The Laboratory Tests of the Embedded Block System with High Vertical Elasticity

ANTOLIK Łukasz[1,a,*] and SIWIEC Jakub[1,b]

[1]Instytut Kolejnictwa (The Railway Research Institute), Materials & Structure Laboratory, 50, Chłopicki Street, 04-275 Warsaw, Poland

[a] lantolik@ikolej.pl, [b] jsiwiec@ikolej.pl

Keywords: Fastening System, Embedded Block System, Slab Track

Abstract. The resilient system that fastens rail to the ground is a very responsible element of the railroad track construction. This article discusses the function characteristics of an embedded block system (EBS) with high vertical flexibility, a range of the product application, methods of mechanical tests carried out in the laboratory and criteria of the tests result approval.

Introduction

Since the early beginning of the railroad transport system, there has been a parallel problem of the fixing rail to the ground technique. The world markets are mostly dominated by solutions such as types W, Fastclip, Nabla, SB, RN etc. [1]. Some areas use domestic solutions prepared for the specific exploitation conditions e.g. tram railway [10]. The multitude of design solutions and their impact on the production cost, easiness of maintenance, failure rate, atmospheric susceptibility and truck loading are so large that every market can use ready-made solutions.

Each type of the system that fastens rail to the ground is characterised by a number of advantages and disadvantages. Unfortunately, the weakness of these solutions is that they are based on placing rail pads between the rail and support. It is undoubtedly the responsible and weakest part in any fastening system, and additionally it takes only 1% of the height of the railroad construction chain. The classical fastening systems may not be used in urban areas or engineering objects, where relatively high parameters relating to the vibration absorbing properties of the track and substructures are required. In order to increase the level of vibration dumping, course lined with anti-vibration mats, rails embedded in the anti-vibration coat or embedded block system (EBS) are used. All the above-mentioned solutions fix rail by adhesion or mechanical technique and do not use any ballast.

Methods of the rail vertical elasticity in relation to the rigid bed using an EBS placed in an elastic layer made of polyurethane resin are discussed in the further part of the article.

This solution is characterised by a relatively high vertical flexibility and a high degree of vibration dumping, while maintaining a high operating resistance.

Execution of tests

For approval purposes, some reference shall be made to the common European requirements, which the fastening systems are subjected to. This unification of functional parameters aims at designing solutions that are interchangeable in all countries belonging to the European Economic Area (EEA). The essential requirements are set out in Regulation 1299/2014 of Technical Specification for Interoperability for the Infrastructure subsystem [2]. This refers to the requirements of EN 13481-5+A1:2017 [3] regarding the fastening systems used in the slab track. Testing a new solution in the laboratory conditions is therefore associated with compliance with strictly defined requirements. Not only is the quality of the performed tests important but also their sequence due to their possible influence on the results of the tests. The embedded block system described in this article has been subjected to mechanical tests for category C, at loads corresponding to the maximum load of a single axle of the 260 kN and the minimum radius of curve r=150 m. Table 1 shows loads used in the fatigue tests of the fastening systems to the slab track depending on the track category.

Table 1. Test loads and positions [source: EN 13481-5+A1:2017]

k_{LFA}[c]	< 50 MN/m			≥ 50 < 75 MN/m			≥ 75 < 100 MN/m			≥ 100 MN/m		
Category	α °	X[d] mm	$P_v/\cos\alpha$ kN[a,b]	α °	X[d] mm	$P_v/\cos\alpha$ kN[a,b]	α °	X[d] mm	$P_v/\cos\alpha$ kN[a,b]	α °	X[d] mm	$P_v/\cos\alpha$ kN[a,b]
A	45	100	50	45	100	55	38.6	50	65	38.6	50	80
B	38.6	100	55	38.6	100	60	38.6	50	70	38.6	50	85
C	33	25	60	33	25	65	33	25	75	33	25	95
D	26	15	60	26	15	65	26	15	75	26	15	95

[a] The test loads apply only to rail sections included in EN 13674-1 (excluding 49E4) and EN 13674-4+A1
[b] The test loads take into account the possible use of slab track with higher cant deficiencies than ballasted track
[c] k_{LFA} = Low frequency dynamic stiffness measured at 5 Hz according to EN 13146-9+A1 and Table 2 above
[d] For embedded rail and web supported rail, the rail section shall be unmodified (i.e. X = 0)

The tested embedded block system was first checked for main static parameters according to the specified order, i.e. the tighten force was first applied to the concrete block support according to EN 13146-7:2012 [4]. The aim of this test was to check clamping force of the rail by the fastening system. The test was performed by applying the vertical tensile force with the rising rate of 10 kN/min. until the rail pad was able to be removed and the rail foot retuned to its original position.

