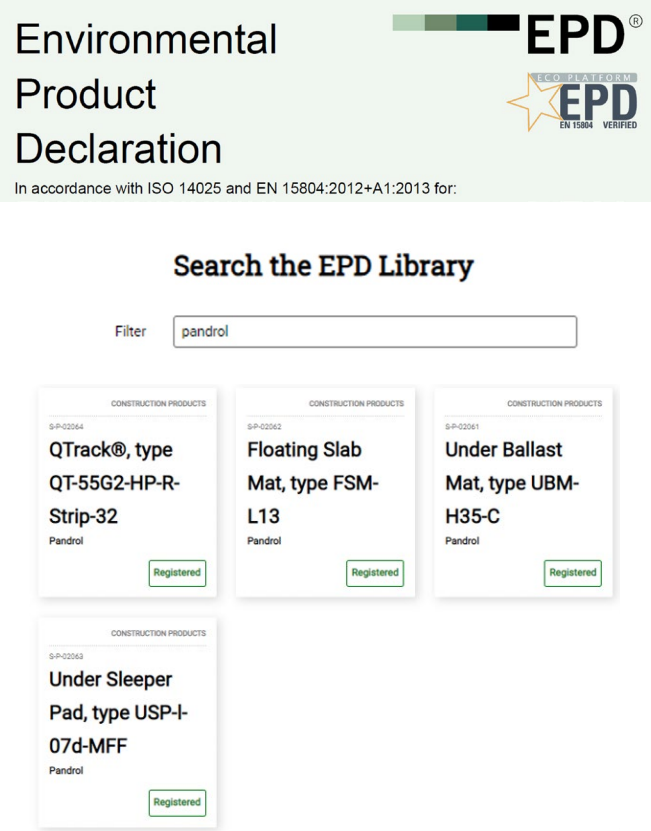
Environmental Product Declaration

Pandrol's SRS solutions have been independently certified for Environmental Product Declaration and are 100% recyclable.

Internationally accepted, an Environmental Product Declaration (EPD) is a transparent, third-party audited comparison tool that uses scientific parameters to measure a business' or product's environmental impact. Independently verified and used across all sectors, the EPD process supports increased understanding of environmental impact throughout the supply chain and provides businesses with a benchmark for continuous improvement.

Pandrol Sustainable Resilient Systems exhibit a best-in-class CO_2 footprint due to our proven and award-winning upcycling/recycling material sourcing strategy. Their CO_2 equivalent footprint is two to three times less than comparable microcellular polyurethane products made of non-renewable chemical products.

The detailed EPD document can be found here:
www.environdec.com/library/ – search for 'Pandrol'



Closing statement

This report and the documents it refers to demonstrate that Pandrol's recycled rubber solutions perform technically as well as, or even outperform, similar products made of materials such as microcellular polyurethane. In addition, their CO_2 footprint is two to three times smaller, for an equivalent or lower cost.

Recent climate events and the IPCC report have only underlined what we already knew – although rail is one of the most environmentally friendly forms of transport, we need to do all we can to reduce our carbon footprint even further.

With governments and businesses under increasing pressure to commit to net zero, these types of innovations and initiatives have never been a higher priority. Reducing the environmental impact of track infrastructure makes business sense, improves working conditions, brings competitive advantage – and is our industry's way of safeguarding the planet.

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