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A PASSION FOR RED

The distinct precast cladding of a Manchester hotel

LOW-CARBON CONSTRUCTION

Decarbonising concrete with no impact to cost or programme

REPAIR AND STRENGTHENING

Carbon savings of a repair and rehabilitation alternative

NEW CONCEPT SLEEPERS FOR THE RAIL INDUSTRY

Mark Schumacher and **Rinaldo Pinchiroli** of **FSC Tech** describe the features of dry-cast concrete railway sleepers with a reinforcing technology based on 'wrapping in tension' of 'fibres impregnated with resin'. The results are long-lasting railway sleepers that are cost effective, corrosion free, high dampening, conductivity free and with a reduced carbon footprint. A valid alternative to standard concrete and wooden sleepers.

Steel is the 'Achilles heel' of the current practice of reinforcing concrete elements used in structural applications. A new method of providing reinforcement to concrete elements eliminates the use of steel as a reinforcement and imparts a level of flexural strength to these elements not possible with any other technology. Eliminating embedded steel in an element provides the following benefits:

- longer lifespan – no steel corrosion, no overstressed reinforcement and subsequent early failure
- lower cost – less expensive than steel, yet provides better reinforcement characteristics
- lower carbon footprint – the reinforcing used has an embodied CO_2e footprint 30% less than steel and also allows the use of low-carbon binders since there is no longer any steel to protect
- conductivity free – no steel means no 'phantom' currents to disrupt signalling infrastructure
- enables dry-cast production – this is fundamentally a lower cost-production method and it will use about 25% lower cement (binder)
- high dampening properties – this comes naturally from the flexural properties but can be customised for specific requirements
- cracks are no longer a problem, given that there is no steel to protect.

