UDC 625.143.5
IRSTI 73.29.11
RESEARCH ARTICLE

DYNAMICS OF APPLICATION AND COMPARATIVE ASSESSMENT OF INTERMEDIATE RAIL FASTENING SYSTEMS ON REINFORCED-CONCRETE SLEEPERS OF THE JSC «NC KAZAKHSTAN TEMIR ZHOLY» NETWORK

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Abstract. *This article presents a comparative analysis of the distribution of intermediate rail fastening systems installed on reinforced-concrete sleepers across the JSC «NC Kazakhstan Temir Zholy» (JSC «NC KTZ») network, based on operational statistics for 2017 and 2025. Four principal fastening system groups were examined: the KB-65 fastening system, clip-based SKL, GK1 systems, ZhBR-65/ZhBR-65Sh fastening systems, and the KPP-5 anchor-type fastening system. The methodology included a comparative assessment of track lengths by fastening type, a synthesis of technical and regulatory characteristics, and an analytical calculation of longitudinal resistance to rail creep and the rail "breathing" zone for CWR track with KB-65 and SKL, GK1 systems. Between 2017 and 2025, the share of SKL, GK1 systems increased from 22.9% to 53.3% (+5,907.84 km), whereas the share of KB-65 systems decreased from 52.3% to 30.6% (−909.43 km). The calculation showed that the transition from KB-65 to SKL, GK1 systems increases longitudinal resistance to rail creep by 25%, from 14.72 to 18.40 kN/m, while reducing the rail "breathing" zone length by 20%, from 83.5 to 66.8 m. The findings confirm the transition towards resilient baseplate-free fastening systems and substantiate the need for standardised diagnostics of the sleeper-fastening assembly. The obtained results may be applied in selecting fastening systems for major track repair sections and in substantiating measures to enhance the stability of CWR track on the JSC «NC KTZ» network.*

Keywords: *intermediate rail fastening systems; reinforced-concrete sleepers; KB-65; SKL; GK1; ZhBR-65/ZhBR-65Sh; KPP-5; continuously welded rail track; JSC «NC KTZ».*

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https://doi.org/10.51488/1680-080X/2026.2-13

ӘОЖ 625.143.5
ҒТАМР 73.29.11
ҒЫЛЫМИ МАҚАЛА

АҚ «ҰК «ҚАЗАҚСТАН ТЕМІР ЖОЛЫ» ЖЕЛІСІНДЕГІ ТЕМІРБЕТОН ШПАЛДАРЫНДА ҚОЛДАНЫЛАТЫН ТЕМІРЖОЛ АРАЛЫҚ РЕЛЬСТІК БЕКІТПЕЛЕРДІҢ ҚОЛДАНЫЛУ ДИНАМИКАСЫ МЕН САЛЫСТЫРМАЛЫ БАҒАЛАНУЫ

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Аңдатпа. *Жұмыста 2017 және 2025 жж. пайдалану статистикасының деректері негізінде АҚ «ҰК «ҚТЖ» желісіндегі темірбетон шпалдарда қолданылатын аралық рельстік бекітпелердің қолданылу құрылымына салыстырмалы талдау жүргізілді. Төрт негізгі жүйе тобы қарастырылды: КБ-65, SKL, GK1 жүйелері, ЖБР-65/ЖБР-65Ш және КПП-5. Зерттеу әдіснамасы бекітпе түрлері бойынша жол учаскелерінің ұзындықтарын салыстырмалы бағалауды, олардың техникалық және нормативтік сипаттамаларын жалпылауды, сондай-ақ КБ-65 және SKL, GK1 жүйелерімен жабдықталған үзіксіз жол үшін рельстің бойлық жылжуына погондық кедергіні және «тыныс» учаскесінің ұзындығын аналитикалық есептеуді қамтыды. 2017–2025 жж. кезеңінде SKL, GK1 жүйелерінің үлесі 22,9%-дан 53,3%-ға дейін өсті (+5 907,84 км), КБ-65 үлесі 52,3%-дан 30,6%-ға дейін азайды (−909,43 км). Есептеу нәтижелері КБ-65-тен SKL, GK1 жүйелеріне өту погондық кедергіні 25%-ға арттыратынын және «тыныс» учаскесінің ұзындығын 20%-ға қысқаратынын көрсетті. Атап айтқанда, погондық кедергі 14,72-ден 18,40 кН/м-ге дейін артады, ал үзіксіз жолдың «тыныс» учаскесінің ұзындығы 83,5-тен 66,8 м-ге дейін қысқарады. Алынған нәтижелер АҚ «ҰК «ҚТЖ» желісінде серпімді табансыз бекітпе шешімдеріне көшу үрдісін растайды және «шпала–бекітпе» түйінін бірыңғай диагностикалаудың қажеттілігін негіздейді. Есептелген 14,72 және 18,40 кН/м мәндері бекітпе клипсінің стандарт қысу күші кезіндегі рельс табаны мен прокладканың үйкелісінен туындайтын бойлық кедергінің клипстік (парциалды) құраушысына сәйкес келеді.*

