Bulletin of the *Transilvania* University of Braşov
CIBv 2013 • Vol. 6 (55) Special Issue No. 1 - 2013

Y SHAPE RAILWAY SLEEPERS FROM FIBER REINFORCED FOAMED URETHANE

V.V. UNGUREANU[1] **A.N. MARIŞ**[2]

Abstract: *This paper has as main objective the development of a new type of composite rail sleeper, which satisfies the requirements of sustainability, efficiency and environmental protection requirements imposed by the modern tendency to apply the principles of sustainable development in all areas of life. In this regard it is proposed a Y shape from fibber-reinforced foamed urethane (FFU), that is completely recyclable, which makes the whole track working as a truss, with higher resistance to buckling than conventional track systems. In addition the Y sleeper has all the advantages of wood sleepers without their shortcomings.*

Key words: *railway sleepers; composite materials; fier-reinforced foamed urethane (FFU).*

1. Introduction

Since the dawn of railway construction questions have arisen about finding a material that satisfies the strength, durability and economy aspects for railway sleepers [10]. Environmental problems we are facing have led to the research and development of new materials to meet the requirement of environmental protection.

Nowadays is very important for a good operation of railway lines to minimizing the traffic disruption due to maintenance or repairing of railway track. This work comes to support development of a new type of composite sleeper and solutions as well lateral resistance of track panel.

Throughout this paper it analyzed the behavior of composite Y sleepers by fiber-reinforced foamed urethane (called further FFU) to track lateral displacements. For this purpose it was necessary first to go through the regulations and literature regarding the design, manufacture, introduction and maintenance of railway sleeper of composite materials FFU .

Secondly it was necessary to develop a prototype Y composite sleeper based on the technical characteristics of normal sleepers made of FFU, which satisfies the strength, durability, environmental and economic aspects.

Research and development has now been focused on fiber composites to gain similar usability as hardwood timber. However, several challenges need to be overcome for a fiber composite Y sleeper to become a suitable alternative to railways.

[1] Civil Engineering Faculty, *Transilvania* University of Braşov.
[2] S.C. TUNELE BRAŞOV S.R.L.

2. Railway Sleepers Now and Future

The first railway sleepers were made of wood because of the advantages they have.

As advantages include adaptability, low cost manufacturing and workability. Wooden sleepers are used widely today even with the disadvantages that have such as high sensitivity for biological attacks. The most common failure modes of a wood rail sleeper are rotting and cracks. Nowadays the focus is on the environmental impact that it has on the use of timber railway sleeper and chemical treatment that they receive to increase their life circle.

Resistance to lateral movement of railways wood sleeper is due to the interaction by friction and interlocking between sleeper and ballast.

Concrete sleepers provide good resistance to lateral loads and track geometric stability better than wooden sleepers due to their supplementary weight.

They are suitable for continuous welded rail (CWR) [1].

Railway sleepers by steel gives have very good mechanical characteristics but they come with many disadvantages such as no electrical insulation, poor corrosion resistance and high construction cost.

Concrete and steel sleepers will have a limited expansion due to intensive energy consumption manufacturing processes.

Currently there are in research a lot of new materials and experimental sections with new types of railway sleepers. There are a variety of composite materials for railway sleepers, such as:

• matrix fiberglass reinforced HDPE
• reinforced rubber-modified HDPE
• fiber reinforced polymer matrix
• hybrid: steel, concrete and plastic composite materials
• urethane foam matrix reinforced with glass fiber FFU (fiber reinforced foamed urethane) etc.

These sleepers will be used in the future on the wide scale after optimizations and passing of in situ/laboratory tests.

3. Fiber-Reinforced Foamed Urethane Sleeper (FFU) Adaptability

Railway ties of synthetic materials are only one of many applications of FFU [2].

