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SCREW SPIKE PULLOUT TEST OF RECYCLED PLASTIC

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ABSTRACT

Plastics or composites with plastic matrix are widely used in industry as well as in railway engineering. In this paper is introduced ordinary recycled plastic used in the fabrication of storage pallets. The main part of this paper includes the screw spike pullout test of recycled plastic and its verification, whether this material would be suitable for the production of the railway sleepers. The outcome is ultimate strength of material, at which the screw is pulled out. The test was also conducted on conventional oak wood for comparison of the recycled plastic. The last part describes the recommendation for the use of chosen recycled plastic in the production of railway sleepers.

Keywords: Consumer Waste, Railway Superstructure, Recycled Plastic, Screw Spike Pullout Test, Sleeper

I. INTRODUCTION

The article deals with railway sleepers, which are beside the slab track the most common type of railway support. The attention in the article is paid to a sleeper screw as a crucial part of fastening and also to the resistance of screw to pulling out from a sleeper. As is shown in Fig. 1, the sleeper screws fasten the rest of fastening on a sleeper.

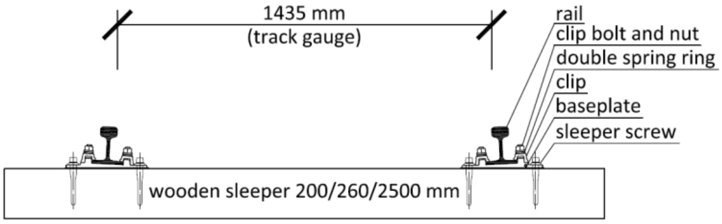


Figure 1: Basic Nomenclature of Railway Sleeper [1]

In the production of railway sleepers in the European Union the traditional materials are used e.g. as hard wood, concrete, steel and also the plastics as a new material for railway sleepers and bridge sleepers.

1.1 Why is the test important

In a railway track a screw is strained from vertical force caused by influence of passing railway vehicles. Vertical force is generated from following reasons:

- the weight of a railway vehicle causes the lift of rail around the wheel in a distance from third to sixth sleeper from the wheel (Fig. 2). This is the case, where the screws carry the tensile stress. The rail lifting is consequence of track bed elasticity.

- In case with wooden sleepers fitted with inclined base plates the outer screws are strained by tensile forces. It is caused by excessive forces occurred by rail inclination (1:40 or 1:20). A steel base plate is laid on a wooden surface is laid a steel base plate. It can press down the wood on inner side of railway string [2].

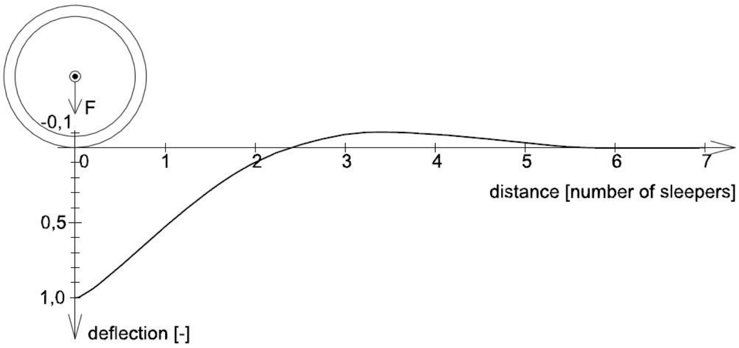


Figure 2: The deflection of a rail string in the adjacent area of the wheel load [2]

Insufficient screw spike pullout strength or failure of fastening would lead to safety hazard. It caused many railway accidents in the past. For example the bad condition of railway fastening brought the derailment of four carriages in Kladno in the Czech Republic in 2013 [3].

II. SCREW SPIKE PULLOUT TEST

In this test the railway screw is vertically extracted from the specimens. The outcome is ultimate strength of material, at which the screw is pulled out.

2.1 Methodology

In accordance to EN 13481-2 the test is usually performed on a specimen prepared as a whole railway sleeper; however it was not possible in this paper in accordance to the test equipment of a laboratory. For this research the specimens were cut as parts of plastic pallets and wooden sleeper so as to prevent unwanted deviations in results. The advantage is the easy handling with the specimens. There was expected, that a screw is mounted in the adequate distance from edges of the specimens [4].

