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# INFLUENCE OF ELEMENTS FASTENING SYSTEM TYPE SB FOR CHOSEN EXPLOITATION PARAMETERS

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**Abstract** – The paper presents a comparative analysis of the clamping force on the operating parameters of the SB fastening system. An overview of used elastic fastening systems for prestressed concrete sleepers is presented. The results of laboratory research carried out in accordance with the applicable European standards of the PN-EN 13481 and PN-EN 13146 series are described synthetically. Specially prepared clamp type SB with different stiffness within the range allowed by PKP PLK S.A. were selected for the tests. All tests were done in accredited laboratory. The paper presents the impact of the SB clamp stiffness on the basic parameters of the fastening system, such as the clamping force and longitudinal resistance. A reduced value of the static stiffness of the clamp may fail to fulfill the requirements of the fastening system shown in the Technical Specifications for Interoperability. The risk of non-repeatability of the SB clamp should lead to the development of a solution or even a change to the W-type fastening system.

**Key words** – clamping, force, fastening system SB, laboratory research of fastening system, Technical Specifications for Interoperability

**JEL Classification** – L70, L90, L92

## INTRODUCTION

According to COMMISSION REGULATION (EU) No 1299/2014 of 18 November 2014 on the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union (with later changes) [1, 12] fastening systems used in ballasted tracks are recognized as an interoperability constituent. Therefore fastener has to fulfill the requirements of Commission Regulation and applicable European norms series EN 13481 [2] and EN 13146 [3]. Fulfilling requirements allows the design of fastening systems with equivalent parameters, which can be successfully used on interoperable railway lines in the European Union countries.

It should be noted that the sleeper and the fastening system are interoperability constituents with a common interface in the form of an anchor element installed in the concrete beam at the stage of its production. Therefore, it is necessary to consider the fastening system together with the appropriately designed prestressed concrete sleeper. This determines the execution of a properly profiled rail seat and the required sleeper height at the rail support point to obtain strength parameters.

## 1. OVERVIEW OF SELECTED FASTENING SYSTEMS USED IN THE EU MEMBER COUNTRIES

For historical reasons, European railways infrastructure managers use different elastic fastening systems. The most popular solution is fastener type W with clamp type Skl 14 (Fig. 1.). This system is used on railway tracks with a wide variety of rail pads, angle plates (Wfp) customized to dimensions and steel elements with different anticorrosion protection layers. Fastening system W14 is very popular in many countries, e.g., in Germany, Czech Republic, Slovakia, the Netherlands, Italy, Romania, Spain, Switzerland, Austria, Spain and to a certain extend in Poland. In all these countries that system can be used with some modifications in clamps (Skl 14, Skl 21, Skl 30) and different angle plates.

The second widely used fastening system is Fast Clip (Fig. 2). The Fast Clip system is most often used in the UK, France, Belgium, Norway and Sweden.

In Poland, CNTK (Central Research and Development Center for Railway Technology, today Railway Institute) in 1979, started a development project on the SB elastic fastening system (Fig. 3)., protected by patent No. 128,477 [4]. Currently, manufacturers are modifying the system by improving the rail pads and optimizing the anchor.