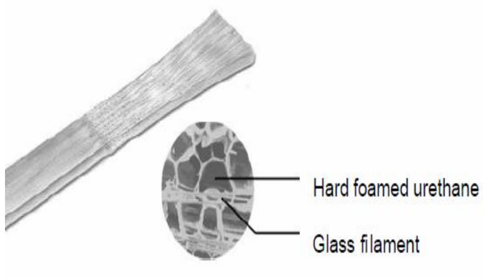


Fig. 1. *FFU composition*

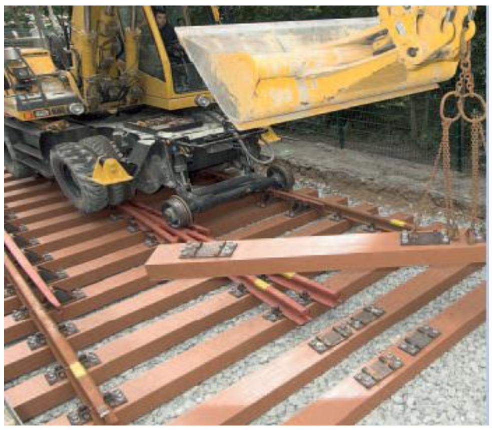


Fig. 2. *FFU rail sleeper on a rail switch [4]*

In Table 1 it can observe that the FFU composite sleepers respond very well to the subject requirements. [3] FFU sleepers cost is still high because the manufacturing process is a relatively new and evolving.

Over 1,000 kilometers of railway lines, using FFU sleepers, were made to the same dimensions as the wooden beams are tested successfully for 25 years in main lines, bridges, tunnels and switching and crossing, almost all of them in Japan.[4]

Comparation between railway sleepers types Table 1

Properties	Hard wood	Soft wood	Concrete	Steel	FFU
Adaptability	easy	difficult	difficult	difficult	easy
Workability	easy	easy	difficult	difficult	easy
Handling and installation	easy	easy	difficult	difficult	easy
Durability	small	small	high	small	high
Maintenance	high	high	small	high	small
Replacement	easy	easy	difficult	difficult	easy
Availability	small	high	high	very big	medium
Cost	medium	small	high	high	high
Fastening	good	bad	very good	bad	good
Sleeper – ballast interaction	very good	good	very good	bad	very good
Electrical conductivity	small	small	medium	high	small
Impact	very good	very good	small	medium	small
Weight, kg	60-70	60-70	285	70-80	80
Life span years	20-30	20	60	50	50

4. The Y FFU Sleeper Design Concept

Given that this type of railway sleeper is a prototype and a breakthrough using this material, it is proposed an idealist manufacturing process taking into account that at the end we obtain an Y sleeper component that satisfy actual standards, as is shown in Figure 3.

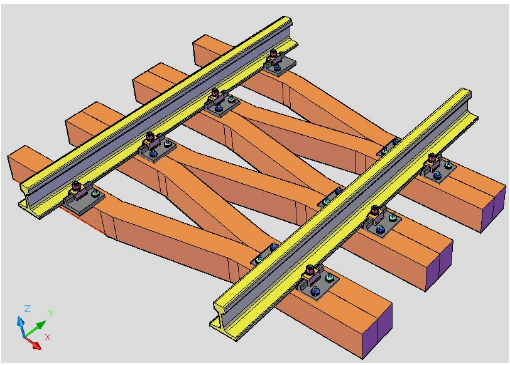


Fig. 3. *Railway track panel with Y FFU sleepers*

Taking into account the mechanical properties of classical FFU sleepers, the Y FFU sleepers can be produced in similar production lines to those that have been developed and improved over the past 20 years.

The Y FFU sleeper design was based primarily on the major advantage of this material namely the possibility of modelling their shape to the requirement [5] [6].

Depending on the manufacturing process it can use two methods to produce Y sleepers. In Figure 4, red lines represent cutting lines to obtain Y elements. In Figure 4 is represented the continuous mode to produce a Y sleeper element:

a) two Y pieces
b) one Y piece.

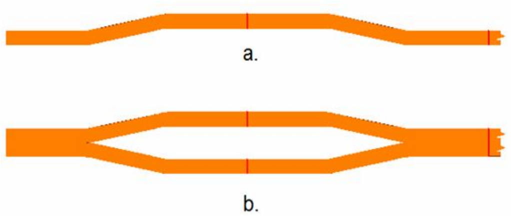


Fig. 4. *Y FFU sleeper producing modes*

Using this model it can see that the only dimension that it changed, to the classical FFU sleeper, is the width (Figure 5).

