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Road and Rail Infrastructure III

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PLASTIC SLEEPER ANCHORS IN CZECH REPUBLIC

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Abstract

Sleeper anchors are used to increase lateral resistance of sleepers in continuous welded rail. Steel sleeper anchors are commonly used in the Czech Republic at present time. Chládek & Tintěra Pradubice company came up with the idea to use recycled plastic for the sleeper anchors production. The advantage of recycled plastic is less environmental impact and corrosion resistance. On the other hand problems with resistant to load were anticipated. This paper presents laboratory test of material of plastic anchors EVA V production. These tests were done during the developing of the plastic anchor shape. Similarly, in-situ tests were done on the trial test section to compare sleeper with plastic and steel anchors lateral resistance and sleepers without anchors lateral resistance are presented. For the supply of plastic sleeper anchors were parallel with the laboratory and in-situ tests compiled the technical specifications for control tests and where are listed all controllable conditions. These tests are described in this paper as well

Keywords: sleeper anchors, continuous welded rail, tearing resistance, lateral resistance

1 Introduction

Sleeper anchors are used to increase lateral resistance of sleepers in continuous welded rail. Steel sleeper anchors are commonly used in the Czech Republic at present time. Because plastic anchors are new product used in railway tracks and can affect the safety of operation to do many tests was necessary. Plastic anchors were primarily tested in the laboratory. In the laboratory was developed shape of sleeper anchors that was not problem with its production and ensure resistance to cyclic loading. After laboratory test plastic anchors were put into trial track section in the regional railway track with small radius curve. Plastic anchors in trial track section are monitored for a long time and also were made comparative tests of sleeper lateral resistance. For the supply of plastic sleeper anchors is necessary make technical specifications where all controllable conditions are listed.

2 Laboratory tests of plastic sleeper anchors and material properties

The Laboratory tests, aimed in evaluation of material properties and mechanical behaviour, were carried out in three stages. The EVA III design of plastic sleeper anchors was modified into the EVA V design after the first stage of laboratory tests. The design modifications include a new design of embedded steel parts without sharp corners and a new position of the casting point into the centre part of the sleeper anchor. Both modifications have improved anchor resistance against cycling loading as initial crack points were removed.
First of all the material from which plastic sleeper anchors are made was tested. The structure of the plastic sleeper anchor consists of the outer massive shell roughly 10 mm thick and the

inner relatively porous material as a consequence of the manufacture process. The samples for material tests were cut from the inner massive shell part of anchors. The objective of material tests was to measure basic mechanical properties – density, bending modulus and Charpy impact properties. Sensitivity to extreme temperatures – both low and high – was also inspected. Regarding the storage of sleeper anchors the flame resistance test was also carried out. The tests of material properties were performed in the Institute for testing and certification, a.s. Material properties were evaluated by following tests:

- material density by EN ISO 1183-1;
- bending behaviour by EN ISO 178;
- Charpy impact properties by EN ISO 179-1/1eA;
- Vicat softenenig temperature by EN ISO 306;
- determination of resistance to low temperatures – Charpy impact properties by EN ISO 179-1/1eA at temperature -10 °C;
- ignitability of products subjected to direct impingement of flame by EN ISO 11925-2.

Test results are summed in the Table 1. All tests of mechanical behaviour of plastic sleeper anchors were performed in Institute of applied mechanics Brno, Ltd., see [2, 3, 4]. The static load test was the basic test by which the mechanical behaviour was evaluated. This test simulates extreme load acting on sleeper anchors in track. An ultimate force that an anchor can resist is the result of this test. The tests were always performed to anchor destruction.