**Fig. 1. Fastening systems W14 on B70 prestressed sleepers W14 in Czech Republic**

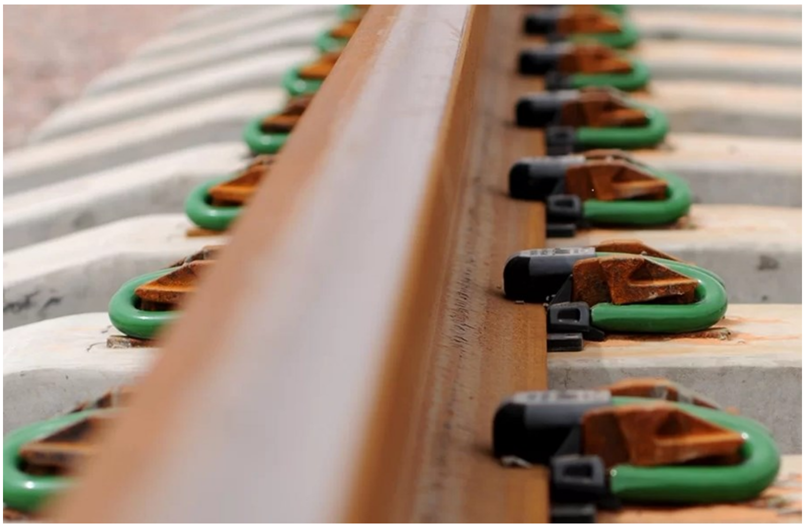

**Fig. 2. Fastening system type Fast Clip** [**9**]

**Fig. 3. SB fastening system in PKP PLK tracks**

The rail seat in a pre-stressed concrete sleeper determines the type of fastening system. Thus a fastening system has to be considered together with the sleeper for a reliable long year service.

## 2. Construction of the SB fastening system

The ballasted track is a multi-layer system consisting of rails, fasteners, sleepers and ballast. Each subsequent layer has a larger surface, which changes the stresses caused by the movement of the rolling stock. Load transfer works on the principle of stress reduction, which means layer by layer, as depicted schematically in Figure 4 [13]. Figure 5 shows the acting of forces on the fastening system.

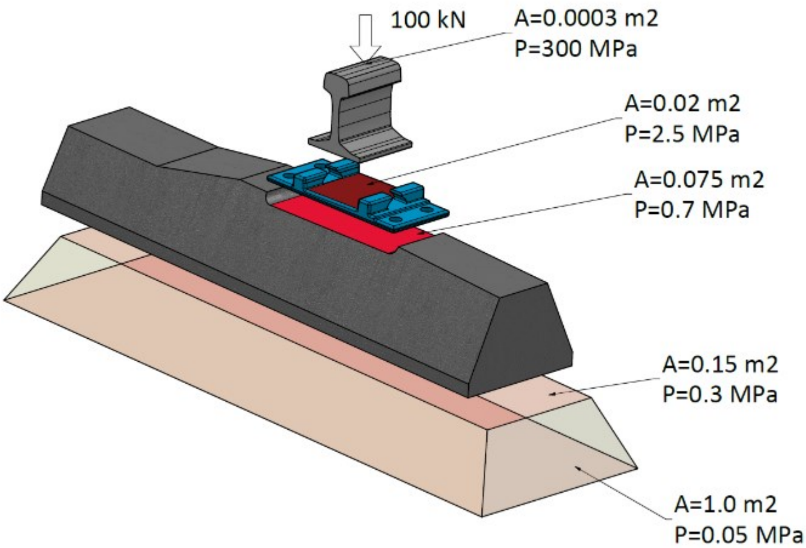


**Fig. 4. Principle of load transfer** [**13**]

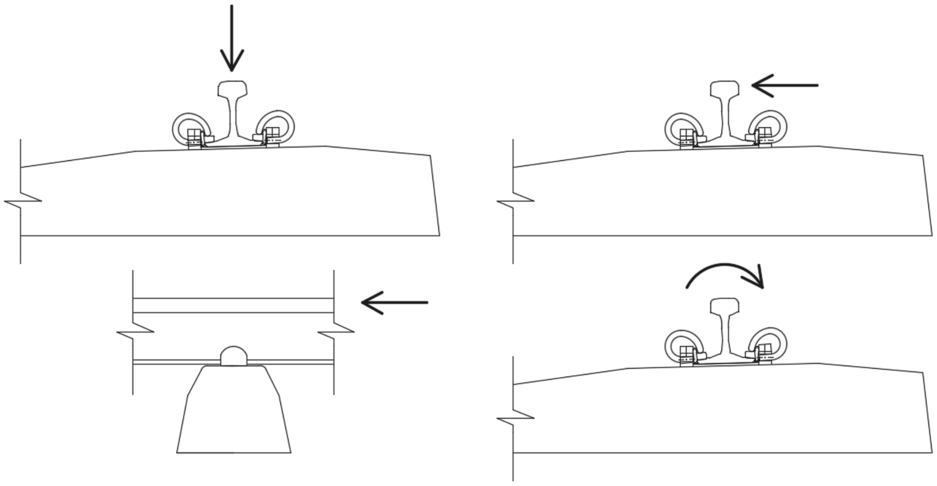

Fig. 5. Forces acting on the fastening system / railway track [5]