Almost the same material volume is used to improve the railway track.

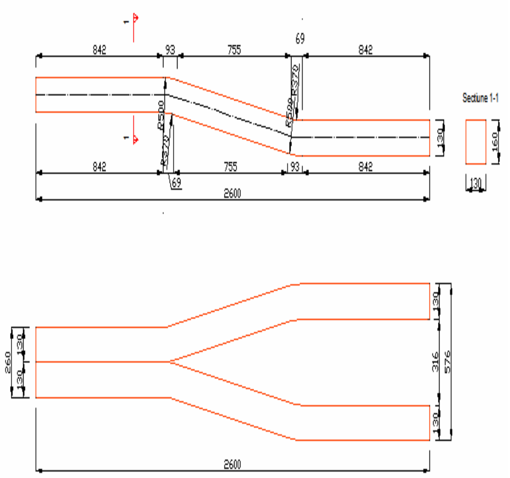


Fig. 5. *Y FFU sleeper geometrical characteristics*

Rail is fastened on ties using a modified 60 type fastening baseplate and K or Vossloh W12 fastenings (Figure 6).

The size of the baseplate has been so designed that the axis of sleeper screws corresponds to Y sleeper element axis. Thus the two beam elements are linked to form a rigid block through the base plate and four screws, as shown in Figure 6.

The rails and sleepers linked with rail fastenings are working as a truss. The diagonal truss beams are in this case the sleepers, gives way to lateral displacement increased stiffness (Figure 7).

The main parameters of panels are:

- Sizes of Y sleepers: 130x160x2600 mm;
- Sleepers weight: 40.23kg/piece
- Laying distance between Y sleepers axes: 576 mm
- Number of sleepers per kilometer of track 1736.

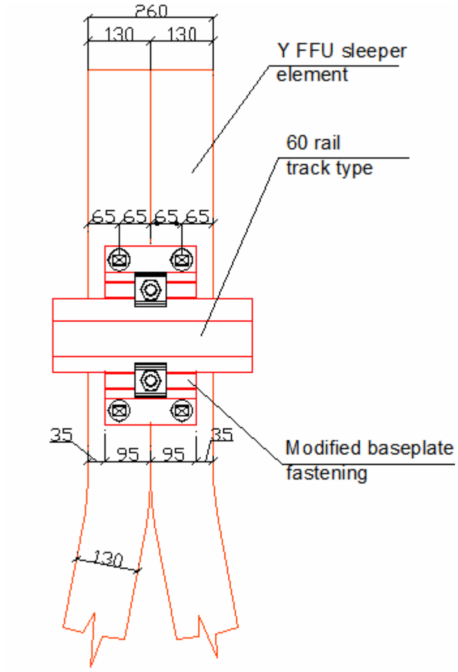


Fig. 6. *Rail fastening for Y FFU sleepers*

5. Behaviour of Y FFU sleepers in a railway panel to the lateral displacement

Lateral resistance is the reaction offered by the ballast against lateral displacement. It is a tie-ballast interaction parameter which is influenced by several factors such as ballast section, condition, consolidation, maintenance, tie type and condition, and train loads. As such, track lateral resistance becomes a fundamental but highly variable Parameter in track lateral stability assurance, and is the focus of this paper.

Lateral resistance in Y FFU sleepers case has four contributing components of bottom friction (F_b), side friction (F_s), end or shoulder restraint (Fe) and Y fork arms restraint (F_i), Figure 8. [3] [7] [8].

Calculation of lateral resistance was conducted in two hypotheses by analytical and numerical calculation using SAP 2000 finite element program, Figures 9-11.

