Sekisui Chemical Group has been one of the leading manufacturers of synthetic products for more than 60 years. Worldwide, Sekisui Chemical is represented by more than 200 subsidiaries. With approximately 20,000 employees, the company generated a total turnover of ca. 8 billion euro (in 2009). Sekisui possesses extensive experience in polymer technology and is continually developing innovative products.

The creed of Sekisui Chemical is the provision of cutting edge technology while complying with the highest standards of corporate responsibility. Sekisui Chemical is sub-structured into three main business areas. In the Housing Division, well over 10,000 pre-fabricated houses with a high quality finish are produced annually for the Japanese market. Each house is adapted to the respective customer requirements and meets the latest standards in energy efficiency.

The High Performance Plastics Division includes interlayer safety film for windshields and architectural glass, cross-linked polyolefin foam material for use in the automotive industry and in many other industrial applications. The Medical Technology Division offers a wide range of pharmaceuticals, diagnostics and medical devices. Other business sectors in this division are fine chemicals and specialty chemicals as well as industrial adhesive tape and films.
The main business sector- Urban Infrastructure and Environmental Products- primarily encompasses the provision of sustainable and environmentally friendly systems for water supply. Simultaneously, Sekisui Chemical develops highly effective systems for pipe refurbishment and very successfully produces wide-dimensioned pipes in glass-fibre-reinforced plastic. This segment is completed by a wide range of industrial pipe systems, building products and the railroad technology segment.
1978  Okouchi Prize and Award of the Directorate General of Japan’s Research and Development Agency for the development of synthetic wood
1979  Deming Prize for high level and comprehensive quality control
1980  Field trials of FFU railway sleepers on the bridge over the Miomote River and in the Kanmon tunnel
1985  Examination of test sleepers by the Japanese Railway Technical Research Institute with outstanding results. FFU synthetic sleeper becomes the standard sleeper of Japanese National Railways (JNR)
1991  Further positive test results of FFU railway sleepers on test track lead Japanese state and private railway companies to use FFU synthetic sleepers
1996  The Japanese Railway Technical Research Institute carries out a further 100 million load changes on the test track sleepers. The product life of FFU synthetic sleepers is forecast to be more than 50 years
2004  First bridge project in Europe using FFU synthetic sleepers
2007  Japanese industry standard JIS E 1203 is published
2008  First switch system using FFU synthetic sleepers in Germany
2009  Approval of FFU for use in the railway network of Serbia
2009  The German Federal Railway Authority (EBA) grants SEKISUI approval for in-service testing of FFU synthetic sleepers on Germany’s railway infrastructure
2010  Installation of FFU synthetic sleepers on the bridge over the river Sava in Belgrade
2010  Installation of level crossings of FFU synthetic sleepers at Austrian Federal Railways (ÖBB)
2010  Installation of FFU synthetic sleepers on the switch system of the Hamburg Hochbahn

FFU Railway Sleepers Timeline

During the expansion of the national rail network, Japanese National Railways (JNR) recorded in internal notes that around 70% of the wooden sleepers used at that time had to be replaced regularly due to weathering. To guarantee a high-performance rail network with, as far as possible, continuous and failure-free operation, collaboration began with Sekisui Chemical on developing a railway sleeper made of long-lasting, durable and low-maintenance synthetic material, which was to meet the highest standards. As early as 1980, the partners installed the newly developed FFU synthetic sleeper in a field trial on a bridge supporting structure as well as in a tunnel on the Shinkansen high-speed line. Five years later the FFU sleepers used in the trial were removed and extensively examined. The results of the field test were that the FFU sleepers performed extremely well during continuous operation.

The quality and resilience of the sleepers tested was indistinguishable from the new FFU sleepers in any way whatsoever. Therefore JNR has been using FFU synthetic sleepers as standard sleepers in regular operation and to their complete satisfaction since 1985. In 1996, the authority responsible, the Railway Technical Research Institute, carried out further tests on FFU sleepers on the test sections of track used in 1980 where they were subjected to a further 100 million repeated loads.