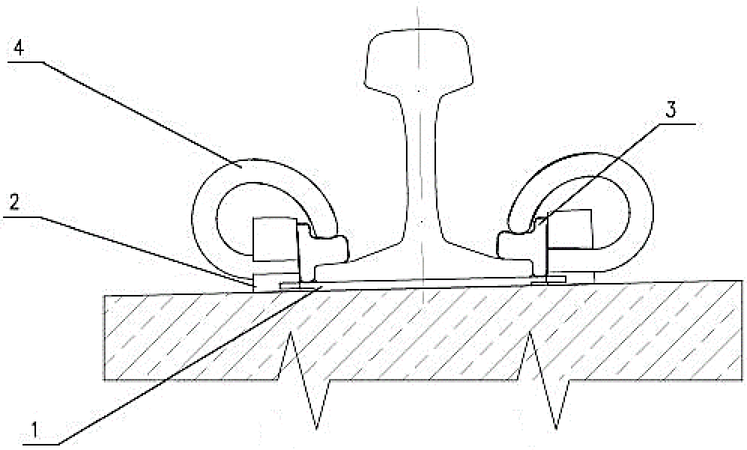


**Fig. 6. Fastening system type SB**. **1 – rail pad**, **2 – anchor**, **3 – electric insulator**, **4 – SB clamp**

To ensure the correct and reliable functioning the of railway track, it is necessary to use a fastening system that will comply with the requirements. Therefore, it is important to select the static stiffness of the rail pad depending on the load, which will not change its properties excessively after many years of operation (it will increase or decrease the stiffness by 25% of the initial value).

The static stiffness of the rail pad must also provide vibration damping. Selecting a clamp that will provide the required clamping force and longitudinal force of the fastening system is also necessary. The fastening system is a set of mutually cooperating elements that enable the rail to be fixed to the support (the sleeper) in the required position, while allowing (flexible system) move of the rail within the prescribed range (vertical, transverse and longitudinal displacements) [10]. In this paper, special attention was focused on selected parameters of the SB rail fastening system, widely used in Poland. The W14 fastening may become an alternative solution to the SB, due to its advantages related to production, transport of material for the construction site and operational parameters. As a result of the research, special attention was paid to the influence of the method of fastening the rail to the sleeper, which is directly related to the functional properties of the SB - type rail fastening system. Figure 6 shows the construction of the SB fastening system.

## 3. Laboratory Tests of Fastening systems

To carry out a complete assessment of the suitability of the fastening system for use in railway networks in EU, it is necessary to perform tests in accordance with the European standards of the PN-EN 13481 [2] and PN-EN 13146 [3] series, and to meet the requirements of the EU Commission Regulation No. 1299/ 2014 [1]. Regulation [1-3] defines the effects of repeated loading of 3 million load cycles. The adopted assumptions define the maximum changes for:

– Vertical stiffness of the rail fastening ≤ 25%,
– Clamping force of the rail to the sleeper ≤ 20%,
– Longitudinal resistance of the rail ≤ 20%.

The longitudinal resistance of a single fastener must be at least 7 kN for conventional rail. For high-speed rail (above 250 km/h) the longitudinal resistance must be more than 9 kN. Complete laboratory tests additionally include:

– Determination of torsional resistance,
– Determination of attenuation of impact loads,
– Determination of vertical dynamic stiffness of the fastening system,
– Determination of the electrical resistance,
– Determination of severe environmental conditions,
– Determination of the influence of dimensional tolerances on the track width,
– Determination of overall dimensions,
– Determination of pull – out resistance for anchored elements of the fastening system [2-3, 11, 15, 18].

After carrying out a set of tests, in accordance with the applicable regulations, the fastening system and all its components must not show any use, scratches, or cracks – this also applies to elements concreted in a sleeper.

This paper presents a comparative analysis of the influence of clamping force generated by elements implementing pressure on selected operating parameters of SB-type fastening systems, i.e. vertical stiffness, clamping force, and longitudinal resistance. All analyzed samples were loaded according to standard [1] part 2 – maximum axle load 260 kN, minimum curve radius 150 m (category C). Figure 7 shows how the rail is loaded when investigating the effects of repetitive loads. For loading category C, the following are assumed: $\alpha = 33°$, $X = 15$ mm, $P_v / \cos\alpha = 70$ kN (for static spacer stiffness $50 \le k_{LFA} \le 200$ MN/m).