2.2 Recycled Plastic Chosen for the Test

The source of recycled plastic chosen for this test is mainly obtained as consumer waste placed in the containers and as technological waste from industry production. The material contains mainly polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PE), polystyrene (PS) and other substances which contaminate the materials such as paper, textile or metals. This recycled plastic is based on PE (65%) [5]. Input plastic is formed in granules and is molded by the extrusion process with temperature about 220° C and the pressure about 100 MPa. The homogenized plastic melts down and is put in the steel forms. The shapes of the forms are presented as the finished products in Fig 3. [4]

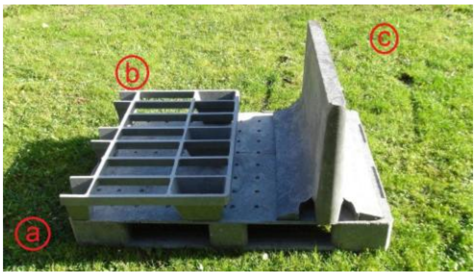


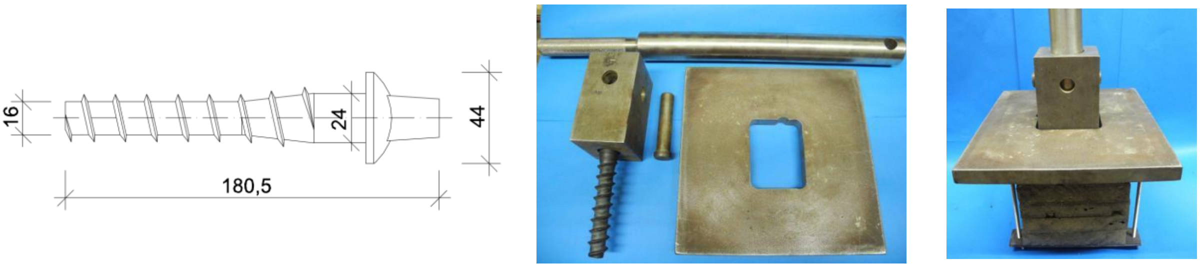
Figure 3: The basic products made from the chosen recycled plastic: (a) a storage pallet, (b) a lightweight storage pallet, (c) a barrier

2.3 Test Set Up

The test device was divided on following main parts:

- loading frame,
- set for mounting of screw (Fig. 4).

For loading was used the laboratory press EU 40 with maximum load of 200 kN attached with a string dilatometer for the measurement of displacement. The screw spike pullout test was performed with screw R1 (Fig. 4). Screw was mounted with the set of tools, which is shown in Fig. 4. The set is consisted from four steel parts: a load distribution plate, a block with hole for screw, a locking pin and bar, which is fastened into the loading frame. The important set up of the test is the length of screw shank screwed into the specimen. This factor could straight affect the ultimate strength of the material. It is worth mentioning that the typical length for real fastening in a railway track is about 122 mm. The set of tools in the test enabled the use of screw shank only with length of 115 mm.



a) screw R1 – most common screw used in fastening in the Czech Republic (in accordance to SŽDC terms) [1]

b) disassembled set for mounting screw

c) Assembled set for mounting screw

Figure 4: The set for mount of a screw in a specimen and in the loading frame

The screw spike pullout test was performed in the same way for recycled plastic as well as for oak wood with the following steps:

- insertion of screw R1 into the specimen,
- mount of tools set on the specimen,
- placement of specimen into the loading frame,
- load of the specimen until the full extraction of screw from the specimen.

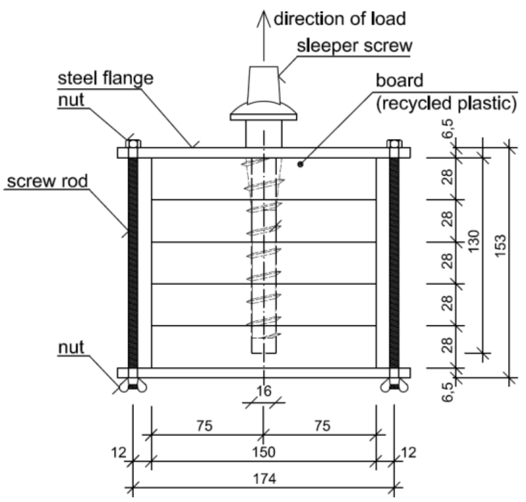
The load rate was performed manually in two following load steps:

- 0.05 kN·s^{-1} (load under 10 kN),
- 0.6 kN·s^{-1} (load above 10 kN).

2.4 Specimens Variation

he specimens from recycled plastic were prepared in similar way as it is defined for concrete in EN 13481-2. The screw spike pullout test of other materials used in the production of sleepers such as concrete is performed directly on concrete sleepers or on specimens in accordance to technical standard EN 13481-2 which requires the distance of 100 mm between screw and edges of specimen [4].

The preparation of the recycled plastic specimens is described in the following text. It was complicated due to weaknesses in technology. In the process of recycling the plastic there is a need to fill the melt in the robust steel forms together with the simultaneous action of high pressure and temperature. The preparation of specimens was subjected to the amount of mass and availability of shapes. Since the company has got only forms for plastic pallets, the specimens had to be prepared from the pallets. And as there was the insufficient of plastic mass in the storage pallet, the samples were prepared from five stacked boards, which were cut directly from the storage pallets. As is shown in Fig. 4, the specimen consisted of five boards which were closed with steel flanges and screw rods. The screw-edge distance was about 75 mm. There was the assumption, that this construction made from boards is able to substitute the mass of material.



a) design of the specimen [6] **b) the specimen prepared for the test**

Figure 5: Specimen made of recycled plastic for the screw spike pullout test

The second set of specimens was sampled from new oak sleeper generally used in railway tracks. In accordance to SŽDC (infrastructure manager in the Czech Republic) the shape of wooden sleeper was E1. It was produced and impregnated with creosote oil in 2008. The dimensions of specimens were 350 x 260 x 150 mm, with a screw placed in the centre. In accordance to SŽDC regulations the screw was placed more than 150 mm from the edge because of longitudinal cracks, however the specimen ends were fitted with gang-nail plates to strengthen the ends of specimen due to cracking.