Table 1 Results of laboratory tests – material properties

Measured quantity	Value	Uncertainty
Density [g/cm^3]	1,02	0,01
Bending strength [MPa]	16,5	3,5
Bending modulus [MPa]	845	37
Vicat softenenig temperature [°C]	52,2	0,1
Charpy impact properties [kJ/m^2]	3,29	0,18
Charpy impact properties -10 °C [kJ/m^2]	2,32	0,09

The static load tests were carried out in the special loading frame. A sleeper anchor was attached to the steel element modelling the sleeper cross section. The force was applied by speed 2 kN/s, maximum speed of deflection was 5 mm/s. The force-deflection diagram was being recorded during the test and the anchor screw connection was visually inspected. Required force, which an anchor shall resist, is 12 kN with respect to the fact that minimum increase of the lateral sleeper resistance with anchor is 10 kN.

Tested samples were different during the stages of laboratory testing of plastic sleeper anchors. The first stage of testing (EVA III type of anchors) was performed only with new anchors that had just been manufactured. The last stage of testing was performed for new anchors, for anchors removed from test track section after 7 month of performance and for anchors which were put for 7 month into a climate box in temperature -18 °C. Termovision images were taken for deeply frozen anchors before and after tests. The results of static tests (average value) in last stage were:

- 21,4 kN for new anchors;
- 24,2 kN for anchors removed from the track;
- 22,4 kN for frozen anchors.

Figure 1 Assembly of static load test of sleeper anchor [2]

All results of the ultimate static force are significantly higher than required value 12 kN. Next important tests of plastic sleeper anchors were tests of resistance to cyclic loading, both regarding mechanical resistance and regarding abrasion. The parameters of the test of mechanical resistance were determined in aim to express the real loading of anchors in track. The particular test parameters were determined in accordance to administrator requirements:

- sin wave time course of applied force, min force in the cycle $F_{ZA, min}$ = 4 kN, max force in the cycle $F_{ZA, max}$ = 10 kN, the mean value $F_{ZA, mean}$ = 7 kN;
- number of cycles $N_{ZA} = 2 \cdot 10^6$.

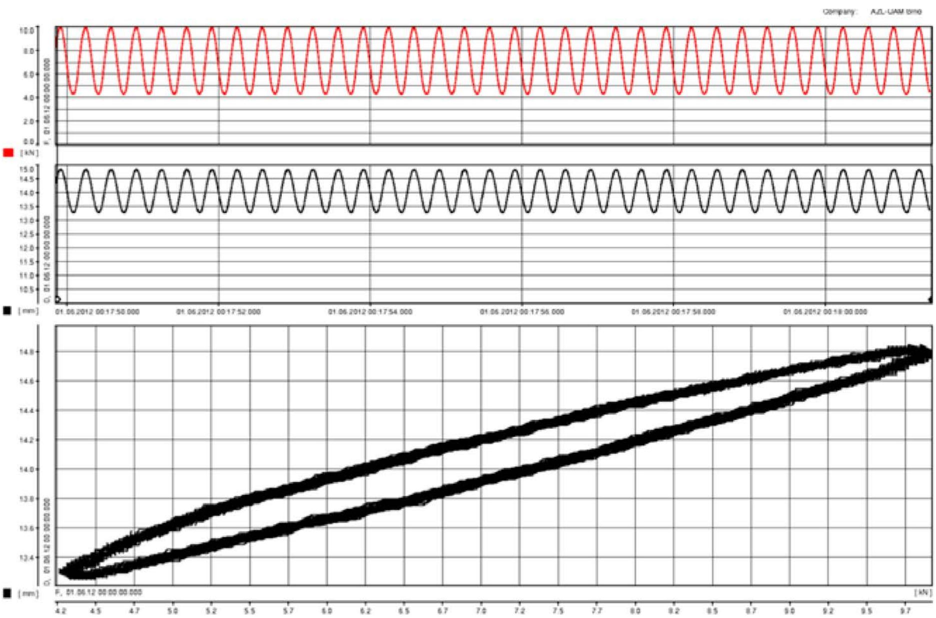

Figure 2 Test of cycling load resistence [3] (red color – force in kN, black color – deflection in mm)

Durability of plastic material (any cracks) and behaviour of the screw connection, especially tightness and squeezing the plastic anchor, were being inspected during the test.

