**Methodology of Experimental Research with the Use of Elastic Sleeper Gaskets in the Butt Zone of Railway Lines of JSC “Uzbekiston Temir Yullari”**

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**Abstract.** The article deals with the method of reducing vibrodynamic force and ensuring stable operation of the railway track in the joint zones with the use of elastic sleeper pads for the movement of heavy-weight and high-speed trains in the areas of Joint Stock Company “Uzbekiston temir yullari”. At the present moment it is expedient to return to the questions of reduction of vibration, oscillations and correction of irregularities of a track in a transverse and longitudinal profile, in joints with laying of elastic elements directly under a sole of reinforced concrete sleepers at crushed stone ballast, that allows plastic properties of elastic sleeper pads do not lead to abrasion and crushing of crushed stone, as in case of ballast contact with concrete sleeper, allowing crushed stone particles in the contact zone to be pressed into the lining material and increasing the service life of track structure materials and thus ensuring stable operation of joint zones, and the methodology of the conducted experimental research is described.

**Keywords:** Dynamics, vibration, joint zone, track faults, trackless track, rail, sleeper, crushed stone, ballast, rolling stock, sleeper pads, subsidence, residual deformation

**INTRODUCTION**

At present, one of the main tasks of railway engineers of the transport sphere of independent Uzbekistan is to increase the speed of freight and passenger trains along the main and industrial directions of the republic's railways.

Significantly increased equipment of railway construction, operation and current maintenance of roads requires improvement of technological processes, methods of their planning and organisation to ensure safe movement of trains, wide use in practice of rational design of works at all levels of repair, increasing the efficiency of railway operation, identification of the use of reserves to reduce the cost of track repair, implementation of a set of measures to save consumption of all kinds of resources and protection of the environment. Further improvement of railway tracks is based on improvement of already known constructions, technological processes, principles and methods of intensification of track works production and on realisation of new constructions. In this respect, one of the scientific and technical directions of development of technical progress is the introduction at all levels of more perfect methods and systems of management, planning and organisation of current maintenance of railway tracks and work of track fitters [1, 2, 3].

In railway transport, the main operational parameters determining the force impact on the railway track are freight intensity, train speeds, rolling stock axle loads, train weight, etc. The vibration impact on railway track elements during the passage of rolling stock wheels, especially in the joint zone, increases significantly. In connection with the increase of train speeds, line load and axle loads, the vibration impact on railway track elements increases significantly during the passage of rolling stock wheels, especially in the joint zone.

Development and optimisation of the railway track has led to an increased need for accurate determination and change of elastic properties and reduction of vibration effects of the track elements. The railway track is an engineering structure that performs heavy work in difficult conditions, trains of large mass with high speeds pass along the track. Wheels of the rolling stock affect the rails with great force, therefore, the protection of railway track elements from the harmful effects of force (vertical and horizontal) and vibration loads is a very urgent problem. When creating new structures, it is necessary to provide for design measures that reduce the level of vibration loads and wheel impact forces. This is achieved, among other things, by introducing sleeper pads of increased elasticity into the design as shock absorbers [4, 5, 6].

The presence of irregularities on wheels and in the track, joint gaps, harmful space, deviations from the norms of track and rolling stock maintenance (within tolerances), as well as non-sprung masses and vibrations of the superstructure lead to the fact that the vertical and horizontal forces transmitted to the rails from mobile loads change rapidly in time. Under the influence of vibration load, there is a weakening of bolted joints, in particular the loosening of joints and intermediate rail fastenings, and this leads to sleeper displacement, ballast prism collapse and the appearance of many defects in the joint zone. It also leads to increased labour costs for tightening bolts, correcting skewed sleepers, filling sleeper boxes with crushed stone.

In railways, the dynamics of rolling stock is of fundamental importance. Increase in speed and transported cargo has led to an increase in vibrodynamic forces and load on the rail, as well as to an increase in vibration and noise, in addition, in the joint zone, an increase in the number of sagging of one or both joints, misalignments, defects in rail geometry, cracks on 4 or 6 hole pads, fracture of lining, fracture and fatigue in the elements of fasteners, fatigue of under-rail and nashpalovye pads, spills, skewed sleepers, cracks and fracture of sleepers, destruction of the geometry of the ballast prism and increases the residual deformations caused by the rolling stock. At elimination of the above presented defects of a way in a joint zone it is foreseen works on current maintenance: urgent, first-priority and planned-preventive. These works are divided into those carried out in time intervals between trains and in technological interruptions included in the train schedule or in specially provided “Windows”. And this leads to an increase in extraordinary costs, additional time for elimination, material demands and the need for manpower.

The main cause of track vibrations is the presence of joints and irregularities on rails and wheels. When wheels pass over unevenness and joints, additional inertial forces of unbraced masses are generated, which in turn cause vibrations of rails, sleepers and ballast.

Deterioration of track geometry as well as noise and vibration have been identified as current problems that need to be reduced, which could be possible by modifying the vertical stiffness of the rolling stock wheelset and obtaining a more uniform value along the track. Increased dynamic overloading, which can accelerate track wear, a problem that is particularly noticeable on tracks with unsuitable values of vertical stiffness, making it necessary to obtain an optimal global infrastructure stiffness.