For both tested materials total of three specimens were prepared. In relation to R1 screw (Fig. 4) and to the technical regulations of SŽDC the hole in the specimens was drilled with a diameter of 15 mm.

III. RESULTS EVALUATION

In this section the mean values of screw spike pullout test of chosen recycled plastic and oak wood are evaluated. The results of screw spike pullout test of other recycled plastics used in production of railway sleepers abroad are cited. It is necessary to mention, that results in Table 1 were not achieved with the same technical regulations i.e. conditions of the tests probably were not the same.

Table 1: The results of the screw spike pullout test of recycled plastic and oak wood. Comparison with recycled plastics used in the production of railway sleepers abroad [7, 8, 9, 10]

property	recycled plastic	oak wood	Axion	Lankhorst	TieTek	Integrico
pullout strength [kN]	58,4	57,0	31,6	35,1	36,3	74,8
technical standard	EN 13481	EN 13481	ASTM D6117	EN 13230	not published	not published
assessment	ok	ok	already developed and applied			

In the Fig. 6 load-displacement curves of oak wood and recycled plastic for each specimen are presented.

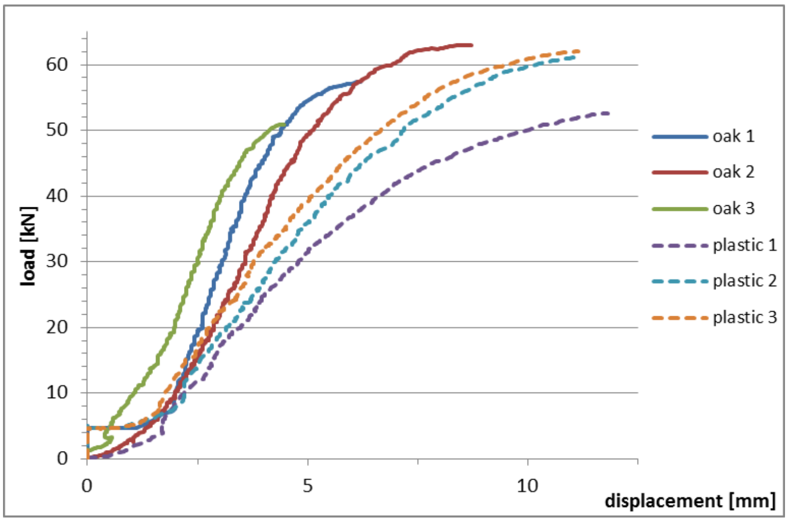


Figure 6: The load-displacement curves of screw spike pullout test of oak wood and recycled plastic specimens

The curves in Fig. 6 are clearly divided into two groups in accordance to the material. The continuous curves in Fig. 6 show the test of oak wood, dashed curves show recycled plastic. Wood exhibited less displacement for the same load than it shows the recycled plastic. The difference was about twice more.

IV. DISCUSSION

The measurements of the material resistance to pullout force show several interesting facts about the screw spike pullout test and about the preparation of the specimens.

Table 1 presents mean achieved values for the specimen made of recycled plastic boards. The values of pullout strength show that the assumption made for preparing the plastic samples from boards were chosen well. Fig. 7 shows the failure of plastic specimens and the effect of layers. All three plastic specimens cracked in the top three layers; two others were not destructed. In case that the screw was in compact mass of recycled plastic, the resistance to the extraction of screw would be even higher than the achieved value in this test. To other hand the greater mass in the production of plastic occur the greater proportion of cavities are in the porous core.

In Fig. 7 below the oak wood specimens are shown. There were no significant longitudinal cracks in the direction of the wooden fibers in the area of cracked hole. This means that the gang-nail plates at the ends of the test specimens do not affect the result of pullout strength. Their functions might occur during long-term tests in many years.

Figure 7: The specimens made of recycled plastic and of oak wood after conducting the screw spike pullout test

V. CONCLUSIONS

The initial test results show that the chosen recycled plastic used in the production of storage pallets might be suitable for the production of railway sleepers. The material has satisfactory ultimate screw spike pullout strength. It was proved in terms of ultimate force acted on a screw inserted in the recycled plastic samples. However the behavior of material requires special attention, because loaded screws exhibited considerable deformation of chosen recycled plastic. Together with high frequency of loading cycles under railway vehicles the excessive deformation could cause fatigue effect of recycled plastic. On the base of this fact, the additional test of plastics is recommended.

VI. ACKNOWLEDGEMENT

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