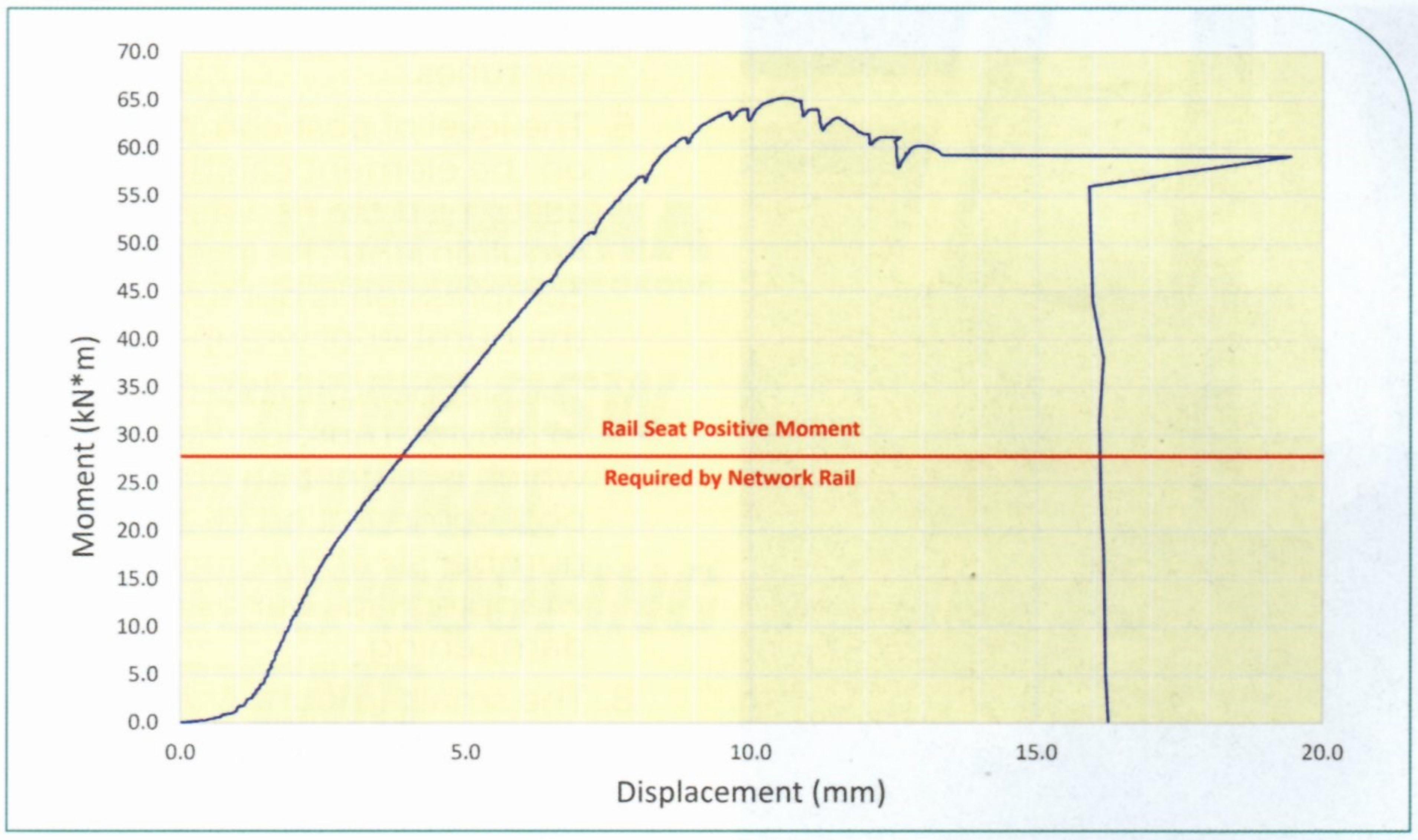
BACKGROUND

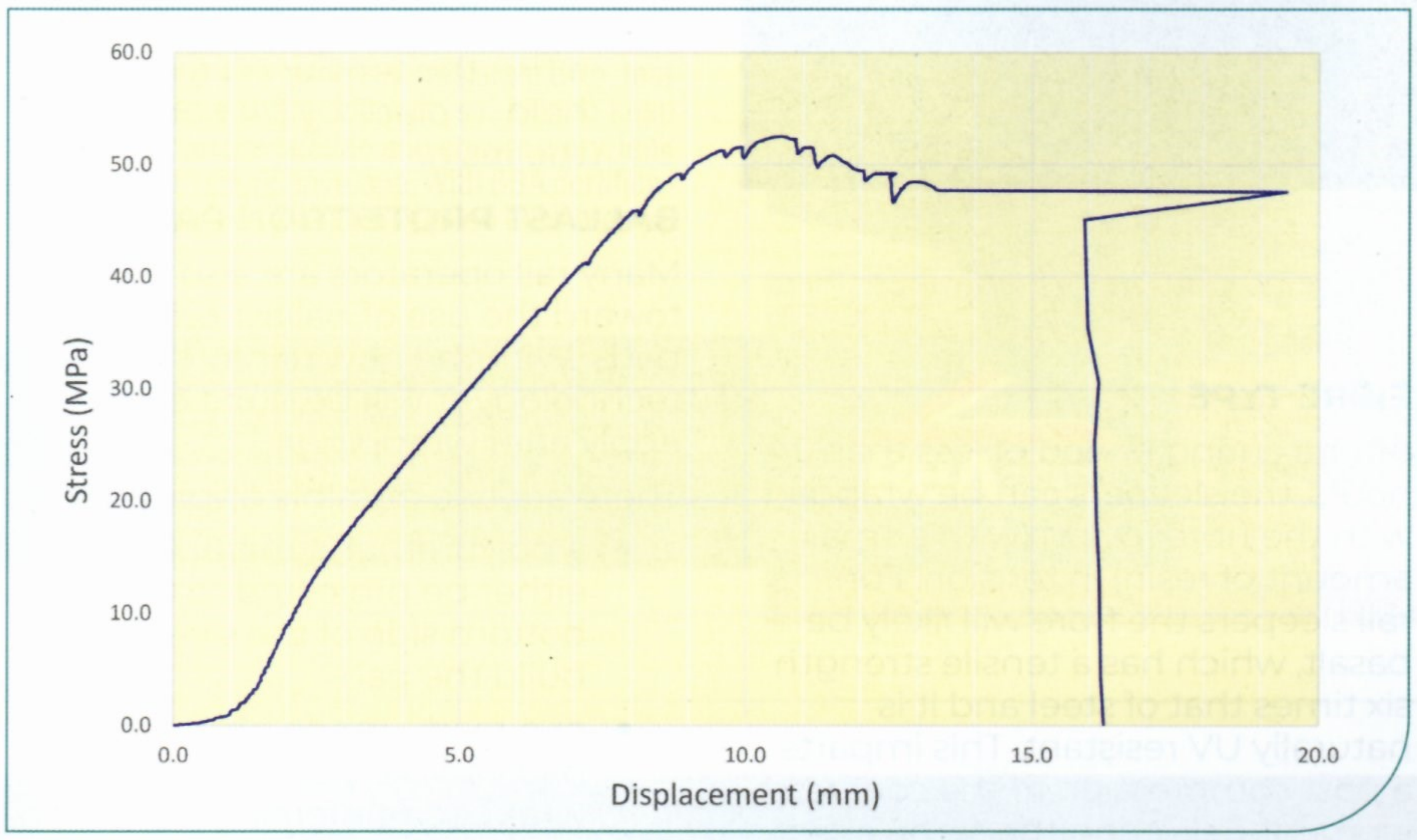
The origins of this technology came in the concrete pipe industry. The inventor was the chief technical officer of the largest concrete pipe production machinery manufacturer in the world, Hawkeye/Pedershaab. The impetus for research was the erosion of the market share for concrete pipe, being taken over by plastic pipes. The historical use of steel reinforcement was one of the primary factors for this market erosion and the goal was to find a new way to reinforce concrete pipes.