The test to abrasion of plastic sleeper anchor was performed in the ballast box. The plastic anchor was loaded in vertical direction. The vertical displacement in loading cycles was determined in value 1 mm, which roughly corresponds with sleeper deflection under axle load. The ballast layer was checked every 12 hour to ensure full contact of the anchor and the ballast. The test parameters were:

· amplitude of vertical displacement s_{ZA} = 1 mm;
· number of cycles $N_{ZA} = 2 \cdot 10^6$.

Figure 3 Test of tearing resistance in ballast

The weight of anchor before and after the test was compared. The weight before test was 4,3120 kg, the weight after the test was 4,3118 kg so the weight loss was very small. A visual inspection of the anchor surface was carried out as well. The anchor surface was intact with only minor scratches caused by aggregates after the test. Plastic sleeper anchors resistance to abrasion in ballast was stated.

Figure 4 Plastic sleeper anchor after abrasion resistance test

Based on laboratory test results the use of plastic sleeper anchors EVA V in test track sections was approved. The test results were used for the declaration of material properties and mechanical parameters in the technical regulations of Railway Infrastructure Administration.

3 Technical specifications of EVA V plastic anchors

3.1 Material for EVA V sleeper anchor production

The EVA V type of sleeper anchor consists of a steel upper plate and an anchor segment. The anchor segment is made of material with a trademark of TRAPLAST which is manufactured by recycling of plastic waste. The surface layer of the anchor segment is comprised of not less than7mm thick compact material which creates a bearing shell. The sleeper anchors are used by mounting the upper plate and the anchor segment on sleeper then fixed by the use of two bolts and two self-locking nuts. Therefore there is a steel sheet in a flange of the anchor segment. It ensures a required contact with the fasteners. The material of the sleeper anchor is environment friendly, resistant to mechanical, climatic, chemical and biological effects and heat resistance.

3.2 Technical specifications

Supplier's technical specifications are obligatory technical specifications for delivery of the plastic sleeper anchors which are binding for the Czech railways. These specifications concern workshop production, testing, quality verification, acceptance, supply and use. The scope and frequency of the tests are prescribed by the technical specifications. Sleeper anchors EVA V properties and material quality for this product are proved by initial type testing repeated type testing and control product testing. The initial type testing is a test which is carried out before a new product is launched. It has been proved that the anchors meet the design requirements and parameters. The initial type tests of EVA V or its materials are:

- material properties for the anchor segment – bulk density, modulus of elasticity in bending, bending strength, heat resistance which is defined by softening temperature after Vicata, impact value after Charpy, fire-technical properties;
- lateral resistance of a sleeper with anchor (see chapter 4.1);
- ability of sleeper anchor to resist the loading required– static load test (see chapter 3.3);
- sleeper anchor ability to resist epeated loading – fatigue test, abrasion test (see chapter 3.5).

Repeated type testing is carried out if some changes, which could influence the properties of a sleeper anchor (for example in structure, material or shape), come to pass during large-scale production. The scope of the repeated type testing is determined by the user on the basis of changes proposed by the supplier. Control product tests are defined to verify continuously the quality of the product. These tests are ensured by the producer in scope and frequency according to the product management system or according to the inspection and test plans. Control product tests cover:

- dimensions of sleeper anchor;
- weight of sleeper anchor;
- bulk density;
- impact value after Charpy;
- static load test.

Expected lifetime of the sleeper anchor EVA V is 40 years. An intensified corrosion of steel parts might be expected in case of aggressive environment effect – the lifetime of the sleeper anchor might be decreased. The fasteners and the steel upper plate are possible to be coated with anti-corrosive paint.
Sleeper anchors EVA V don't require any maintenance. Regular control of fasteners is recommended especially in case of aggressive environment.