An example of the test diagram is presented in Fig. 1.

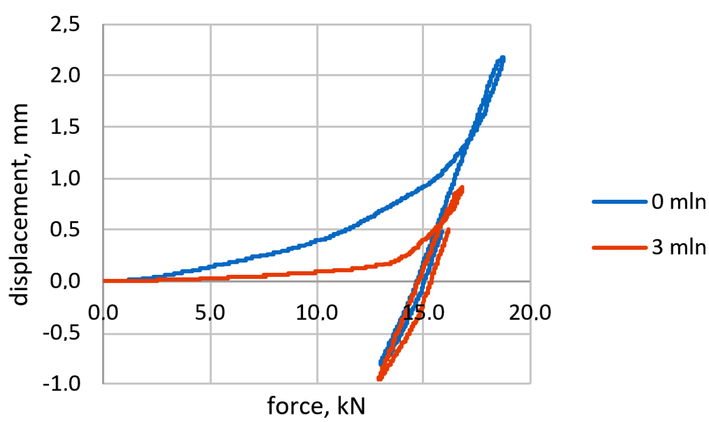

Fig. 1. Comparison of the clamping force before and after the fatigue test. [Author: J. Siwiec]

The subsequent test was to check a longitudinal resistance according to EN 13146-1+A1:2014 [5]. The aim of this test was to determine the characteristics of the longitudinal movement of the rail relative to the block support.

In order to do this, a horizontal load with a rising rate of 10 kN/min was applied to the rail until the rail slipped relative to the block support. The plastic and elastic displacement of the rail in relation to the concrete support was determined. The results of this test are particularly important from the point of view of the superstructure design, taking into account its susceptibility to temperature influences and resistance to longitudinal loads e.g. due to train emergency braking. An example of the test result is presented in Fig. 2.

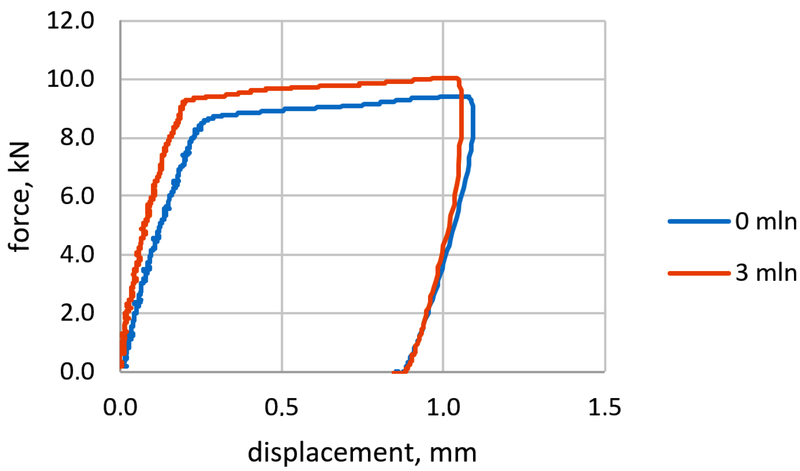

Fig. 2. Comparison of the longitudinal rail restraint before and after the fatigue test. [Author: J. Siwiec]

The last static test was to check the vertical stiffness, i.e. susceptibility of the concrete under static and dynamic loads in the vertical plane according to EN 13146-9+A1:2011 [6]. The construction assumption of the test was to obtain a density of polyurethane resin which would guarantee high flexibility and high operating resistance. During the test, a 3–fold linear incremental load of up to 64 kN was applied. Additionally, the support's response to the dynamic load of 5 Hz frequency was checked and the stiffness coefficient was calculated, which equals 18.2% for the new product.

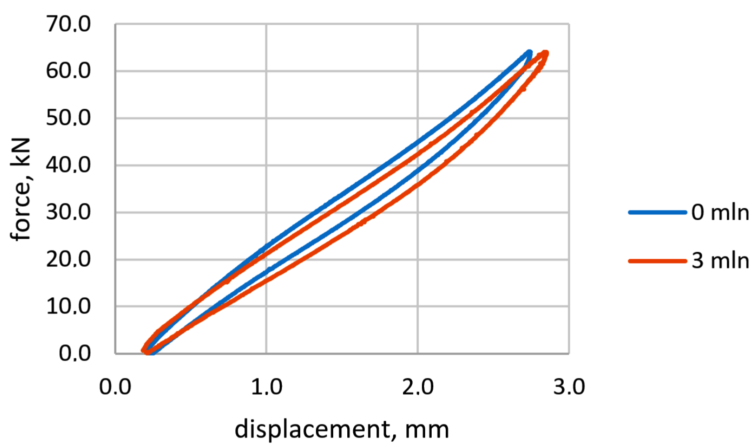

Fig. 3. Comparison of the vertical stiffness of the embedded block system before and after the fatigue test. [Author: L. Antolik]