To properly configure the complete fastening system and enable its use on railway lines, for example, by PKP PLK S.A., special care should be taken in choosing right clamp and stiffness of pads for SB fastening system.

Individually prepared SB fastening systems were used for the research. In the case of the SB system, clamp with extreme stiffness parameters C of 1.18 kN/mm and 1.52 kN/mm with the same rail pads (type A) were used. PKP PLK S.A. determined the The nominal value of C = 1.47 kN/mm in [7-8]. On models prepared in this way, the stiffness of complete fasteners was determined, as well as longitudinal strength and clamping forces. Detailed results are presented in Table 1.

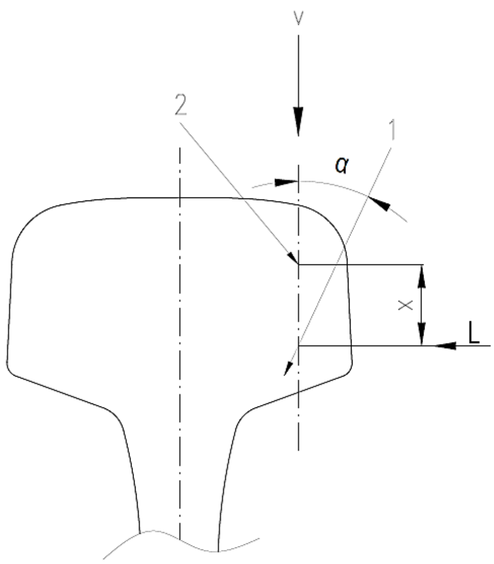


**Fig. 7. Method of applying force when testing the effects of repetitive loads** [**2**], **1 - line of load application, 2 - centre of gauge corner radius**

**Table 1. Selected results of laboratory tests of SB fastening systems**

| **Parameters** | **Fastening system SB C = 1.47 kN/mm ± 10%** | |
|---|---|---|
| | **Probe nr 1 1.52 kN/mm Rail pad type A** | **Probe nr 1 1.18 kN/mm Rail pad type A** |
| Static stiffness [kN/mm] | 96.54 | 109.13 |
| Longitudinal resistance [kN] | 20.7<br>21.2<br>21.5<br>21.7 | 16.1<br>16.6<br>16.7<br>16.6 |
| Clamp force [kN] | 20.6<br>20.8<br>20.9 | 14.8<br>14.4<br>14.3 |