3.3 Static load test

Maximum force on limit loading capacity of the anchors is monitored during a static load test. Deformations of a trial sample depending on an acting force are monitored. The static load test is carried out in a loading frame on a model of sleeper anchor. A sleeper is replaced with a steel model. The shape of the model corresponds with the lateral cross section of the sleeper in the place of anchor. Bearing area of the sleeper's model has a shape of a rectangle. The length of the bearing area corresponds with the width of an underneath surface of the sleeper. The width of the bearing area is 200 mm. Roughness of the bearing area which is in contact with the plastic anchor segment corresponds with roughness of the underneath surface of the sleeper. The biggest unevenness mustn't be higher than 1 mm. The upper steel part surrounds the sleeper's model and the anchor segment fits to the bearing area. For arrangement of the test see Figure 5. The test is carried out on three trial samples which are loaded until destruction. A loading rate is 2 kN/s.

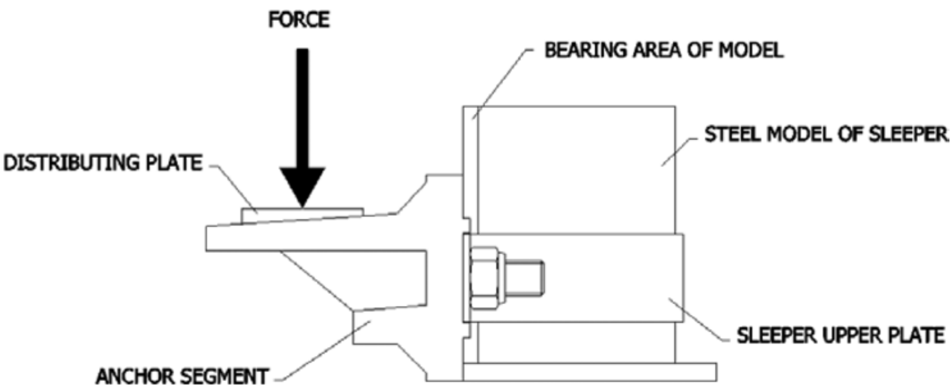

Figure 5 Static load test arrangement

3.4 Long-term fatigue test

Fatigue test examines the ability of the anchors to resist repeated loading. The fatigue test is carried out in a loading frame on the same model as the static load test (see Figure 5). One trial sample is loaded by a cyclic loading from 4 kN to 10 kN. The loading is introduced with a frequency range from 2 to 5 Hz. Number of load cycles is $2{\cdot}10^6$. Holding power of screw joints, lifetime of the plastic part and a squeezing of plastic are controlled visually during the fatigue test.

3.5 Abrasion test

An abrasion test monitors the ability of plastic material of the anchor segment to be resistant to cyclic loading. The abrasion test is carried out on a model of a sleeper with a sleeper anchor in a ballast box. Crushed rock of fraction 31,5/63 is placed on a solid base – concrete or steel plate. Sleeper is substituted for a steel model. The bearing area of the steel model represents an underneath surface of the sleeper. It has a shape of a rectangle. Its longer side corresponds to a width of the underneath surface of the sleeper. Its shorter side has a length of 200 mm. Roughness of the bearing area which is in contact with the plastic anchor segment corresponds to roughness of the underneath surface of the sleeper. The biggest unevenness has to be less than 1 mm. For the test arrangements see Figure 3.