Wagons together with the railway track form complex dynamic systems with a large number of degrees of freedom. Carriage dynamics is a complex physical process of forces, moments (elastic, friction and inertial), movements of the constituent elements of the car due to the interaction of its running parts and the railway track, as well as locomotives and cars in the train. Changes in the traffic mode, rolling stock and track condition significantly affect the nature of their interaction and serve as one of the main causes of faults of the railway track [7].

This additional impact causes track disturbances, which accumulate in the rail joint zone much more intensively than in the middle part of the rails, and, consequently, in the joint zone there is a much faster failure of the track structure elements. For example, vertical precipitation of the track accumulates in the joint 2 - 3 times more intensively than in the middle of the rail link. In this connection attempts were made to reduce the harmful influence of the rail joint on the track operation.

To ensure long service life of the railway track it is necessary to introduce the latest scientific developments both for the track design as a whole and for individual elements, as well as technological processes for their current maintenance and servicing.

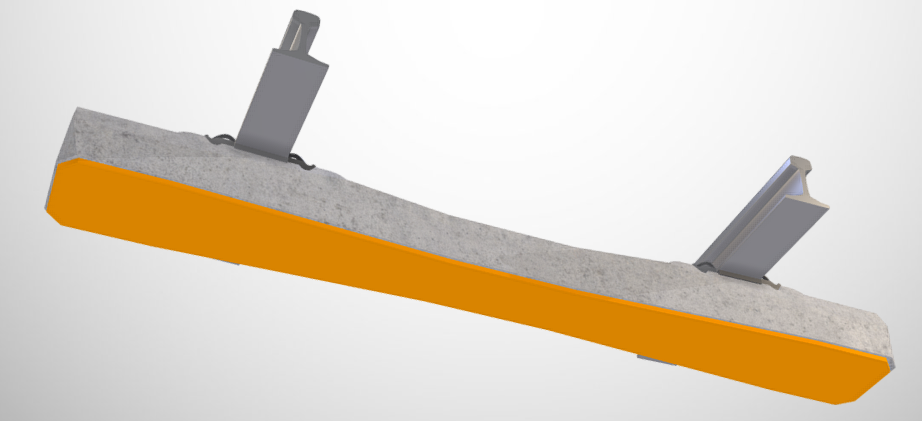
All railway elements work together, and the main task of each element is to distribute the perceived load over as large an area as possible, which reduces the amount of stress on the lower layers of the track. On the way with reinforced concrete sleepers, the acceleration in ballast in the under-rail area next to the sleeper is about 2-3 times greater than on the way with wooden sleepers. Consequently, the ballast for reinforced concrete sleepers is subject to much more intense vibrations than the ballast for wooden sleepers. The impact of rolling stock on the railway track, in particular on the junction zones, has been studied and analyzed for many years in order to significantly improve the technical characteristics of the elements of the upper structure of the track to solve specific problems.

Rails, sleepers, ballast and earthwork make forced vibrations under the influence of these forces and free vibrations under the influence of elastic forces. The rail itself makes complex vibrations - it covers a significant mass of the rail; such vibrations are like an entire beam on elastic supports. A sleeper can have at least two types of vibrations. Some of them represent translational vibrations of it as a rigid body on an elastic base. This shape is characterized by the equality of vibration parameters at all points of the sleeper. Others are bending vibrations. Both types add up. Therefore, the vibration accelerations of the ends of the sleepers are greater than the accelerations measured along the axis of the track. The ballast layer fluctuates differently under the sleeper and in the sleeper box, at different depths, etc.

In the process of interaction between the track and the rolling stock, the vibrations of different elements add up and interfere, resulting in a complex oscillatory process. For practical purposes, it is important to know which track elements are most susceptible to vibration, which vibrations are inherent in rails, sleepers, and ballast, and which vibrations should be isolated from the sub-rail base, and which ones are small and do not pose a danger.

**RELATED WORK**

Thus, at present, the issues of ensuring long-term stability of the track in the butt zone are still relevant. Reducing the stiffness and vibrations of the railway track on reinforced concrete sleepers is possible by changing the stiffness of the intermediate fastening gaskets or by using additional gaskets in the elements, for example, sleepers as shown in the Figure 1. An analysis of the current situation shows that at the moment it is advisable to return to the consideration of the issues of reducing vibration, oscillation and straightening track irregularities in the transverse and longitudinal profile, in joints by laying elastic elements directly under the sole of reinforced concrete sleepers in the butt zone, without violating the caked compacted sleeper bed.



**FIGURE 1.** View of elastic sleeper’s pads

Freight trains in the considered zones (sections) of the track overcome additional bumps at the joints, which create new shock loads on the joint zone from wheelsets, which negatively affect the roadway of the joint and the undercarriage of wagons and locomotives, shortening their service life.

The interaction between the wheelsets of the rolling stock and the railway track appears below the following forces:

1. Vertical forces:

• Forces from the wheelsets of locomotives and wagons;

• Additional forces that occur when driving along a curved section, in the junction areas of the track and uneven train travel.