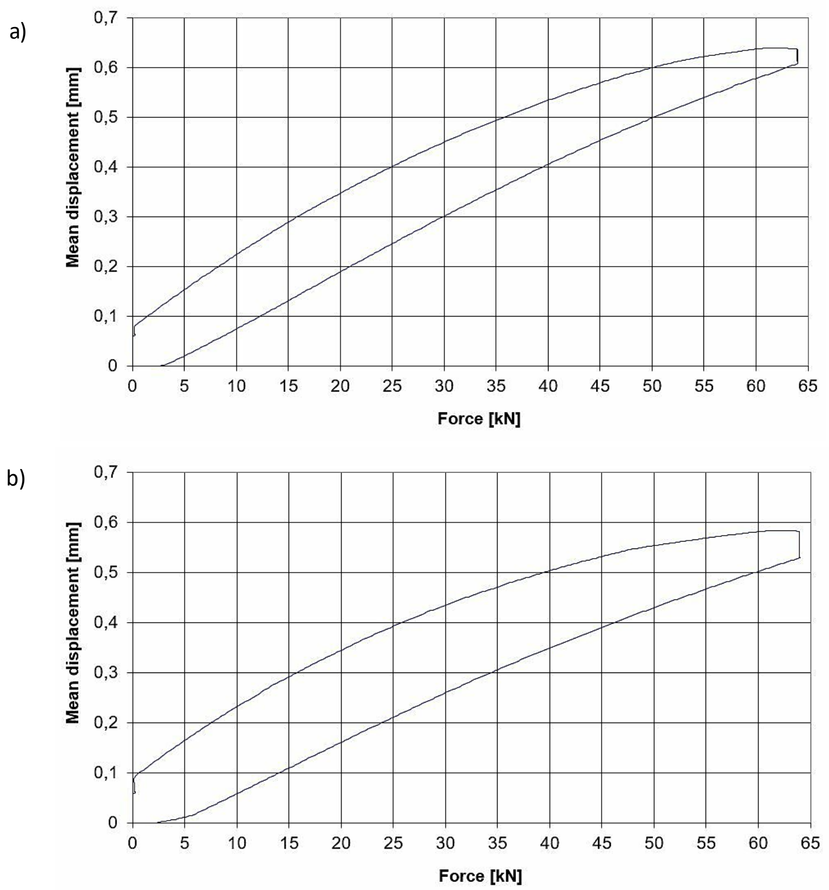


**Fig. 8. Example of a force - displacement diagram for the fastening system** (Own source),
**Sample 1 – clamp stiffness SB C = 1,52 kN/mm, Sample 1 – clamp stiffness SB C = 1,18 kN/mm**

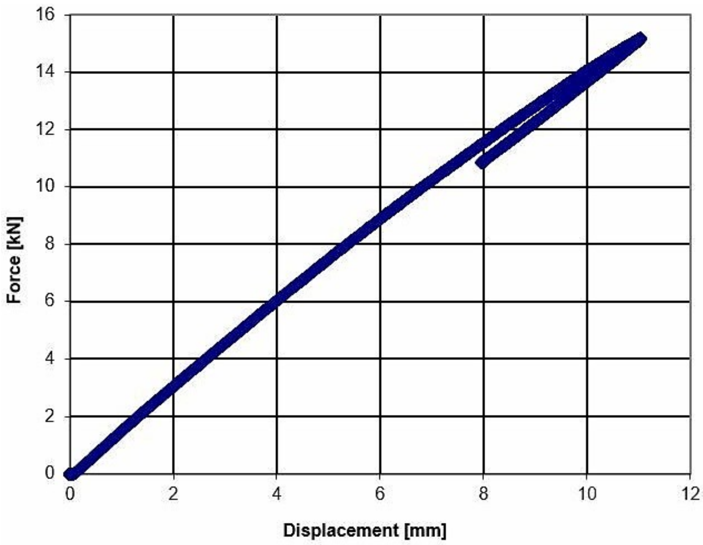


**Fig. 9. Diagram of elastic SB clamp** (Own source)

From the results of the SB fastening system research, it can be stated that the influence of the elastic clamp on static stiffness is relatively small. The difference in stiffness is about 13 %.

Execution of the stiffness of the SB clamp with a tolerance of +/- 10% has a significant impact on the clamping force. As a result of the tests, it was noticed that the clamping force of the fastening system exceeds even 30% (Table 1). An additional force loss can be achieved with repeated assembling and reassembling of the clamp in the track. According to manufacturer instructions clamps shouldn't be reassembled more than 5 times [16-17]. This is because the higher initial clamping force in the fastening system after assembling the SB clamp causes the pressed rail pad through the rail seat by the rail.

This phenomenon directly impacts on the other analyzed parameters that the discussed fastenings must meet. It should be noted that the lack of sufficient stiffness of the elastic clamp causes a significant decrease in clamping force, and thus directly affects the reduction of longitudinal resistance. Detailed results are presented in Table 1. Figure 8 shows static stiffness diagrams for the SB fastening system, while Figure 9 shows an example of elastic characteristics for the SB clamp.