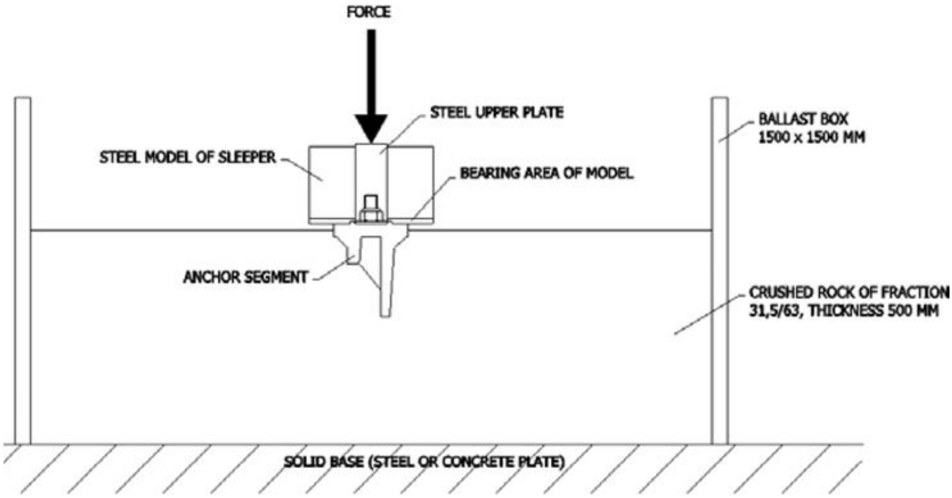

Figure 6 Abrasion test arrangement

The test is carried out on one trial sample. The Intensity of force is chosen according to the vertical movement of the sleeper anchor – maximum amplitude ±1 mm. The introduced loading has sinus course with frequency range from 2 to 5 Hz. Number of load cycles is $2 \cdot 10^6$. Weight loss of the anchor segment is controlled and is determined from the weight before and after the abrasion test. Surface of the sleeper anchor is controlled visually after the test.

4 Tests in trial test section

The trial test section was set up in regional track Svitavy – Polička in the Czech Republic. It is circle with radius 200 meters, cant 75 milimeters and 32 meters long transition curves. Superstructure consists of continuous welded rails S 49 on concrete sleepers with ribbed baseplates. The ballast bed is gravel fractions of 31.5 / 63. Ballast bed was changed only in the upper layer, from the underneath surface to the top sleeper, during the track reconstruction. Ballast bed under sleepers is very dirty. The shape of the ballast bed is prescribed with enlargement (1.75 m) and overcutting (0.1 m) on the outer side of the curve. There is sleeper anchor on every sleeper in circle. There are plastic sleeper anchors in first half of circle and steel sleeper anchors in the second half of circle.

4.1 Lateral resistance test

Measurement preparation starts by removing ballast behind sleepers head (rear in the direction of extrusion) in order to put the extrusion head. Next, remove the sleeper screw in the baseplates of both rails. Both rails are lifted, but just to be pulled away the pads from sleepers. For the lifting of rails is necessary to loosen the sleeper screw and the neighboring sleepers as well. Extruder head is put on the end of sleeper and the device is aligned by supporting rod. Prepared extruder device is shown in Fig. 7.
Displacements are measured against 1.5 meters long fixed frame above tested sleeper. The force is set into the system by hand operated hydraulic cylinders with pressure gauge. Measurement is performed by shifting sleeper in 1 millimeter increments, and each shift values are assigned values read from the pressure gauge. Dependence shifting on the load power is gotten. After steady resistance sleeper, which are reflected by shifting sleeper without the increase the strength force decrease to zero.

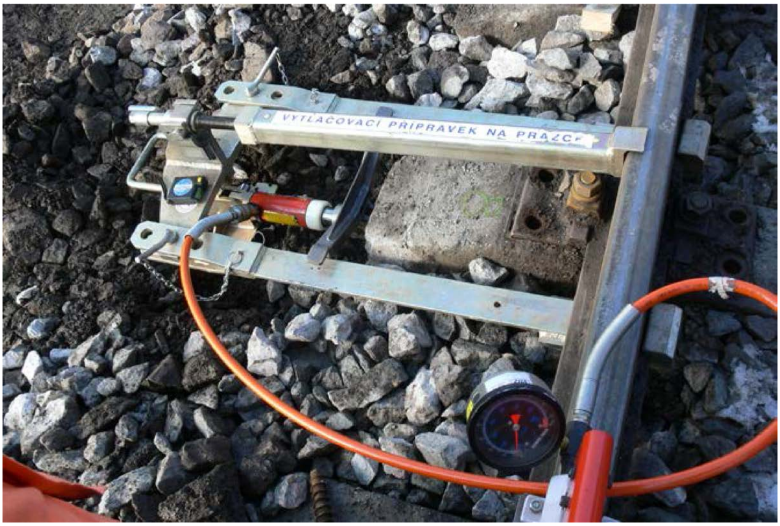

Figure 7 Extruder device

During the test the lifting sleepers is undesirable. The test arrangement with disassembled sleeper screw and by minimum lifting the rails with baseplates, lifting sleeper is impossible. After the test is necessary to sleeper move back to the starting position – after unloading remain displaced. It is not possible to repeat the test on the same fret.