The fatigue test scheme of the EBS was carried out in the number of 3 million cycles according to Table 1, cat. C for the fastening system with vertical stiffness below 50 MN/m. Figure 4 shows the object prepared for the fatigue test. The nature of the test and the maximum resultant force of PV/cosα = 60 kN are equivalent to maximum loads of the EBS during train running in a curve, assuming that the individual supports take the load according to the scheme shown in Fig. 5. This is equivalent to an uninterruptible load of 18 Tg transferred by support, which according to estimates gives trains the mass of about 90 Tg.

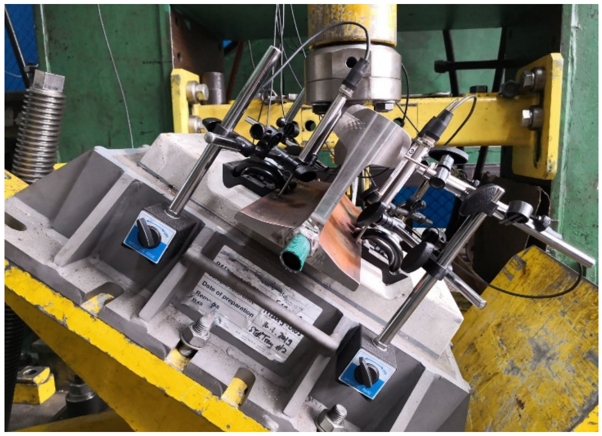

Fig. 4. Embedded block system during the fatigue test. [Author: L. Antolik]

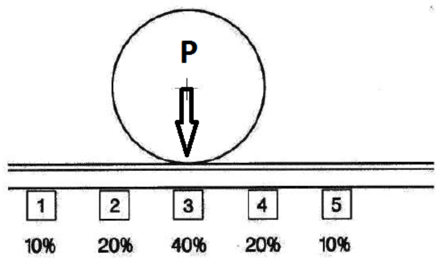

Fig. 5. General idea of the load distribution for each support. [7]

During the cyclic test, the displacement of the rail head and foot at 6 points was measured. The measurements were made for the first 1000 cycles and for the last 1000 cycles of 3 million load cycles. The results of the measurements in points 1÷4 in Fig. 6 are related to the vertical stiffness achieved by the block support. Particularly important measurement points are those marked with number 5 and 6 in Fig. 6. The values of plastic and elastic displacement measured at these locations lead to determination of the stability of the track gauge.

According to the Id-14 [8] maintenance instruction, the track gauge is measured at virtual points located 14 mm below the rolling surface of the rail head. Limit values of the track gauge in-service are shown in Table 2.

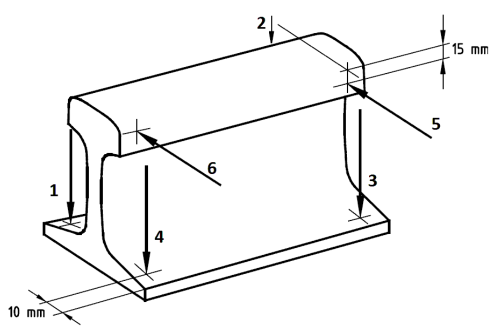

Fig. 6. Displacement measurement places. [Author: L. Antolik]

After the fatigue cycle, the vertical stiffness of the embedded block system, the longitudinal resistance of the rail to the block support and the rail clamping force to the support were re-examined in a fixed order. A visual inspection of the support components for mechanical damage was also carried out. It was stated that none of the elements was damaged. The polyurethane resin did not show any cracks. Re-fixing or delamination that could disqualify the element were also not observed.

Table 2. Track gauge deviations in-service [9].

Velocity [km/h]	Alert limit AL		Intervention Limit IL		Immediate Action Limit IAL		Limit values acc. to TSI	
	min.	maks.	min.	maks.	min.	maks.	min.	maks.
	[mm]							
V ≤ 80	–7	25	–9	30	–11	35	–9	35
80 < V ≤ 120	–7	25	–9	30	–11	35	–9	35
120 < V ≤ 160	–6	25	–8	30	–10	35	–8	35
160 < V ≤ 230	–4	20	–5	23	–7	28	–7	28
230 < V ≤ 300	–3	20	–4	23	–5	28	–5	28

Table 3. Results of the fatigue tests.

