The FFU-Sleeper – Development and use in slab Track

FFU synthetic sleeper is a material that has much better material properties than natural timber while it can be handled and processed as easily as natural timber. The synthetic sleeper has virtually the same specific mass as the natural one, yet a very considerable longer service life than the latter, and its weathering properties are also superior.

Development and short history

In 1978, a company called Sekisui was awarded several prizes in Japan for a technological development that initially went under the name of "Eslon Neo Lumber FFU". The letters "FFU" stand for "fibre-reinforced foamed urethane".

In 1980, the Railway Technical Research Institute (RTRI), working in cooperation with the Japanese railways (JR), laid sleepers made of this material on two experimental sections of track in Japan. On one of this field tests FFU was installed at a slab track as twin block at the Kanmon tunnel. Following on from a period of five years of practical experimentation RTRI, tested one of the sleepers installed in 1980, which fulfilled all the specified requirements. FFU has since then been used by the Japanese railways as a standard product on steel structures, under points and crossings as well as in tunnels in combination with both ballasted and slab track. In 1996, the RTRI removed another synthetic sleeper from the experimental track sections and subjected them to a new series of tests. Among other tests a fatigue test with 100 million load changes showed that technical figures of FFU synthetic sleeper after these were similar as the ones of a new oak tie. Extrapolating the results recorded at that time, FFU synthetic sleeper would be expected to have an in-situ service life of more than fifty years, considering Japan's very high train rate. FFU synthetic sleeper have now also been in use in Europe since 2004.

Production of FFU sleepers

The technique used for the manufacture of FFU synthetic wood is pultrusion. Oriented and endless glass-fibre strands are drawn through a pulling device, coated in polyurethane and cured at a higher temperature to result in a particularly high-grade, pore-closed material.

If so ordered, it is possible to manufacture the synthetic sleeper ex works as semi finished product in the shape of railway sleepers and bridge timbers with millimetre precision. Every sleeper form that can be shown on drawings can already be produced with every detail in the manufacturing plant.

Each of the synthetic-sleepers produced in the works which should meet a precise special requirement is given a unique marking, to make sure that it is laid at the intended location on the engineering site.

Reference applications of FFU

If all the sections of railway track on which synthetic sleepers made of FFU have been laid since 1985 were to be added together, the total number of kilometres is more than 1.100. Some of this has been on light-rail systems and some on really heavy rail systems with axle loads in excess of 30 tons. The predominant use of FFU synthetic sleepers in Japan has been on the high speed network, along with applications on regional, cross-country and metro lines.

The use of FFU on slab tracks

FFU synthetic sleepers are installed since the 1980ies on slab track, on the high speed track of Shinkansen and the regional train track as well as on many metro tracks in the world (Fig. 1). On Shinkansen and regional train tracks FFU are specially used in the area of switch points and also in train stations. In metros FFU are furthermore used on the regular track in the tunnels. For example it is installed in Tokyo, Osaka, Shanghai, Vienna and other Cities.

Fig. 1: FFU twin block sleepers in Shinkansen station – Japan – SEKISUI

Dr.
Günther Koller

CEO
koocoo technology & consulting GmbH
Vienna/Austria
office@koocoo.eu / www.koocoo.at

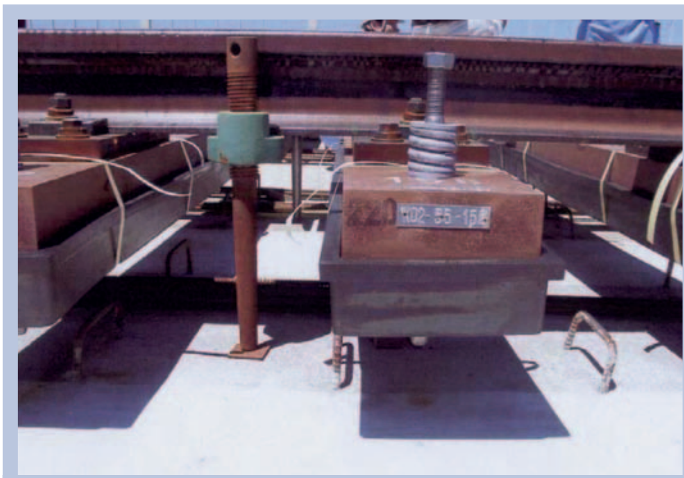

Fig 2: FFU sleeper ready to be bored with concrete – SEKISUI

Fig 3: switch on FFU in slab track – Japan – SEKISUI

Fig 4: FFU sleepers on the regional track Osaka – Horoshima – koocoo

Fig. 5: FFU in slab track, switch prepared to install second part later on – SEKISUI