Түйін сөздер: *рельстік бекітпелер; темірбетон шпалдар; КБ-65; SKL; GK1; ЖБР-65/ЖБР-65Ш; КПП-5; үзіксіз жол; АҚ «ҰК «ҚТЖ».*

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https://doi.org/10.51488/1680-080X/2026.2-13

УДК 625.143.5
МРНТИ 73.29.11
НАУЧНАЯ СТАТЬЯ

ДИНАМИКА ПРИМЕНЕНИЯ И СРАВНИТЕЛЬНАЯ ОЦЕНКА ЖЕЛЕЗНОДОРОЖНЫХ ПРОМЕЖУТОЧНЫХ РЕЛЬСОВЫХ СКРЕПЛЕНИЙ НА ЖЕЛЕЗОБЕТОННЫХ ШПАЛАХ СЕТИ АО «НК «ҚАЗАҚСТАН ТЕМІР ЖОЛЫ»

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Аннотация. *В работе выполнен сравнительный анализ структуры применения промежуточных рельсовых скреплений на железобетонных шпалах сети АО «НК «ҚТЖ» по данным эксплуатационной статистики за 2017 и 2025 гг. Рассмотрены четыре основные группы систем: КБ-65, клипсовые системы семейства SKL, GK1, ЖБР-65/ЖБР-65Ш и КПП-5. Методика включает сопоставление протяжённости участков по типам скреплений, обобщение паспортных и нормативных характеристик, а также аналитический расчёт погонного сопротивления продольному сдвигу и длины участка «дыхания» бесстыковой плети для систем КБ-65 и систем SKL, GK1. За 2017–2025 гг. доля систем SKL, GK1 выросла с 22,9% до 53,3% (+5 907,84 км), доля КБ-65 снизилась с 52,3% до 30,6% (−909,43 км). Расчёт показал, что переход от КБ-65 к системам SKL, GK1 увеличивает погонное сопротивление на 25% – с 14,72 до 18,40 кН/м – и сокращает длину участка «дыхания» плети на 20% – с 83,5 до 66,8 м. Результаты подтверждают тенденцию перехода к бесподкладочным упругим решениям и обосновывают необходимость проведения унифицированной диагностики узла «шпала–скрепление». Полученные результаты могут быть использованы при выборе типов скреплений на участках капитального ремонта пути и при обосновании мероприятий по повышению устойчивости бесстыкового пути сети АО «НК «ҚТЖ». Расчётные значения 14,72 и 18,40 кН/м соответствуют клеммному (парциальному) компоненту погонного сопротивления – силе трения подошвы рельса по прокладке при стандартной силе прижатия клеммы. Нормативные значения 25–30 кН/м (Карпущенко и др., 2009) относятся к полному системному сопротивлению пути; основным методическим результатом является относительный прирост на 25% при переходе КБ-65 → SKL, GK1.*

Ключевые слова: *рельсовые скрепления; железобетонные шпалы; КБ-65; SKL; GK1; ЖБР-65/ЖБР-65Ш; КПП-5; бесстыковой путь; АО «НК «ҚТЖ».*

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https://doi.org/10.51488/1680-080X/2026.2-13

1 INTRODUCTION

Intermediate rail fastening systems are among the most heavily loaded components of the railway track superstructure. They transmit vertical, lateral, and longitudinal forces generated by rolling stock, maintain track gauge stability, and prevent longitudinal rail creep. In practice, however, rail fastenings often receive considerably less attention than rails or sleepers, because their operation remains largely unnoticed while the assembly functions properly. Problems usually become apparent only after significant degradation of the fastening assembly has occurred.

As of 2025, the operational length of the railway network of JSC «NC Kazakhstan Temir Zholy» (hereinafter referred to as JSC «NC KTZ») amounted to 16,008.5 km, of which 15,889.7 km were equipped with continuously welded rail (CWR) track. The average traffic density was 23.3 million gross tonne-kilometres per kilometre of track per year [1]. Under such operating conditions, the reliability requirements for the sleeper-fastening assembly increase substantially. High axle loads and intensive traffic mean that even a partial loss of clamping force or loosening of threaded connections can lead to increased track irregularities and accelerated development of defects.