The favourable result: FFU sleepers have an expected product life of more than 50 years. The implementation of the first project in Europe commenced in 2004. Back in Japan, various developments were rewarded and in 2007 FFU synthetic sleepers were standardised under JIS E 1203 (Japanese industry standard). A year later, the first switch made of FFU synthetic sleepers was installed in Germany and in 2009 the Federal Railway Authority (EBA) granted approval for the use of synthetic sleepers on the German rail infrastructure network.
FFU synthetic sleepers are manufactured using a pultrusion-extrusion process. Continuous glass-fibre strands are soaked in special polyurethane and a composite of the materials is obtained by curing at an increased temperature. The whole process is controlled by a drawing tool which pulls the synthetic sleeper profile out of the curing tool. This guarantees the uniformly high quality of ISO-certified production with unvarying material properties. By virtue of the manufacturing process, the FFU synthetic sleeper blanks are non-porous and are cut to a standard length of 12 m. As a result, FFU offers the customer far greater certainty of material performance in practical use when compared to natural wood. Significantly better technical characteristics also allow a better optimisation of the rail section – a huge advantage, particularly in the area of railway bridges. Due to its closed cell structure, FFU does not absorb any moisture. It also exhibits very high chemical resistance to oils, lubricants and pollutants. In the ballast bed the underside of the synthetic sleeper behaves exactly like a wooden sleeper.

**FFU Synthetic Sleeper Technology**

**Correlation**

Bending load – load changes

- **FFU synthetic sleeper**
- **Beech sleeper**

<table>
<thead>
<tr>
<th>Bending load (MPa)</th>
<th>Load changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>5</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
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</tr>
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</table>

Corresponds to approx. 50 years use on Shinkansen HSL

- **Product life** over 50 years
- **Density** equal to wood
- **Machinability** equal to wood
- **Electrical conductivity** very low
- **Chemical resistance** very high
- **Lifecycle costs** minimal
- **Maintenance costs** minimal
- **Dimensionally stable customisation** in mm accuracy
- **Recycling** 100%
- **Track system availability** maximum 25 years in daily use
- **Reference** more than 1000 km of track
<table>
<thead>
<tr>
<th>Properties</th>
<th>Unit</th>
<th>Beech new</th>
<th>FFU synthetic sleeper</th>
<th>Standard</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>new</td>
<td>10 years</td>
</tr>
<tr>
<td>Density</td>
<td>[kg/m³]</td>
<td>750</td>
<td>740</td>
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<tr>
<td>Bending resistance</td>
<td>[kN/cm²]</td>
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<td>14.2</td>
<td>12.5</td>
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<tr>
<td>Bending modulus</td>
<td>[kN/cm²]</td>
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<td>810</td>
<td>800</td>
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<tr>
<td>Compressive resistance</td>
<td>[kN/cm²]</td>
<td>4.0</td>
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<td>6.6</td>
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<tr>
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<td>1.0</td>
<td>0.95</td>
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<tr>
<td>Hardness</td>
<td>[kN/cm²]</td>
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<td>2.5</td>
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<td>Impact bending resistance</td>
<td>+ 20°C [J/cm²]</td>
<td>20</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>- 20°C [J/cm²]</td>
<td>8</td>
<td>41</td>
<td>-</td>
</tr>
<tr>
<td>Water absorption</td>
<td>[mg/cm²]</td>
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<tr>
<td>Electrical resistance</td>
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<td>1.6x10¹⁰</td>
<td>2.1x10¹⁰</td>
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<tr>
<td></td>
<td>wet [Ω]</td>
<td>5.9x10⁴</td>
<td>1.4x10⁶</td>
<td>5.9x10⁹</td>
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<tr>
<td>Rail spike extraction force</td>
<td>[kN]</td>
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<td>28</td>
<td>28</td>
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<tr>
<td>Rail screw extraction force</td>
<td>[kN]</td>
<td>43</td>
<td>65</td>
<td>-</td>
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Technical Characteristics