Fibre-reinforced polymer (FRP) bars

LEFT: Figure 1 – sleeper with grooves for wrapping.

FAR LEFT: Figure 2 – wrapping of sleeper with fibre roving.





LEFT:
Figure 3 – testing displacement capability/flexural strength of new concrete sleepers. Base 230mm; height 180mm; length 2500mm.

BOTTOM LEFT:
Figure 4 – testing stress in the wrapped sleeper, showing capability of much higher stresses than current concrete sleepers.

have been studied and used as a replacement in certain applications for steel reinforcement in concrete elements. However, FRP bars simply applied as a substitute for steel as an embedded reinforcement have a number of issues, including long-term creep and high cost. While they have their place in many applications and they certainly solve the corrosion issue, for concrete pipes, which require flexible circular reinforcement in a very high production environment, FRP bars are not a fit.

Fibre is also available in multi-filament rovings. Most of the fibres available in this form have excellent physical properties, including much higher tensile strength than steel, higher temperature service and of course very high corrosion resistance. These fibres have been on the market for decades, with well-established and tested physical properties, and are the basis of the reinforcement scheme used by the new technology.

TECHNICAL DETAILS

The new technology involves the winding of concrete elements, like rail sleepers and pipes, with a fibre roving in *tension*, applying these high tensile fibre rovings on the surface of the concrete element where the tensile forces are highest. After the fibre roving has been tensioned, a small amount of resin is applied just before the roving is wrapped on the element. The resin acts as a sort of lubricant to facilitate the load sharing of the applied tension to the individual filaments and it also provides an extra level of toughness. In the case of pipes or poles where the entire surface is covered, it also provides an impervious membrane. The resin itself does not carry any structural load since the fibre roving is already in tension, therefore the element reinforced in this way has no creep.

The winding under tension delivers a post compression to the concrete element, similar to the effect that prestressing or post-tensioning of concrete accomplishes. The unique flexural strength properties come from the combination of the higher tensile strength of the fibre compared with steel (four to six times) and the lower Young's modulus than steel of the fibre. It can take a high tensile and dynamic load and return to its original form, over and over again.

SLEEPER DESIGN

The new technology makes possible to develop a sleeper designed around the rail owner's needs; long life expectancy, elimination of corrosion, lower cost, no conductivity and reduced maintenance.