Four principal groups of intermediate rail fastening systems are currently used on reinforced-concrete (RC) sleepers across the JSC «NC KTZ» network: the KB-65 separate clip-and-bolt fastening system; the ZhBR-65 and ZhBR-65Sh elastic direct-fixation fastening systems (hereinafter collectively referred to as ZhBR-65/ZhBR-65Sh); the KPP-5 anchor-type baseplate-free fastening system; and Vossloh SKL fastening systems and their GK1 functional counterparts (hereinafter referred to as SKL, GK1 systems). The KB-65 system has been in service since the 1960s and remained the dominant fastening type for several decades, whereas SKL, GK1 systems have been used on the JSC «NC KTZ» network since 1998 and their share has increased substantially over the past decade.

Global railway practice demonstrates a sustained transition from conventional baseplate bolted fastening systems to resilient baseplate-free fastening systems. This trend is supported by field-testing results [2; 3] and by life-cycle cost assessments of railway track superstructure components [4; 5]. Issues related to the diagnostics and condition assessment of railway infrastructure components within the JSC «NC KTZ» network have been addressed in a number of studies [6-8]. For Kazakhstan, this issue is of particular importance because large temperature fluctuations, substantial axle loads, and the extensive length of the railway network create specific operating conditions for rail fastening systems.

However, no systematic quantitative analysis of the long-term evolution of fastening system distribution across the JSC «NC KTZ» network has been reported in the open literature. Furthermore, the relationship between the observed structural shift in fastening system utilisation and the calculated longitudinal resistance characteristics of CWR track for the specific fastening systems employed in Kazakhstan has not yet been established. This research gap provides the basis for the present study.

The aim of this study is to conduct a quantitative analysis of the application dynamics of intermediate rail fastening systems on reinforced-concrete sleepers across the JSC «NC Kazakhstan Temir Zholy» network for the period 2017–2025, to perform a comparative calculation of longitudinal resistance and continuously welded rail stability parameters for the KB-65 and SKL, GK1 systems, and to substantiate further development and diagnostic directions for the sleeper-fastening assembly under Kazakhstan's operating conditions.

The scientific novelty of this study lies in: (1) the first quantitative assessment of the structural shift in the application of intermediate rail fastening systems on reinforced-concrete sleepers across the JSC «NC KTZ» network for the period 2017–2025, based on verified operational statistics; (2) the first systematic linkage between the operational statistics and the calculated relative change in the longitudinal resistance to rail creep (clip-friction partial component) for the predominant fastening systems (KB-65 and SKL, GK1); (3) the substantiation, based on the combined sta-

https://doi.org/10.51488/1680-080X/2026.2-13

tistical and analytical results, of the need for a unified diagnostic system for the sleeper-fastening assembly, linked to fastening type, line classification, climatic zone, and cumulative gross tonnage.

2 MATERIALS AND METHODS

Global railway practice demonstrates a sustained transition from baseplate bolted fastening systems to resilient baseplate-free fastening systems. Bochkarev and Lapushkin [5] reported that resilient fastening systems reduce track maintenance labour requirements and mitigate dynamic loads acting on sleepers compared with the KB-65 fastening system. Based on railway sections in Siberia, Karpuschenko et al. [9] confirmed that the application of resilient fastening systems lowers routine track maintenance costs and reduces the rate of track geometry deterioration. Chudyba et al. [2] experimentally demonstrated that the clamping force of an SKL clip depends not only on tightening torque but also on the thickness and stiffness of the rail pad. Long-term degradation of SKL15 clips was investigated by Choi et al. [11], who reported a significant reduction in clamping force after 16 years of service.

The reliability of the sleeper-fastening assembly has been investigated in a number of analytical and numerical studies. Berezin et al. [12] developed and validated a finite-element model of the ZhBR-65 fastening clip, achieving a stiffness prediction error of 4%. Based on a review of international experience, Solomatin [10] identified the resilient clip as the most critical component of the fastening assembly and highlighted the absence of a standardised methodology for estimating its service life. Kuznetsova [13] demonstrated that the type and condition of intermediate rail fastenings significantly influence the development of rolling contact fatigue defects in rails. Kosenko et al. [4] demonstrated the economic advantages of resilient fastening systems through life-cycle cost assessments of railway track superstructures.

Under JSC «NC KTZ» operating conditions, Zhangabylova [14] employed vibrodiagnostic techniques to compare the performance of ZhBR-65Sh, KPP-5, Pandrol, and Vossloh SKL-14 fastening systems on sections of the Almaty Railway and demonstrated the superior vibration attenuation performance of resilient systems within the rail-sleeper system. Kvashnin et al. [15] further confirmed the more favourable dynamic characteristics of the Pandrol fastening system compared with KPP-5 under field conditions. Zhangabylova et al. [16] recorded normative clamping forces of KPP-5 clips on the Ulenty-Boshakol railway section; however, the measurements were obtained during a single inspection campaign and did not include an assessment of long-term degradation.