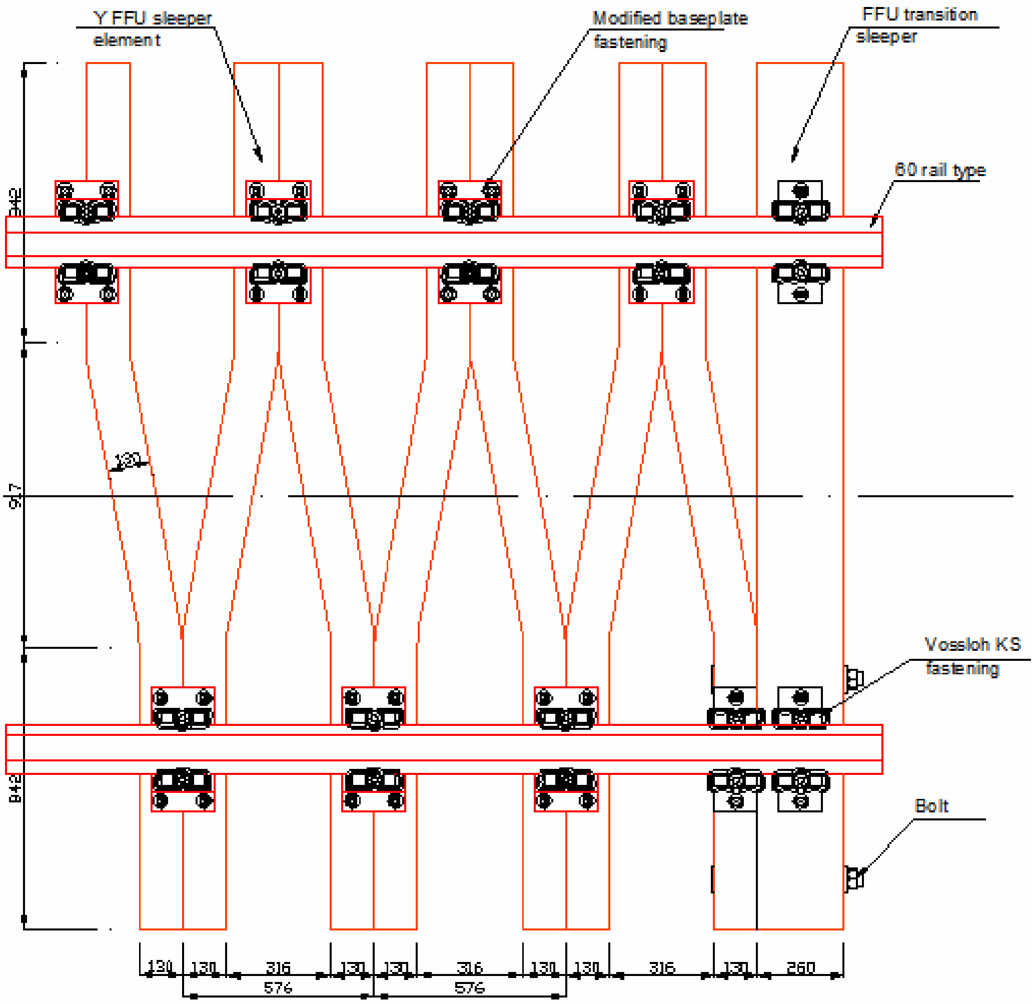


Fig. 7. *Y FFU sleepers -laying plan with Pandrol fastenings*

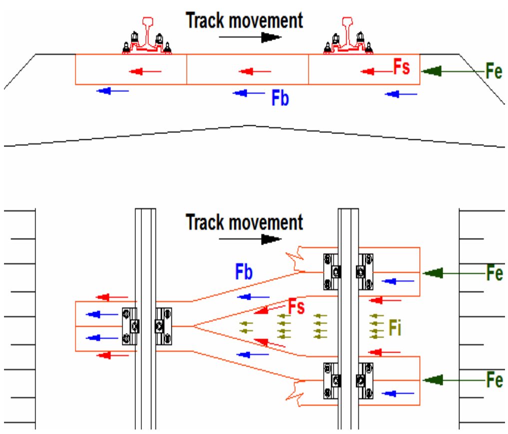


Fig. 8. *Lateral resistance contributing components for Y FFU sleepers*

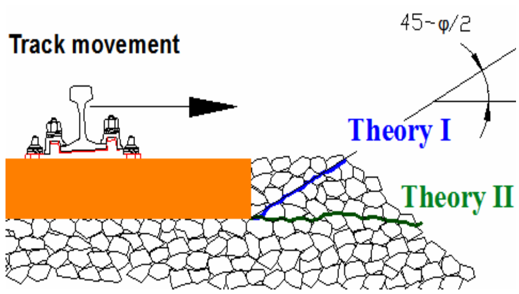


Fig . 9. *Ballast failure theory under lateral track movements [9]*

The coefficient of friction μ is very sensitive to the roughness of Y sleeper.