In the course of various approval procedures for FFU synthetic sleepers since 1985, extensive material tests have been carried out. The Technical University of Munich undertook the last technical examination of the material in 2008. FFU was tested based on applicable European standards since no specific standards for wooden sleepers exist. Consequently, the FFU synthetic sleepers tested had to comply in part with the requirements for concrete sleepers. Fortunately, FFU synthetic sleepers were able to meet all of the requirements imposed. The report by the Technical University turned out extremely positive for FFU in all areas. Based on these favourable results, the Federal Railway Authority granted approval in 2009 for the safe use of FFU synthetic railway sleepers on the rail infrastructure of Germany. The following tests were carried out by the Technical University Munich:

- Effect of repeated loading test
- Tensile force in sleeper screw
- Sleeper screw extraction test
- Impact test
- Electrical resistance
- Static testing in centre of sleeper
- Fatigue testing in centre of sleeper
- Static compressive test
- Static deflection at low temperature R = RT and R = -10°C
Static compressive test

Load introduction on rail and rail fastening in FFU synthetic sleeper

Excerpt from Research Report no. 2466 dated 19.09.2008 by the Technical University of Munich, Chair and Testing Department for Transportation Univ. Prof. Dr.-Ing. Stefan Freudenstein

On July 08, 2009, Sekisui was granted the approval for field testing of FFU synthetic sleepers on the German rail infrastructure by the German Federal Railway Authority. (Please find below an excerpt of this authorization)

Three million load changes corresponding to an axle load of 225 kN in the effect of repeated loading test showed an elastic rail head deflection of less than 0.42 mm. A further 1.28 million load changes carried out at an increased temperature of 48°C demonstrated that the technical characteristics of the material remain constant. The sleeper screw extraction test resulted in a mean extraction force of 61 kN. The impact test, which simulates derailment, was carried out by the application of an impact load with a 500 kg drop weight.
After two impact tests conducted on the same section of the sleeper, the FFU synthetic sleeper merely showed the impression of a wheel flange. The FFU sleeper retained its stability even after this derailment simulation and thus guarantees the retention of the track gauge. The electrical resistance tests conducted on FFU resulted in a value of $R_{33} = 71.9 \, \text{k}\Omega$. The requirement of $R_{33} \geq 5 \, \text{k}\Omega$ was maintained with certainty, confirming the high electrical insulation of FFU synthetic sleepers. During static testing in the centre of an FFU sleeper, a force of 240 kN was deflected without any damage to the sleeper.

By comparison, a wooden sleeper failed by breaking at only 80 kN. The deflection of the FFU sleeper was continuously recorded here by four gauges. The fatigue test was carried out under exceptionally critical test conditions in the middle of the sleeper and only showed a slight change of 0.4mm after 2.5 million load cycles. There were no perceptible signs of fatigue.

When carrying out the static compressive test, a load of 300 kN was applied to the FFU sleeper through the rail and rail fastening. In this test a plastic deformation of only 0.8 mm was measured.

To analyse behaviour at low temperatures, FFU sleepers were put into storage at -20°C. The ensuing test showed that, even at extremely low temperatures, the fibres of FFU synthetic wood remain free of brittleness.

The fatigue test under the sleeper bed was performed in the most unfavourable conditions such as poor track geometry, uneven distribution of loads through the rails, stiff rail seat section and a high dynamic allowance for an axle load of 250 kN. Without exception, no damage of any kind was observable on the FFU sleepers, even after two million load cycles.
In case bore holes are misplaced or drilled in an inaccurate size during on-site work on the FFU sleepers, the FFU synthetic wood technology offers two different quick and easy repair methods without affecting the quality of the material.

Using the first method, the defective bore hole is re-profiled, cleaned and then filled with liquid synthetic resin. After a curing time of just 30 minutes, a new bore hole can be drilled in the correct position a few millimetres away, and the originally intended screw connection made.

Using the second method, the defective bore hole is cleaned and similarly filled with liquid synthetic resin. A FFU synthetic wood dowel is then inserted. With this method curing takes about four hours until a new bore hole can be drilled at the repaired spot.
FFU synthetic sleepers can be manufactured and supplied ex works to the most precise customer specifications. This minimizes:
- Adjustments to the project
- The duration of track closure
- The cost of site logistics
- Preparation expenditures

The following customisations are possible:
- Reinforcements for super-elevations
- Milling grooves for super-elevations
- Drilling bridge sleepers
- Milling of bridge support bearings
- Milling out slots for belt reinforcements
- Milling out slots for rivets
- Surface sanding
- Reinforcement of lateral displacement
- Shoeing of rail sleeper

The FFU synthetic sleepers prefabricated by customer order are already clearly marked at the factory in accordance with the laying plan. This allows installation at the predetermined position to proceed with certainty.