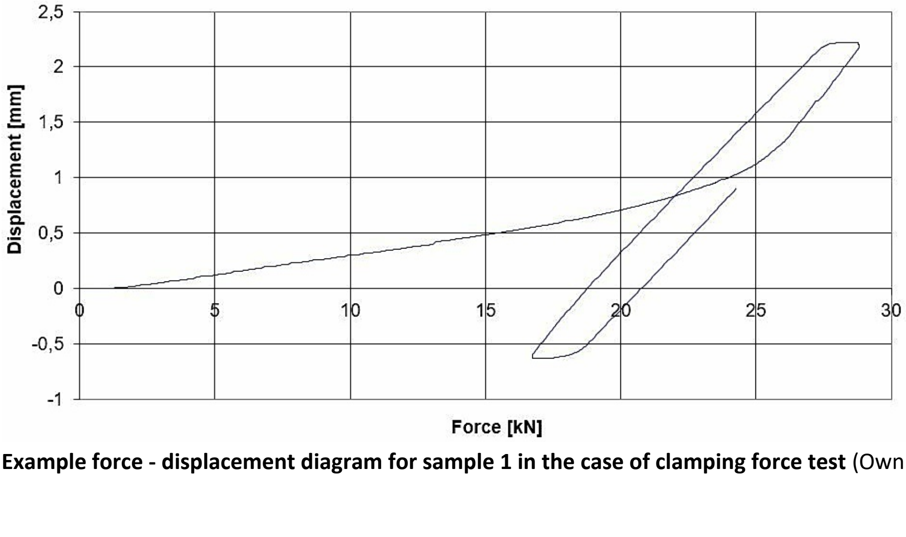


**Fig. 10. Example force - displacement diagram for sample 1 in the case of clamping force test** (Own source)

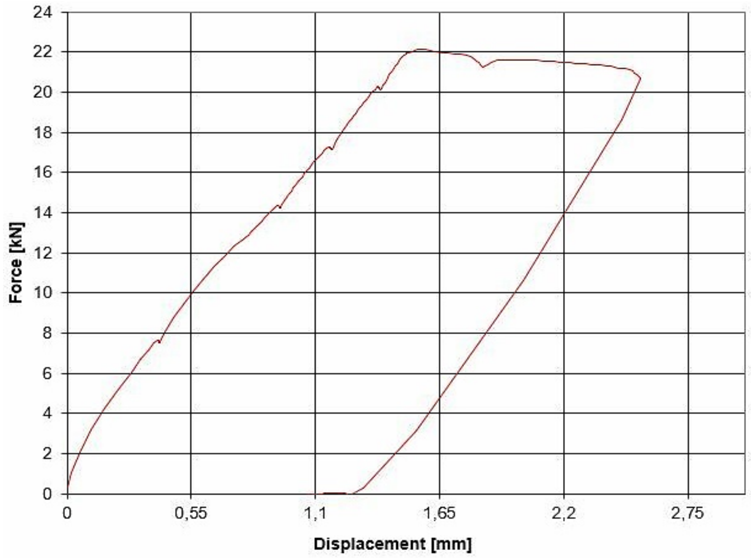


**Fig. 11. Example of a force - displacement diagram for sample 1 in the case of a longitudinal resistance test** [10]

Figure 10 and 11 show, respectively, examples of force-displacement diagrams for the clamping force test and the longitudinal resistance test.

Since the fastening system meets the requirements to achieve satisfactory results of longitudinal resistance and rail clamping force for the initial and repeated loading test. It shows that it is necessary to use SB4 clamp with higher stiffness. Thus, the result of poor selection of the elasticity of the SB clamp may dropped above 20% after fatigue load, which results in the disqualification of the fastening system for safe use in railway networks. In Figure 12, Figure 13, and Figure 14 a comparison of the values of clamping force, longitudinal resistance and static vertical stiffness for the SB system is shown. On the diagram average values and acceptable decreases were shown.