In service the ballast oppose to lateral displacement of railway sleepers by friction. This improves interactions between sleepers and ballast and result the track lateral resistance. [9], [12]

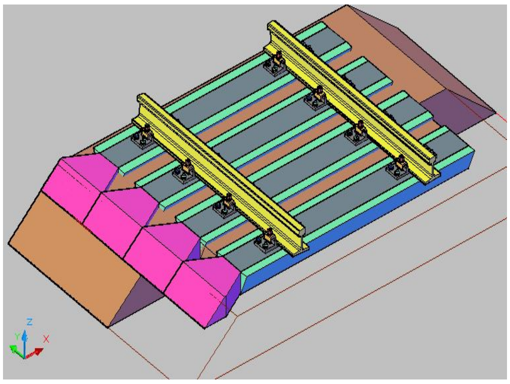


Fig . 10. *Ballast volumes involved into the lateral resistances composition Magenta (Fe) - shoulder restraint, Blue (Fs) side friction, classic FFU sleepers, analytical method - II-nd theory*

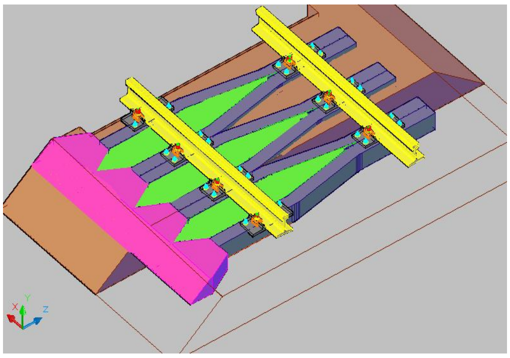
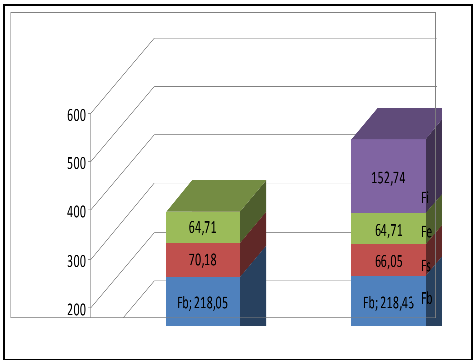


Fig . 11. *Ballast volumes involved into the lateral resistances composition, Magenta (F_e) - shoulder restraint, Green (F_i) Y fork arms restraint Y FFU sleepers analytical method - II-nd theory*

Track consolidation and compaction influence all of the three friction components with different degrees [3].

The stability of railroad is substantially improved due to the shape of Y FFU sleepers that mobilizes a significant amount of crushed stone between Y arms of sleepers.



Clasic FFU sleeper 352.92 [daN]	*Y FFU sleeper 501.92 [daN]*

Fig. 12. *Lateral resistance for classic FFU and Y sleepers in the second theory, for friction coefficient μ = 0.86*

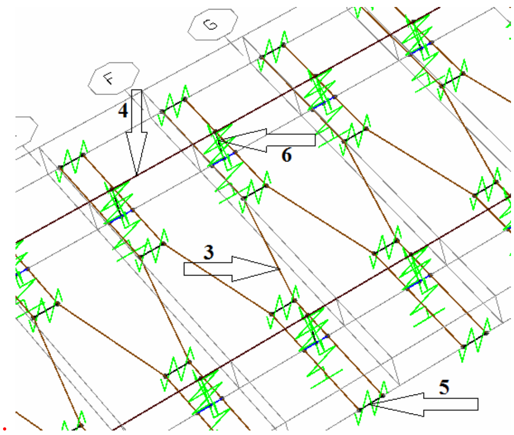


Fig. 13. *Y FFU sleepers panel in SAP 2000 numerical program*

The numerical analysis revealed for a force of 100kN the following results [11]:

- For classic FFU sleepers panel:
- maximum displacement 2.03 m
- maximum fastening rotation 0.16 rad

- For Y FFU sleeper panel (track with joints):
- maximum displacement 0,078 m
- maximum fastening rotation 0,006 rad

- For Y FFU sleeper panel (CWR):
- maximum displacement 0,088 m
- maximum fastening rotation 0,007 rad.