Should the gradients on an existing bridge construction need to be re-established, the individual bridge sleepers can be produced to millimetre precise accuracy and manufactured for the required levels. There is nothing to prevent perfect gradients from the aspect of bridge timber in FFU. As a matter of course, the individual bridge sleepers are clearly marked when delivered to the customer.
FFU synthetic sleepers can be worked in the conventional way, just like natural wood. Standard tools can be used to drill bore holes, saw, mill or chisel rail sleepers of synthetic wood. The advantages of FFU as compared to natural wood are a greater hardness and being almost totally non-porous, whereby the operating life of the tools used can be easily optimised by using WIDEA tools or drills for steel materials. During project machining operations on FFU synthetic sleepers, attention must be paid in order to prevent the overheating of the tools. This can be avoided by selecting a slightly reduced rotational speed or feed rate. This also prevents the glass fibres melting due to overheating. In any case, the standard operating procedures must always be observed.

The density of FFU synthetic sleepers is approximately 740 kg/m³, and thus provides the same advantages as natural wood for transport to the worksite.

The dimensional stability together with milled grooves and false edges already carried out at the factory allow on-site work to be carried out quickly, accurately and safely. The work effort and the duration of track closure can be optimised so that the track is soon available again for train operation.
Railway Bridges

FFU synthetic sleepers can be used on railway bridges technically and commercially in exactly the same way as natural wood. In addition, installing FFU sleepers on railway bridges guarantees significant additional engineering design benefits in bridge construction through:

- Extremely long product life
- Highest weathering resistance
- Identical bridge dead weight
- Maintaining visual appearance
- Constant static system
- Consistency of gradient
- Homogeneity of bridge sleepers
- Use of conventional fastening systems
- Use of identical tools
- Free from insecticides
- Short track closures
- Increased railway safety
- Dimensional stability
- Full-area bedding on bridge supports
- Homogeneous special cross sections
- Very good technical properties
- High track availability
- Reduction in maintenance
- Lower maintenance costs

FFU synthetic sleepers can be installed quickly, competently and accurately by professional railway companies and construction companies.
In 2010 a considerable number of railway operating companies are already using FFU synthetic sleepers on a worldwide track length of over 1,000 km, a large percentage of which was laid on bridge structures.

In Europe, FFU has been used on projects since 2004, always to the complete satisfaction of the customer.

Maximum availability of the track network is a primary goal for the majority of railway operating companies. For example, taking into account the typical observation of maintenance intervals:
- Corrosion protection after 30 years
- Rail replacement after 30 years
- Steel structures after 50 years
- Replacement of FFU bridge sleepers after 50 years

With the above target values, prolonged track closures leading to interruption of service does not need to be instigated by the railway operating company until 50 years have passed.
The significantly longer product life, high electrical insulation properties and strong chemical resistance of FFU synthetic sleepers make it the preferred choice for switches. It also wins over particularly on switch systems where the operator is regularly confronted with high costs and maintenance work. Additionally, FFU synthetic sleepers can be manufactured to any desired length and thus overall offer a large range of advantages for use on switches:

- Good interlocking with ballast
- Secure FFU synthetic sleeper footing
- Track safety after derailment
- Full operation after derailment
- High dimensional stability after derailment
- High elastic load-bearing ability
- High safety level in rail fastenings
- High weathering resistance
- No water absorption
- Excellent chemical resistance
- Unaffected by lubricants and industrial greases
- No environmental impact through chemical impregnation
- Free of insecticides
- Quick repair methods
- Reinforcements/lateral stabilisation
- Use of standard fastenings
- Use of standard tools
- Short track closure
- Improving railway safety
- Very good technical properties
- High switch system availability
- High electrical resistance / insulation