Thus, existing publications have examined individual rail fastening systems and their performance characteristics. However, a quantitative assessment of the structural shift in fastening system distribution across the entire JSC «NC KTZ» network during 2017–2025, as well as its relationship with the longitudinal resistance characteristics of CWR track, has not been reported in the open literature. Addressing this gap constitutes the subject of the present article.

2.1 Statistical Database and Selection Criteria

The study is based on data on the length of CWR track installed on reinforced-concrete sleepers across the JSC «NC KTZ» network, classified by type of intermediate rail fastening system for two reference years, 2017 and 2025. The 2025 data were obtained from a report of the Mainline Network Directorate of JSC «NC KTZ», presented at the 6th Eurasian Forum on Transport Safety and Digitalisation [1]. The 2017 data were derived from the doctoral dissertation research of Zhangabylova [14].

The 2025 data were obtained from the official report of the Mainline Network Directorate of JSC «NC KTZ», presented as a plenary paper at the 6th Eurasian Forum on Transport Safety and Digitalisation held at ALT University named after M. Tynyshbayev on 3 October 2025 [1]. The data cover the entire 1520 mm gauge network of JSC «NC KTZ» (operational length 16 008.5 km, including 15 889.7 km of CWR track). Kilometrage was accounted for by aggregating the lengths of

https://doi.org/10.51488/1680-080X/2026.2-13

track sections classified by intermediate fastening system type, based on the operational records of the track maintenance districts.

The analysis included fastening systems installed on reinforced-concrete sleepers with a share of at least 2% of the total track length, while fastening systems used on timber sleepers were excluded. To ensure statistical consistency, Vossloh SKL clip-based fastening systems and GK1 counterparts were combined into the "SKL, GK1 systems" group due to their common design principle: resilient baseplate-free rail fastening using a W-shaped clip. ZhBR-65 and ZhBR-65Sh fastening systems were grouped together as structurally equivalent systems. Pandrol Fastclip systems (76.91 km; 0.48%) and dowel-type fastening systems (3.33 km; 0.02%) were excluded from the analysis because their share of application did not meet the selection threshold. The grouping is performed by structural type, not by manufacturer; GK1 is a functional analogue of the Vossloh SKL family, developed and manufactured in Kazakhstan for the operating conditions of JSC «NC KTZ». A detailed comparative analysis of individual structural modifications (SKL-14, SKL-15, and GK1/GRM AY1) is a subject for future research.

2.2 Technical Characteristics of Rail Fastening Systems

For the comparative evaluation of the fastening systems, technical and regulatory parameters were compiled from GOST 16277-2016, GOST 33186-2014, ST RK EN 13481-2-2012, and the corporate standards of JSC «NC KTZ» [17–20]. The principal characteristics of the fastening systems are summarised in Table 1, while their structural configurations are illustrated in Figure 1.

Table 1 - Principal structural and operational characteristics of intermediate rail fastening systems

№	Parameter	KB-65	SKL, GK1 systems	ZhBR-65/ZhBR-65Sh	KPP-5
1	Sleeper type	Sh1	Type III	Sh3	SB3-2
2	Number of components per sleeper, pcs	21	9	19	7
3	Assembly weight, kg	12.94	1.55	4.68	2.66
4	Steel consumption, kg	10.3	1.49	4.68	2.33
5	Tightening torque, N·m	180-200	180-200	180-200	-
6	Clamping force, kN	-	10	10	10
7	Gauge adjustment, mm	-	±10	-	-
8	Axle load, t/axle	25	25	25	25
9	Cost per set, KZT	49 215	26 270	26 360	22 189