Fig. 6: FFU on slab track of Metro Tokyo – SEKISUI

Japan and Asia

The installation of FFU on slab tracks of high speed trains or regular trains are similar to the installations of other non monolithic slab tracks systems. Generally FFU will be placed in a rubber booth. This rubber booth will be fixed on the sleeper before concreting and finishing the slab track. Additionally to other systems the FFU sleepers will be fixed with screws and heavy springs into the basement of the slab track. On the one hand this gives the system more stability and on the other more elasticity (Fig. 2).

Why Japanese Railway organisations are using this FFU sleeper technology in their slab tracks? One reason is that RTRI's results of 100 million load changes fatigue test gives them very high safety concerning technical properties of FFU and his life time. This means that FFU sleepers should at least work as long as the slab tracks where it is installed. According the experiences of some technical universities in Europe, a better spring stiffness is given for the switch by using FFU sleepers. As you know in the railway tunnel between England and France the switches also ran on wooden sleepers. This gives the operator of the track the possibility to change the switch (iron part) resting on FFU any time or on the end of the switch's life time without influencing the track system as a whole because of this change. As you can see the operator will hence be more flexible in the switch area of his slab tracks by using FFU. This for the possibility using higher quality and "geometries" of switch technology may be developed in the near future. Furthermore it gets the advantages of the slab track plus the flexibility to always run the best technology in the switch area. Finally it also offers the possibility to change FFU sleepers easily after more than 50 years if needed. This always guarantee the best track availability for his trains (Fig. 4, 5, 6).

On metro tracks further advantages are experienced by clients using FFU such as easy fixing of any kind of leading tool for the train, cables, third rail and more.

Europe

In 2008, Wiener Linien started a long-term programme for replacing the existing sleepers made of other synthetic materials with new ones made of FFU synthetic wood. (Fig. 7) They now will install FFU sleepers on their slab track area construction as heavy or light mass spring track system piece by piece. In this track system the existing sleepers are resting in rubber booth and

Fig. 7: FFU on heavy mass spring system – metro Vienna – koocoo

the height of this sleeper is only 10 cm. The existing sleepers have to be removed and new FFU sleepers will be installed. Because of the millimetre exact manufacturing of FFU it is possible to order FFU two or five millimetre smaller or shorter than the existing one. This helps a lot if the Client is facing problems for the installation of new sleepers in the old and existing space. Finally more than 30 km track will be upgraded like this.

Technical properties – Munich University of Technology [1]

The initial discussions with the objective of creating the preconditions for FFU synthetic sleepers to be authorised by the EBA (German Federal Railway Authority) for the use on the track belonging to infrastructure managers in Germany (i.e. "DB Netze") took place in January 2008. The tests to be carried out were defined jointly with the transport infrastructure engineering department at Munich University of Technology. The following sections present the results of some of the individual tests and examinations.

Fatigue test

The deflection of the rail in relation to the sleeper after three million load cycles at ambient temperature showed values which experience has shown to be within admissible range. Another test phase involved an additional 1.28 million load cycles at the higher temperature of 48 °C. The values measured were of the same order in magnitude as those at ambient temperature. Hence the system's mechanical behaviour is not generally affected by higher temperatures.

Screw extraction test

The tests were carried out on all eight screws in a single FFU sleeper. The load was increased continuously until the screw was pulled out. The extraction force needed for this was found to be 61 kN. This is considerably higher than that needed for natural wooden sleepers, for which Munich University of Technology had measured a value of only 35 kN in the same test in 1997.