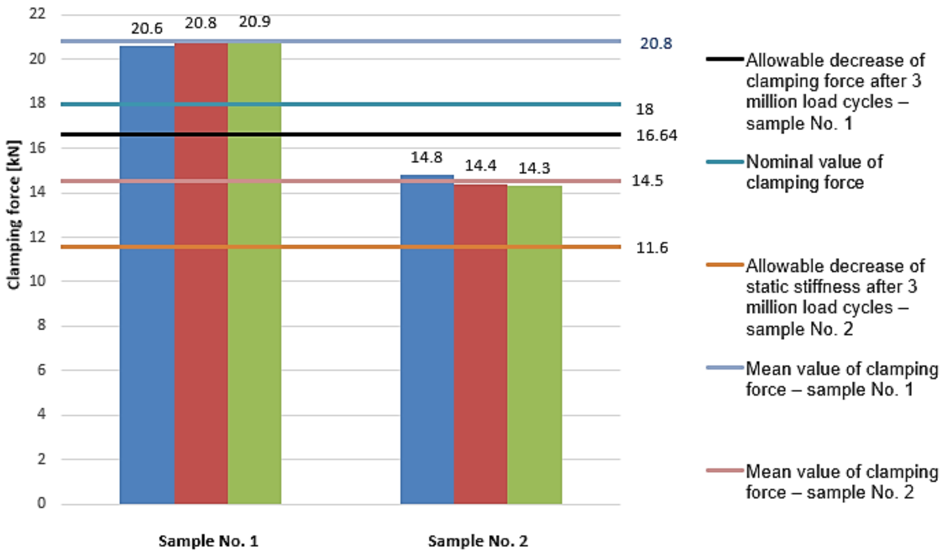


**Fig. 12. Comparison of clamping force values for SB-type attachment for two extreme characteristics** (Own source)

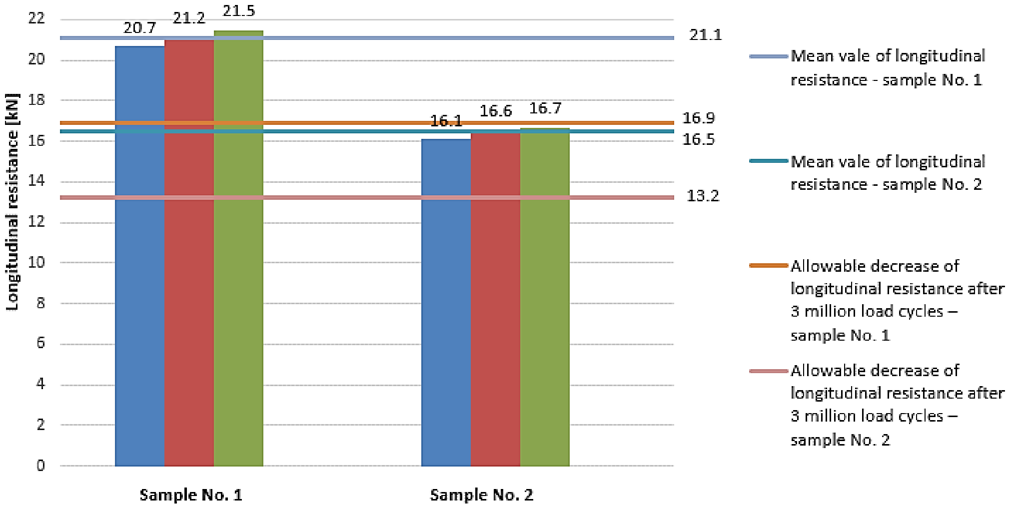


**Fig. 13. Comparison of the longitudinal resistance values for the SB-type attachment for two extreme characteristics** (Own source)

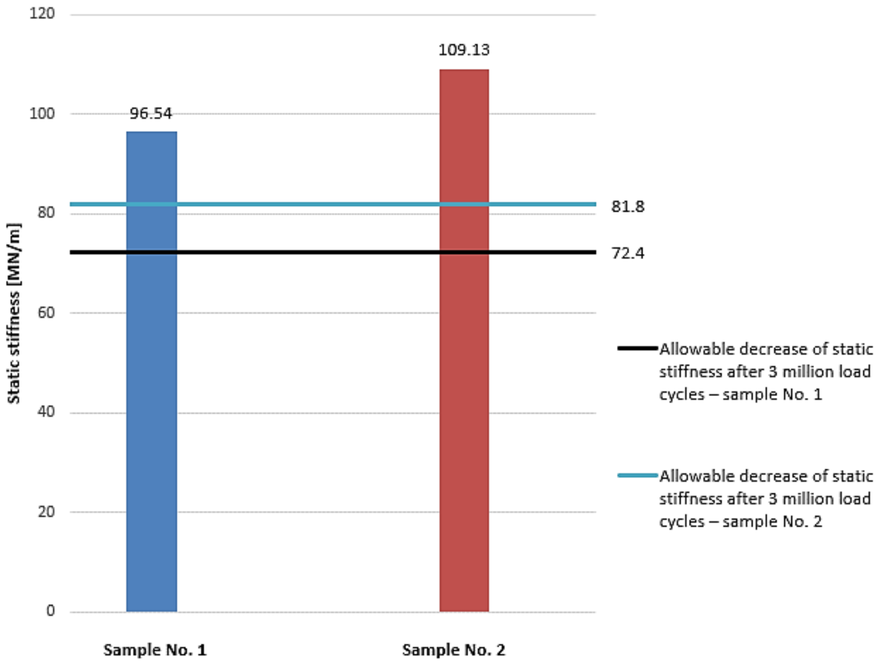


**Fig. 14. Comparison of the vertical stiffness of the SB-type fastening system for the two extreme characteristics of the SB4 spring feet** (Own source)