https://doi.org/10.51488/1680-080X/2026.2-13

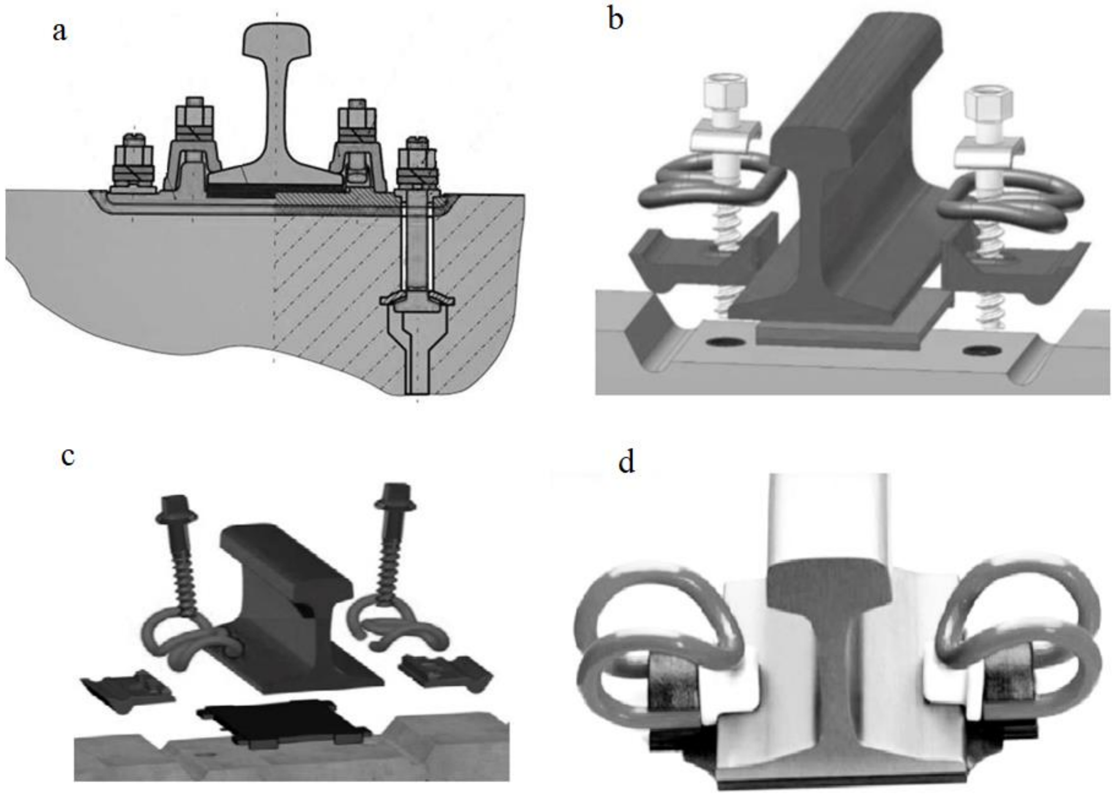

Figure 1 - Structural configurations of the principal rail fastening systems installed on reinforced-concrete sleepers in the JSC «NC KTZ» network: (a) KB-65; (b) ZhBR-65/ZhBR-65Sh; (c) SKL, GK1 systems; (d) KPP-5 [Authors' material]

The KB-65 fastening system is a conventional separate fastening assembly incorporating two layers of pads and providing high resistance to rail creep; however, it requires regular retightening of approximately 16,000 threaded connections per kilometre of track. SKL, GK1 systems are classified as low-maintenance resilient fastening systems with a design service life of 40 years and the capability for track gauge adjustment. ZhBR-65/ZhBR-65Sh fastening systems provide resilient behaviour of the fastening assembly while requiring less steel than the KB-65 system. The KPP-5 fastening system is an anchor-type baseplate-free assembly incorporating a cast-in AZ-2 anchor and containing no threaded connections.

2.3 Analytical Calculation Methodology

The analytical calculations were performed for the KB-65 and SKL, GK1 systems, as these systems are the primary drivers of the structural shift observed across the JSC «NC KTZ» network. In 2025, their combined share accounted for 83.9% of the total track length, while their contrasting trends – a reduction of 909.43 km for KB-65 and an increase of 5,907.84 km for SKL, GK1 systems – constituted the dominant pattern during the study period. Calculations for the ZhBR-65/ZhBR-65Sh and KPP-5 fastening systems are considered a subject for future research.

The longitudinal thermal force in a continuously welded rail track is calculated using Equation (1):

$$N_T = E \cdot A \cdot \alpha \cdot \Delta T \tag{1}$$

where:

N_T – longitudinal thermal force in the continuously welded rail, kN;

E – modulus of elasticity of rail steel, 2.1×10^5 MPa;

A– cross-sectional area of the R65 rail, 8 265 mm^2;

https://doi.org/10.51488/1680-080X/2026.2-13

α– coefficient of linear thermal expansion of steel, 1.18×10^{-5} °C^{-1};

ΔT– design temperature differential adopted for Kazakhstan's operating conditions, 60 °C.

Substitution of the above values into Equation (1) gives:

$$N_T = 2.1 \cdot 10^5 \cdot 8{,}265 \cdot 1.18 \cdot 10^{-5} \cdot 60 = 1{,}228.8 \text{ kN}$$

The longitudinal resistance to rail creep is determined using Equation (2):

$$r = (n_{cl} \cdot \mu \cdot N_{cl}) / a \quad (2)$$

where $n_{cl} = 2$ is the number of clips per rail fastening assembly;

μ is the coefficient of friction between the rail foot and the rail pad ($\mu = 0.40$ for KB-65 and $\mu = 0.50$ for SKL, GK1 systems, according to manufacturers' specifications);

$N_{cl} = 10$ kN is the standard clamping force of a single clip; and a = 0.5435 m is the sleeper spacing corresponding to a sleeper density of 1,840 sleepers per kilometre.