Impact test

The purpose of an impact test is to establish how sleepers would behave if subjected to impact loads as the result of the derailment of railway vehicles. The damage caused in the test was limited to a narrow zone (90 mm) around the point at which the impact load was applied. The fibres were severed to a depth of 25 mm. The surface deformation at the point of impact showed no more than the shape of the flange. The FFU synthetic-wood sleepers did not show any signs of warping or twisting as a result of the impact loads. This also means that the track gauge will remain constant.

Electrical resistance

The standard underlying the test, DIN EN 13146-5, requires a minimum resistance of R33 ≥ 5 kΩ as the mean of three measurements. The tests produced a value of R33 = 71.9 kΩ for the electrical resistance of FFU synthetic wood, so it was shown to satisfy the permissible minimum value with a very big safety margin.

Static test in the middle of the sleeper

In order to examine the behaviour of an FFU sleeper under conditions of bending stress, a static test was applied to the middle of the sleeper (basically) along the lines of DIN EN 13230-2. The test force applied initially was 20 kN and this was then increased in increments of 5 kN, during which the amount of deflection in the FFU synthetic sleeper was recorded on four dial gauges. Up as far as a load of 240 kN (which corresponds to a bending tensile stress of 74 N/mm^2 on the underside of the sleeper) no crack was detected in the bent zone. On the basis of the measured deflection, the modulus of elasticity of the synthetic sleeper was calculated to be around 7000 N/mm^2. An analogous test was performed on a wooden sleeper made of beech with the same dimensions. For the same test setup, that sleeper failed under a load of 80 kN in the zone affected by the bending tensile stress.

Fatigue test under the rail pads

The compressive fatigue test under the rail pads follows the basic principles of DIN EN 13230-2 (which actually deals with reinforced concrete sleepers), with a spacing of 600 mm between pads. The load is applied through the fastenings for the ribbed base plates with the complete rail fastening in place. A force of 150 kN acting through the rail pad was chosen for the fatigue test. This corresponds to unfavourable conditions in real life, such as a poorly positioned track, uneven distribution of loads through the rails, stiff rail supports and a high dynamic allowance for a static wheel-set force of 250 kN. No damage to the synthetic-wood sleepers was observed during the fatigue test with two million load cycles. The elastic deflection at the end of this period was only 0.2 mm greater than beforehand.

Static compressive test

For the purpose of investigating the behaviour of the synthetic sleeper when a sleeper is subjected to a vertical load, it was laid on a flat surface and a vertical force, representing the force acting through a rail pad, was applied through the rail and a fully assembled rail fastening, including a ribbed base plate. No plastic deformation was detected up to a load of 150 kN, while the maximum plastic deformation of 0.8 mm was measured for a load of 300 kN.

Static deflection of the sleeper at different temperatures

These tests were carried out at ambient temperature and at –10 °C, with a test force going up to a maximum of 200 kN. In the case of the low-temperature tests, the synthetic-wood sleepers were kept at –20 °C for two days previously in a climate controlled storeroom. The results of these tests confirmed that the deformation of FFU synthetic-wood sleepers subjected to bending-moment stress is only marginally temperature-dependent. No embrittlement occurred at low temperatures. There was no significant change in deformation between the first and third load application. From this, it may be concluded that the fibres do not even fracture at low temperatures when a bending stress with this intensity is applied.

Concluding summary

Eslon Neo-Lumber FFU synthetic wood for the use in railway tracks was developed in 1978. Since 1985 it has been used for more than 1.100 km of track in Japan (Fig. 8), the People's Republic of China, Taiwan, Australia and Europe. It is in use in Europe since 2004 on open load-bearing structures in steel, under railway points and crossings and also on slab track build as heavy mass-spring system tracks. In September 2008, Munich University of Technology presented the final report on a research activity into the properties of FFU synthetic-wood sleepers, and its findings can certainly be summarised as very positive. The EBA (German Federal Railway Authority) granted its approval for FFU synthetic wood in April 2009. DB (German Railway) did their first project with FFU synthetic sleepers in 2011.

Fig. 8: structure joint - special solution with FFU – Japan – koocoo

Reference:

[1] Research Report No. 2466 of 19 September 2008 by Munich University of Technology, transport infrastructure engineering department and test laboratory, Univ. Prof. Dr.-Ing. Stephan Freudenstein