## Conclusions

As a result of the conducted research and analysis, it was found that the selection of elements in the fastening system significantly impacts on obtaining parameters that meet the operating requirements contained in the series of standards [2-3]. Depending on the configuration of the fastening system, SB in terms of elastic clamp stiffness SB4 (C = 1.18 kN/mm or C = 1.52 kN/mm) affects the initial values of longitudinal resistance, clamping force or static stiffness for conducting repetitive effects tests. The appropriate stiffness of the elastic clamp in the SB fastening system results in a higher value of clamping force in the fastening system. This value directly determines the longitudinal resistance force and thus better performance parameters for long-term use. From the results of the SB fastening system research, it can be stated that the influence of the elastic clamp on static stiffness is relatively small. The difference in stiffness is about 13 %. Execution of the stiffness of the SB clamp has a significant impact on the clamping force. As a result of the tests, it was noticed that the clamping force of the fastening system exceeds even 30% Depending on the track class and traffic intensity on the analyzed railway section, the operation of the fastening system itself is more exposed to loads than rolling stock. The static stiffness of the SB fastening system impacts on vibration damping, and thus the durability of the track. The lack of stable stiffness values of the SB clip may hurt the operation of the railway line. A reduced value of the static stiffness of the clamp may result in failure to fulfill the requirements of the fastening system shown in the Technical Specifications for Interoperability. Therefore, the development of fastening systems in Poland should be considered through alternative solutions, such as the W-type fastening system. The risk of non-repeatability of the SB clamp should lead to the development of a solution or even a change to the W-type fastening system. In the standards [14] concerning the railway superstructure of PKP PLK S.A. on lines with the highest class and the highest speed in all types of tracks, he prefers using the W fastening system.

The research shows the necessity for continuous improvement and development of fastening systems to eliminate as many risks as possible related to the production and reliable operation of the railway track.

The above analysis presents only selected aspects of the fastening system. The described dependencies also largely depend on the appropriate selection of the rail pad, the correct setting of anchors and dowels in relation to the requirements and tolerances on production. The proposed issues require further analysis. It seems advisable research long-term loads and their impact on the parameters of the fastening system after years of operation.

## WPŁYW ELEMENTÓW SYSTEMU PRZYTWIERDZENIA SB NA WYBRANE PARAMETRY EKSPLOATACYJNE

W pracy przedstawiono analizę porównawczą wpływu siły docisku generowaną poprzez elementy realizujące docisk na wybrane parametry eksploatacyjnych systemów przytwierdzeń typu SB. Przedstawiono przegląd stosowanych sprężystych systemów przytwierdzeń do podkładów strunobetonowych. Opisano syntetycznie wyniki badań laboratoryjnych przeprowadzonych zgodnie z obowiązującymi normami europejskimi serii PN-EN 13481 i PN-EN 13146. Do badań wybrano specjalnie przygotowane łapki SB o różnych sztywnościach w zakresie dopuszczalnym przez PKP PLK S.A.. Badania wykonano a akredytowanym laboratorium. W pracy przedstawiono wpływ sztywności łapki sprężystej na podstawowe parametry systemu przytwierdzenia takie jak siła docisku oraz opór wzdłużny. Obniżona wartość sztywności statycznej łapki może spowodować brak spełnienia wymagań systemu przytwierdzenia stawianym przez Techniczne Specyfikacje Interoperacyjności. Ryzyko braku powtarzalności wykonania łapki SB, powinno prowadzić do rozwoju rozwiązania lub nawet zmiany na system przytwierdzenie typ W.

**Słowa kluczowe**: badania laboratoryjne systemów przytwierdzeń, siła docisku, system przytwierdzenia SB, Badania laboratoryjne systemów przytwierdzeń, Techniczne Specyfikacje Interoperacyjności.

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