On account of its numerous advantages, FFU synthetic sleepers are the preferred choice for switch systems in a ballast bed or on slab track, with rubber shoes generally being used in the latter case. Dimensional stability and the resultant positional stability when assembling switches in the factory are fascinating aspects of FFU synthetic sleepers. Rapid and reliable assembling of switches demands only a very brief occupation of capacity in the switch factory. Switch systems built with FFU synthetic sleepers have a weight comparable to natural wood (approx. 740 kg/m³) and offer huge advantages in transportation and installation logistics. A pre-existing substructure equipped with wooden sleepers can be continued unaltered with FFU synthetic sleepers. Based on many years of experience, FFU synthetic sleepers exhibit the same advantages as previously natural wood in regard to the elastic behaviour of the track in the area of the switch system.

Environmentally damaging impregnation, odour nuisance and weathering processes are unknown when using FFU and remain a thing of the past.
At its initial trial back in 1980, FFU synthetic twin-block sleepers were installed in a slab track segment in a tunnel. The first test results from 1985 confirmed the superior material properties of FFU synthetic sleepers. Installation in a slab track is usually carried out using a rubber shoe, whereas similarly to other slab track systems with bi-block sleepers the rigidity of the inserts can be clearly defined beforehand.

Special profiles of FFU synthetic sleepers with a substantially reduced overall height of just 10 cm and shortened length of only 2 metres, for example, have already been used long-term for the renewal of existing track sections.

The very good experience acquired over an extended period of time with FFU synthetic sleepers is one of the reasons why in the course of the replacement programmes of old rail sleepers other technologies are now being replaced by FFU synthetic sleepers. This replacement is taking place both on slab tracks with rubber shoes and in areas of spring mass systems as well as in the direct fastening to the sleeper.

Profiles with very large dimensions, such as b/h/l = 26/30/420 cm have already been installed successfully on bridge projects in Europe.
In the past, railway crossings on secondary lines were usually made of wood. The rapid weathering of wood and its subjection to heavy loads from forestry and agricultural vehicles and equipment implied that wooden structures had to be replaced within a very short time in order to maintain the required safety regulations for crossing pedestrians. In contrast to wood, FFU synthetic sleepers are based on an almost pore-free material that absorbs no moisture, requires no environmentally harmful chemicals (adherence to environmental and water protection) and is extremely weather resistant.

In addition to an above-average lifespan, FFU synthetic sleepers are 100% recyclable. Under these aspects, the safety on rail crossings is increased and offers the advantage of a substantially longer operational life.

The design of the railway sleepers used in the area of railway crossings, made of concrete, wood or ideally FFU synthetic sleepers, defines the geometry prefabricated from drawings and to the millimetre in the factory.

The few components are mounted easily and accurately at the railway crossing. By using FFU synthetic sleepers, the system is reliably secure against displacement and lifting.

Within just one hour an old crossing can be removed and a new one of FFU synthetic wood installed. Train services can be resumed immediately thereafter and the crossing released for traffic.
Cable Guides

By virtue of its very high electrical insulation (identifiable by a high electrical resistance), synthetic wood is the preferred choice for use as a cable guide, cable trough or for use on open track. The multitude of advantages, plus its long lifespan and resistance to weathering have helped to establish synthetic wood as a value-preserving product for the rail infrastructure.
Calmmoon Rail

Rail web noise control system
Calmmoon Rail is a very effective technology for the lasting reduction of sound emissions directly at the rail. The effectiveness of Calmmoon Rail has already been tested successfully in several series of field trials. The Federal Railway Authority has granted approval for the use of Calmmoon Rail on the rail infrastructure in Germany.

Calmmoon

Calmmoon noise control sheet consists of a sound and vibration dampening synthetic resin layer bonded to a sheet steel covering. Thin and highly noise-dampening, Calmmoon combines the virtues of a flexible and easy-to-install noise control system. Due to its high adhesive power and effective noise reduction, Calmmoon is increasingly used in quiet zones of passenger aircraft and high-speed trains, in shipbuilding - especially cruise ships and larger passenger ferries, as sound damping cladding for steel bridges, as well as for industrial air conditioning systems and compressors.