No.	Type of test	Results obtained after 3 mln cycles of repeated loadings		Requirements acc. EN 13481-5+A1:2017
1	Determination of the vertical stiffness	Sample 1	**approx. 6%**	change ≤ 25 %
		Sample 2	**approx. 5%**	
2	Determination of the longitudinal restraint	Sample 1	**approx. 7%**	$F_{min} \geq 7$ kN change ≤ 20 %
		Sample 2	**approx. 17%**	
3	Determination of the clamping force	Sample 1	**approx. 2%**	change ≤ 20 %
		Sample 2	**approx. 0%**	

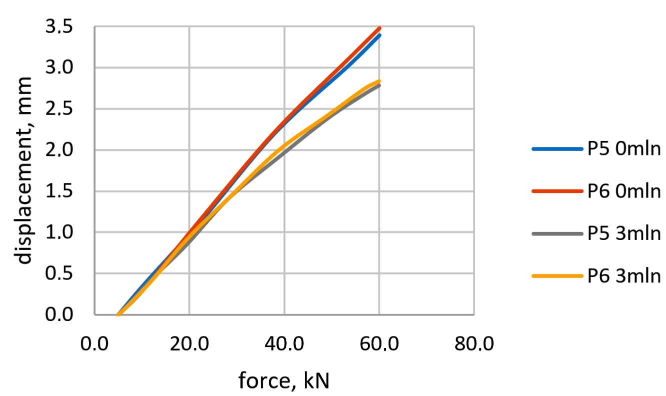

Fig. 7. Effect of fatigue tests for measured lateral elastic displacement. [Author: L. Antolik]

Table 3 presents the results of the fatigue tests. They are satisfactory from the point of view of the application possibilities of the tested embedded block system in the operation in the C category track according to EN 13481-5+A1:2017 [3] and at the operating speed of up to 250 km/h. At the same time, Fig 7 chart, which shows measured elastic side displacement of the rails enables to establish that within the maximum forces during laboratory tests, which should never occur in operations, the rail spacing may increase by approx. 3.5 mm due to the elastic displacement of the support, whereas after 3 million cycles this value decreases to approx. 2.8

mm taking into account the plastic displacement of the support in relation to the seat, which was not measured during the experiment.

Conclusions

The application of a specific solution for fastening the rail to the support system depends on the results expected by the infrastructure manager. Investment costs have also significant impact on the selected solution. In urban areas or engineering applications, where high damping properties are required, a slab track in combination with an embedded block system with relatively high elastic and vibration absorption is an effective solution.

The lifetime of each engineering object lasts longer if less vibration from the passing trains is absorbed. This also applies to densely populated areas, where seismic vibrations cause discomfort and impair the quality of life. Polish railway infrastructure in agglomerations use mainly wooden sleepers as a vibrations absorber. At the time of global debate on ecology, it is possible to apply a ready-made complementary solution where the parameter of high flexibility and attenuation by the rail fastening system is desired.

References

[1] Chudyba Ł.: Fastening systems to concrete sleepers – comparison of the operating characteristics of fastening systems SB and W14, Przegląd Komunikacyjny no. 11, Warszawa 2017, pp. 27 – 32. https://doi.org/10.35117/A_ENG_17_11_05

[2] European Commission: Commission Regulation No. 1299/2014: on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union, Brussels 2014

[3] EN 13481-5+A1:2017: Railway applications − Track − Performance requirements for fastening systems − Part 5: Fastening systems for slab track with rail on the surface or rail embedded in a channel.

[4] EN 13146-7:2012: Railway applications - Track - Test methods for fastening systems – Part 7: Determination of clamping force

[5] EN 13146-1+A1:2014 Railway applications – Track – Test methods for fastening systems – Part 1: Determination of longitudinal rail restraint

[6] EN 13146-9+A1:2011: Railway applications - Track - Test methods for fastening systems - Part 9: Determination of stiffness.

[7] Ł. Antolik: *Wpływ przekładki podszynowej na pracę systemu przytwierdzenia typu SB,* Problemy Kolejnictwa nr 177, Instytut Kolejnictwa, Warszawa 2017, pp. 7−12. https://doi.org/10.36137/1771p

[8] Id-14 (D-75) Instrukcja o dokonywaniu pomiarów, badań i oceny stanu torów, PKP Polskie Linie Kolejowe, Warszawa 2005

[9] H. Bałuch: Odchyłki dopuszczalne torów według normy europejskiej i wynikające stąd problemy, Technika Transportu Szynowego nr 6, Warszawa 2009, pp. 53 – 58

[10] Lakušić S., Haladin I. Ahac. M. *The Effect of Rail Fastening System Modifications on Tram Traffic Noise and Vibration.* Hindawi Publishing Corporation Shock and Vibration Volume 2016, Article ID 4671302, 15 pages. https://doi.org/10.1155/2016/4671302