So the using of a Y FFU sleeper-rail system increases the stiffness of rails-sleepers frame about 25 times.

Thus traffic loads is distributed much better, resulting in less effort to the rails that leads to a much larger life of the rails and traffic safety.

6. Conclusions

This paper presented the investigation onto the effective use of Y FFU sleepers, unique by our knowledge.

After studying literature in the field of railway sleepers, composite FFU sleepers and analytical calculation of lateral resistance, Y FFU sleepers stands for innovation and clear benefits solution for future railways. The results are amazing:

Effect of Y FFU composite sleepers truss gives lateral displacement stiffness of 2.5 times than classical FFU sleepers.

Railway using Y FFU sleepers represents viable and effective solutions for bridges, tunnels, railway switching and crossing and main line today and, especially, in the future, as production costs will fall after mass production. This way the solution increased resistance to lateral displacement, which it recommends for use in high-speed lines, tram and metro lines unconventional and so on, without any danger of loss of track stability.

Future directions of research will address the following elements:

1) The accurate modelling of Y sleepers and study its behaviour using numerical models with discrete element;

2) Building a full scale prototype Y FFU sleeper;

3) Testing this prototype in the laboratory and in experimental rail sector and monitoring its behaviour;

4) Optimization of Y FFU sleeper shape;

5) Development Y FFU sleepers ribbed on the sides and bottom for better interaction sleeper - crushed stone;

6) The optimization of the manufacturing process of Y sleepers from FFU and others composite materials.

References

1. Manalo A., Aravinthan T., Karunasena W.: *Behaviour of Fiber Composite Sandwich Structures: A case study on railway sleeper application*, February 2011
2. Takai H., Sato Y., Sato K.: *Japanese twenty five years experience an standardization of synthetic sleeper*, Railway Technology Avalanche no. 13, July 31, 2006
3. Kish A., Samavedam G, Wormley D.: *Fundamental of Track lateral shift for high-speed rail applications*, presented at the European Rail Research Institute's Interactive Conference on "Cost Effectiveness and Safety Aspects of Railway Track" Paris, France, December 8-9, 1998
4. ***, *SEKISUI Chemical Co., Ltd. FFU Synthetic Sleeper I Railway Technology*;www.sekisui-railwaytechnology.com
5. Freudenstein S., *Report No. 2466 of 19th of September 2008,* Technical University Munchen, 2008
6. Freudenstein S., *Research Report No. 1687, dated June 30.,1997*, Technical University Munchen, 1997
7. Ungureanu, V.V.: *Cercetări privind simularea pierderii stabilității căii fără joante*, Teza doctorat, Facultatea de Construcții, Universitatea *Transilvania* din Brașov, 2007
8. Ungureanu, V.V.: *Modele de pierdere a stabilității căii fără joante*, Referatul nr.3 din cadrul stagiului de pregătire pentru doctorat, Universitatea

Transilvania din Braşov, Facultatea de Construcţii, Braşov, 2006

9. Kabo, E, Ekberg, A, Jacobsson, L.: *Railway track stability – a state of the art survey*. Research report no. 2004:2, Göteborg: Chalmers University of Technology, 2004
10. Nechita, M., Köllö, G.: *Căi ferate*, Universitatea Tehnica Cluj-Napoca, 1982.
11. Sbancă, I. D.: *Aspecte privind alcătuirea şi calculul unor elemente ale suprastructurii căii ferate*, Proiect de diplomă, Facultatea de Construcţii, Universitatea *Transilvania* din Braşov, 2013.