The calculated values of longitudinal resistance are:

$$r_{KB} = (2 \cdot 0.40 \cdot 10) / 0.5435 = 14.72 \text{ kN/m}$$
$$r_{SKL,GK1} = (2 \cdot 0.50 \cdot 10) / 0.5435 = 18.40 \text{ kN/m}$$

The length of the rail "breathing" zone is calculated using Equation (3):

$$L = N_T / r \quad (3)$$
$$L_{KB} = 1{,}228.8 / 14.72 = 83.5 \text{ m}$$
$$L_{SKL,GK1} = 1{,}228.8 / 18.40 = 66.8 \text{ m}$$

A comparative assessment of the calculated parameters for the two fastening systems is presented in Section 3.

3 RESULTS AND DISCUSSION

3.1 Evolution of Fastening System Distribution Across the JSC «NC KTZ» Network (2017–2025)

According to the statistical data of JSC «NC Kazakhstan Temir Zholy», a substantial redistribution in the application of intermediate rail fastening systems installed on reinforced-concrete sleepers occurred during the study period (Table 2).

Table 2 - Track lengths equipped with the principal rail fastening systems on reinforced-concrete sleepers across the JSC «NC KTZ» network (2017 and 2025)

№	Type of fastening system	2017, km	2017, %	2025, km	2025, %	Change, km
1	KB-65	5 749.40	52.3	4 839.97	30.6	−909.43
2	SKL, GK1 systems	2 520.40	22.9	8 428.24	53.3	+5 907.84
3	ZhBR-65/ZhBR-65Sh	1 908.50	17.4	1 740.18	11.0	−168.32
4	KPP-5	813.60	7.4	801.08	5.1	−12.52
5	Total	10 991.90	100.0	15 809.47	100.0	+4 817.57

Note: 2017 data are from Zhangabylova [14]; 2025 data are from Tulepbergenov [1]. Only fastening systems with a share of at least 2% of the total track length were included in the analysis.

https://doi.org/10.51488/1680-080X/2026.2-13

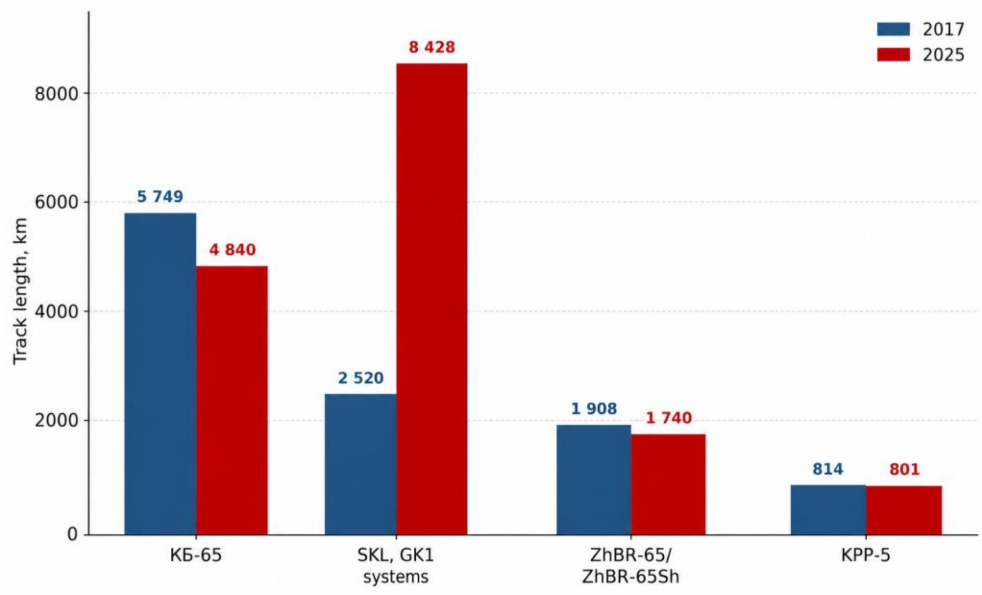

Figure 2 - Track lengths by fastening system group across the JSC «NC KTZ» network in 2017 and 2025 [Authors' material]

The most pronounced growth was observed for the SKL, GK1 systems, with the track length equipped with this fastening group increasing by 5,907.84 km and its share rising from 22.9% to 53.3%. In contrast, the track length incorporating the KB-65 fastening system decreased by 909.43 km, while its share declined from 52.3% to 30.6%. The ZhBR-65/ZhBR-65Sh and KPP-5 systems maintained relatively stable levels of application, with moderate reductions in track length of 168.32 km and 12.52 km, respectively. The evolution of the fastening system distribution over the study period is illustrated in Figure 2.