SLEEPER GEOMETRY

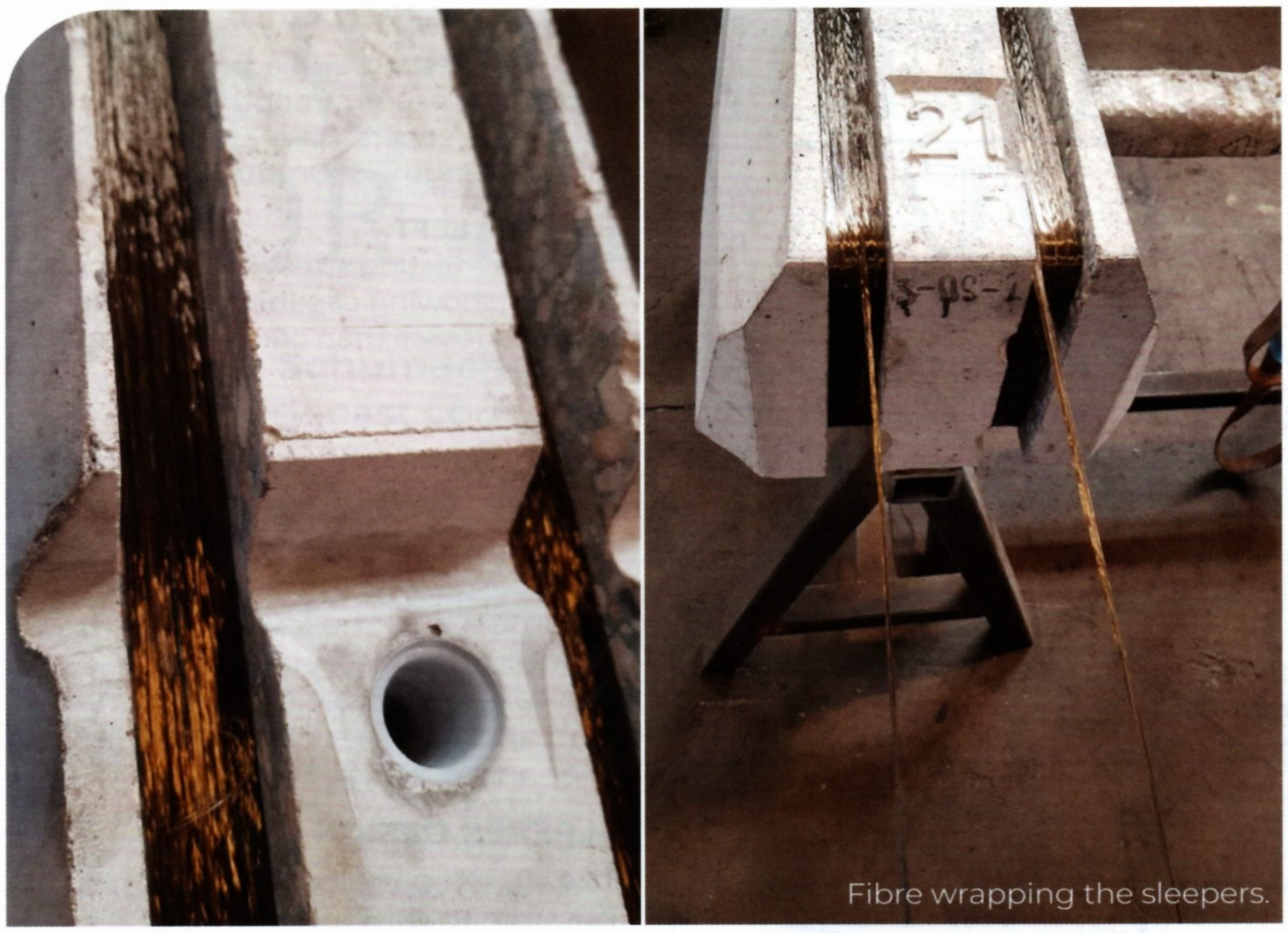
The sleeper geometry can be designed as a trapezoid with the same basic height, weight and length of current sleeper design. However, the geometrical shape is maintained across the entire sleeper to provide a more uniform transfer of load to the ballast based on the centre section having a higher stiffness than is available with current prestressed concrete sleeper design.