4.2 Test in the trial test section

In-situ test were done in two stages – during reconstruction one day after continuous welded rail installation and after 8 month operation. In both stages were tested 10 sleepers – 5 with plastic sleeper anchors EVA V, 3 with steel sleeper anchors and 2 without any sleeper anchors for comparison. Sleepers without anchors are in transition curve because all sleepers in circle are with sleeper anchors.
Between the tested sleepers were always 3 sleepers. Rails were always released only at the measuring sleeper and the immediately adjacent sleepers, which was particularly advantageous due to temperatures. Immediately after the test rails were clamped and then the work began to prepare for further examination. Rails have never been released on more than 3 sleepers and could thus lead to changes in the clamping rail temperature.

4.3 Test routine

After installation extrusion system to tested sleeper was initiated by raising the pressure and ejecting sleepers. Shift sleeper was measured by two displacement sensors. The measured values of both sensors were averaged. The pressure was increased to a steady value. In the case where stabilization occurred the test was finished after 15 mm displacement.
Figure 8 was created by averaging the measured values for sleepers with plastic, steel and without any anchors in both testing stages. There are sleeper resistances similar in both stages of the measurement for both sleepers with EVA V plastic anchors and sleepers with steel anchors. To change the inclination of the curve occurs at a displacement of about 1 mm and a transverse resistance of 7-8 kN, respectively 9-10 kN. In the case of steel anchors there is a change of inclination at a slightly lower resistance value, but the increase in lateral resistance is more significant.

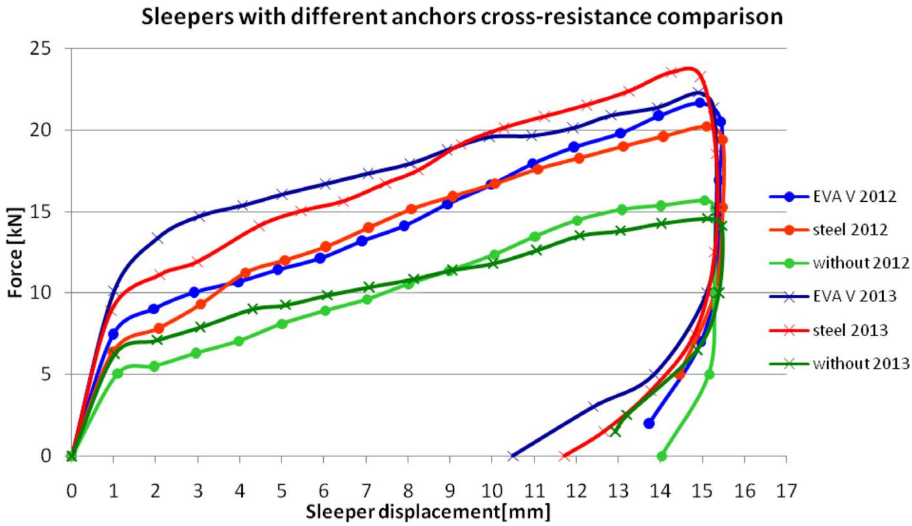

Figure 8 Lateral resistance comparison

5 Conclusions

Plastic sleeper anchors have been developing in several steps with both laboratory and in-situ tests. The latest version plastic sleeper anchors EVA V is in trial operation in regional railway track Svitavy – Polička in the Czech Republic. On the basis of laboratory test and positive experience with trial test section seems using plastic sleeper anchors EVA V as good alternative steel sleeper anchors. Another advantage of the plastic anchor is the use of more environmentally friendly recycled plastic.

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