The cumulative increase in the length of track sections included in the analysis amounted to 4,817.57 km, reflecting the overall expansion of CWR track on reinforced-concrete sleepers throughout the JSC «NC KTZ» network over the study period.

3.2 Results of the Calculation of Longitudinal Resistance and Rail "Breathing" Zone Length

The results of the analytical calculations performed using Equations (1)-(3) for the KB-65 and SKL, GK1 systems are summarised in Table 3.

Table 3 - Results of the comparative calculation of continuously welded rail parameters

№	Parameter	] B-65	SKL, GK1 systems	nit	Remarks
1	Rail cross-sectional area A	8 265	8 265	mm^2	R65 rail
2	Design temperature differential, ΔT	60	60	°C	Kazakhstan operating conditions
3	Thermal force, N_T	1 228.8	1 228.8	kN	Calculated using Equation (1)
4	Coefficient of friction, μ	0.40	0.50	-	Manufacturers' specifications
5	Clamping force, N_{cl}	10.0	10.0	kN	Standard requirements
6	Longitudinal resistance to rail creep, r	14.72	18.40	kN/m	Calculated using Equation (2)
7	Rail "breathing" zone length, L	83.5	66.8	m	Calculated using Equation (3)

https://doi.org/10.51488/1680-080X/2026.2-13

Figure 3 - Longitudinal resistance to rail creep for the KB-65 and SKL, GK1 systems [Authors' material]

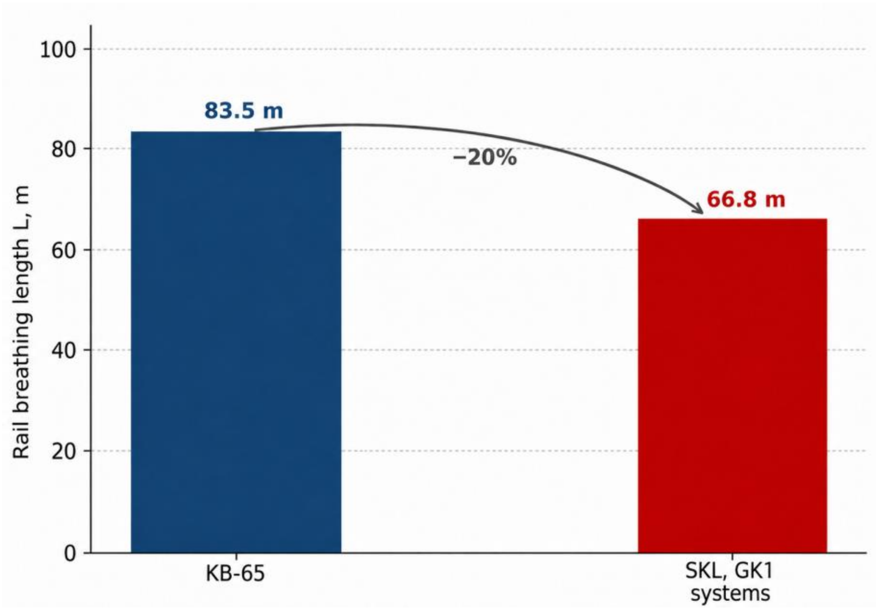

Figure 4 - Rail "breathing" zone length of CWR track for the KB-65 and SKL, GK1 systems [Authors' material]

The calculated values of 14.72 and 18.40 kN/m correspond to the clip-friction partial component of the longitudinal resistance, which characterises the contribution of the rail-foot-to-pad friction under the standard clamping force of the fastening clip. It should be noted that the normative values of 25–30 kN/m reported in [22] refer to the total system resistance of the track structure, which additionally includes the ballast contribution, sleeper–ballast friction, and inertial response of the entire system. Accordingly, the principal methodological result of the present calculation is the relative increase of 25% in the clip-friction partial component during the transition from the KB-65 to the SKL, GK1 systems (from 14.72 to 18.40 kN/m), while the absolute assessment of total system resistance, including the ballast contribution, is a subject for future research. As a consequence of the increased longitudinal resistance, the rail breathing zone length decreases from 83.5 to 66.8 m, reducing the length of rail subject to unrestricted longitudinal displacement.