CASTING PROCESS

The current prestressed or post-tensioned sleepers are produced in either a long line or carousel casting system using wet-cast concrete, where the sleepers must remain in the moulds for 12–24 hours until they have reached a minimum strength to be stripped and handled.

Since the new technology does not use embedded prestressed steel, it now enables concrete sleepers to be produced using the dry-cast process, which is defined as keeping the water:cement (w/c) ratio at a low level, generally 0.28–0.34. This process is the most common method worldwide for production of high-volume precast concrete products including blocks, pavers, concrete pipes and box culverts, manholes and catch basins, and sundry other products.

Dry-cast concrete production has six key benefits for the production of sleepers:



Fibre wrapping the sleepers.

1. Increased production – The stiffness of the mix allows the concrete to be consolidated under intense vibration in the form. The product then can be immediately stripped and will hold its form under its own weight and keep tight tolerances. This means one mould can produce hundreds of pieces per day.
2. The low w/c ratio results in reduced shrinkage and creep, faster strength gain and better freeze–thaw performance.
3. Achieves higher compressive strength than typical wet-cast concrete for the same cement usage.
4. Lower material cost, dry-cast mixes use 20–25% less binder (cement).
5. Eliminating the embedded steel reinforcement opens the door to the use of the new binders with a low-carbon footprint, since there is no longer any steel to protect.
6. The combination of points 4 and 5 make this new dry-cast sleeper much more environmentally friendly than the current concrete sleeper methodologies.

The features and benefits of dry cast are well described here: *https://bit.ly/3I8nZt4*. A production process video for dry cast production of blocks is available here: *https://bit.ly/3XeMLvX*.

FIBRE TYPE

After a curing period of less than 24 hours, the sleepers can be wrapped with the fibre roving (with a small amount of resin) in tension. For rail sleepers the fibre will likely be basalt, which has a tensile strength six times that of steel and it is naturally UV resistant. This imparts a post compression to the concrete element delivering the same effect as prestressing. However, basalt has an elastic modulus about 40% that of steel, which allows for a ductile type of behaviour, which is especially advantageous for elements like rail sleepers that experience cyclic and dynamic loads.

The new reinforcement technology has the following features and benefits:

1. Basalt, unlike steel, is corrosion free.
2. The reinforcement is placed exactly where the tensile stresses are highest – at the surface of the element. This reduces the total quantity of reinforcement needed for the same level of performance.
3. Basalt has zero electrical conductivity.
4. If a sleeper is subjected to a load that strains it to a point where a crack is induced in the concrete, there is no cause for concern. Once the load is removed the crack will close.
5. Basalt-fibre-reinforced concrete sleepers will have an extremely long life cycle, both materials have been around for centuries.
6. The level of post compression on the element can be customised to fit a design requirement. The level of post compression is determined by the number of wrapping laps.
7. The sleepers can be designed to provide more dampening, which is a function of the post compression. As in point number six above, more wrapping laps brings more dampening.
8. The small amount of resin used has no structural relevance. The resin is applied after the fibre roving is tensioned. Even if all the resin is burned off in a fire, the tensioned roving is held in place by friction, *not* the resin.

BALLAST PROTECTION PAD

Many rail operators are also moving toward the use of ballast protection pads. With the new reinforcing technology, it will be quite easy to apply after wrapping.

There are two possible applications:

- a polyurethane material can either be projected to the bottom side of the sleeper to build the pad
- or a ready-made polyurethane pad can be glued to the wrapped reinforcing, providing superior adhesion than just applying to concrete.

The FSC sleeper shows a great displacement capability/flexural strength not achievable by the current concrete sleepers. Test results are shown in Figure 2.

CARBON FOOTPRINT SAVINGS

Carbon footprint savings are of approximately the 50% versus the concrete sleepers due to:

- binder savings for the use of dry-cast concrete that needs less binder
- additional binder savings due to the use of low-carbon footprint binders, allowed by removal of steel reinforcement
- usage of a lower quantity of fibre versus steel reinforcing
- usage of a low quantity resin used, about 10% of the weight of the fibre.

Specification approval will begin soon at MXV in the USA, which is a subsidiary of the Association of American Railroads.