The reduction in the length of the movable rail section indicates that, under the same thermal loading conditions, rail deformations are concentrated over a shorter distance. This reduces the risk of rail creep and improves the longitudinal stability of CWR track. These findings are consistent

https://doi.org/10.51488/1680-080X/2026.2-13

with recommended longitudinal resistance values of at least 25–30 kN/m for CWR track [22] and confirm the structural advantages of resilient fastening systems under high axle loads and substantial temperature variations characteristic of Kazakhstan's operating conditions.

3.3 Discussion

The observed structural shift in favour of SKL, GK1 systems can be attributed to a combination of technical and organisational factors. From a technical perspective, SKL, GK1 systems provide more resilient behaviour of the fastening assembly, reduce maintenance labour requirements due to the absence of threaded connections, and allow track gauge adjustment of up to 10 mm. In addition, the cost of a fastening set per sleeper for SKL, GK1 systems is approximately half that of the KB-65 system (according to data from domestic suppliers, 2025), providing an additional economic incentive during track reconstruction and major renewal works. The decline in the use of KB-65 fastenings has been further accelerated by the discontinuation of serial production of Sh1-type sleepers.

From an operational perspective, the transition to SKL, GK1 systems requires enhanced monitoring of the polymeric and resilient components of the fastening assembly, as their degradation directly affects clamping force and fastening stability. Previous studies have shown that resilient components of clip-based fastening systems are susceptible to degradation during service life [11]. Under the sharply continental climatic conditions of Kazakhstan, this necessitates systematic monitoring of the sleeper-fastening assembly. The effects of vibrodynamic loading on the condition of the track subgrade and track components under JSC «NC KTZ» operating conditions have also been examined by Apshikur et al. [21].

The ZhBR-65/ZhBR-65Sh and KPP-5 fastening systems continue to occupy a limited application niche without exhibiting significant growth, reflecting their specialised role within the JSC «NC KTZ» network. The findings of this study confirm the global trend towards resilient baseplate-free fastening systems [2; 5] and, for the first time, provide a quantitative assessment of its scale across the JSC «NC KTZ» network. To support the selection of fastening systems based on reliability and life-cycle performance criteria, it is necessary to establish a unified defect recording and monitoring system for the sleeper-fastening assembly, linked to fastening type, line classification, climatic zone, and cumulative gross tonnage.

4 CONCLUSIONS

1. During 2017–2025, a substantial structural shift occurred in the distribution of intermediate rail fastening systems installed on reinforced-concrete sleepers across the JSC «NC KTZ» network. The share of SKL, GK1 systems increased from 22.9% to 53.3% (+5,907.84 km), whereas the share of the KB-65 fastening system declined from 52.3% to 30.6% (−909.43 km). The ZhBR-65/ZhBR-65Sh and KPP-5 systems maintained relatively stable levels of application, with only moderate reductions in track length.
2. The analytical assessment demonstrated that the transition from the KB-65 fastening system to SKL, GK1 systems increases longitudinal resistance to rail creep by 25%, from 14.72 to 18.40 kN/m, while reducing the rail "breathing" zone length of CWR track by 20%, from 83.5 to 66.8 m. These results indicate an improvement in the longitudinal stability of the track structure.
3. The identified trend is consistent with the global transition towards resilient baseplate-free fastening systems and is quantified for the first time for the JSC «NC KTZ» network on the basis of verified operational data covering an eight-year period.
4. On mainline railway corridors subjected to high axle loads and significant temperature variations, priority should be given to the application of SKL, GK1 systems, provided that strict control is maintained over installation quality, anchoring condition, and the clamping performance of fastening clips.

https://doi.org/10.51488/1680-080X/2026.2-13

5. For track sections where KB-65 fastening systems remain in service, enhanced monitoring of threaded connection tightening and the condition of the sleeper anchorage zone is recommended, accompanied by gradual replacement during major track renewal works.

6. The informed selection of rail fastening systems based on reliability and life-cycle performance criteria requires the establishment of a unified defect recording and monitoring system for the sleeper-fastening assembly, linked to fastening type, line classification, climatic zone, and cumulative gross tonnage.

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https://doi.org/10.51488/1680-080X/2026.2-13

ACKNOWLEDGEMENTS / SOURCE OF FUNDING

The study was conducted using private sources of funding.

CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

ARTIFICIAL INTELLIGENCE STATEMENT

During the preparation of this manuscript, the authors used artificial intelligence tools (ChatGPT) solely for editorial assistance, such as improving phrasing and checking grammar, spelling, and punctuation. All ideas, interpretations, and conclusions are the responsibility of the authors, who take full accountability for the content of the article.

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Received 30 April 2026; Revised 12 May 2026; Accepted 22 May 2026

https://doi.org/10.51488/1680-080X/2026.2-13