2. Horizontal forces (longitudinal):

• Friction force during movement and braking of the train;

• Rolling friction force;

• Longitudinal forces resulting from continuous temperature changes on the weaves in a seamless path

3. Horizontal forces (transverse):

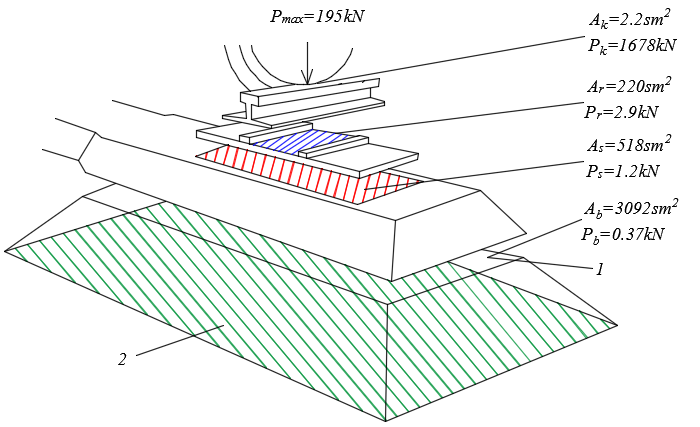
• Guiding force from sinusoidal stroke;

• Centrifugal forces in curves;

• Wind power;

• Additional forces from breaks in the rail.

Dynamic loads from the wheel are transmitted to the rail head over a small area of about 2 sm2 and cause contact stresses up to 1700 MPa as shown in the Figure 2. In the edges of the rail sole, bending stresses reach 340 MPa. The rail distributes the load from the wheel to several sleepers, whose crumple stresses reach 2.9 MPa in the under—rail linings, and 1.7 MPa under the linings. In the ballast under the sleepers, the compressive stresses reach 0.5 MPa. Under the ballast layer on the main surface of the earthbed, the crumpling stresses reach 100 kPa (0.1 MPa). At first glance, these are small stresses, but if we take into account the multiple application of loads from a large number of carriage axles, as well as the weakening of the soil of the main platform of the roadbed from atmospheric influences, the causes of subsidence of the track and its other deformations will become clearer [8].



**FIGURE 2.** Load transfer schemes from the rail to the under—rail base of the track: 1 — the under-sleeper base, 2 - the main platform of the roadbed. Ptt is the load on the rail, kN; Ai is the load distribution area, sm2; Pi is the voltage, N/sm2 [8].

The railway track should be built and maintained in such a way that it can withstand the load and high speed of trains (transport loads) and ensure safe movement, as well as the required comfort on the roads of the republic.

In the sections of Joint Stock Company “Uzbekiston temir yullari”, it is necessary to ensure optimal elasticity of the railway track throughout. This can be achieved only with proper design, construction and operation of the railway track, ensuring the joint operation of each element of the track for their entire service life.

Analyses and research have shown that the higher the load load, the greater the amount of work required for all types of track device repairs. If we plan to eliminate the shortcomings and track work performed, productivity and high-quality work will fit into the “windows”, but at the same time, the capacity of the sections is sharply decreasing and the number of delays for passenger and freight trains is increasing.

To eliminate the shortcomings in the butt zone, the work will have to be done very carefully, bistrot, efficiently and without disrupting the technological process for performing track work.

But the track work performed in the butt zone, more precisely, between the repair work, is carried out for a short time. We, who work in the railway transport sector, must conduct theoretical and full-scale experimental research on the junction area to ensure stable track operation, reduce waste, reduce material consumption and lengthen the time between repairs.

The railway track is under load, during operation it comes into a stressed state and elastic and residual deformations occur in it. Residual deformations (including wear of rails, sleepers, ballast material, etc.) resulting from the operation of the track under load and the effects of natural factors should be minimal, slow-moving over time and evenly manifested along the length of the track.

**MATERIALS AND METHODS**

The process of accumulation of deformations and track disruptions is a consequence of the action of very significant hijacking forces formed during the passage of heavy-duty wagons. Elastic deformations that completely disappear after the load is removed should not be excessively large and vary in magnitude in different sections of the track under the same load.

The above disadvantages lead to the need for a thorough scientific approach to the introduction of additional structures and the calculation of the elements of the sleeper pads. Therefore, it is necessary to conduct field and theoretical experimental studies that could explain the reason for the relative weakness of the joint zones.

The proposed sleeper gaskets are elastic gaskets that are installed on the basis of reinforced concrete sleepers (with the brand Sh-1-1, BF70) and transfer bars of the switch.

These gaskets are characterized by excellent elastic properties for use on ballast tracks. The gasket is installed on top of the ballast, the increased elasticity of the gasket reduces the modulus of elasticity of the rail base and this reduces mechanical loads. This makes it possible to significantly reduce the costs of the current maintenance of the track and repair of the elements of the upper structure of the track in the junction areas. Experimental studies are of great importance for determining the optimal operating conditions of the track in the butt zones using elastic foot pads under a moving load.

Basically, all experimental studies are carried out on sections of Joint Stock Company “Uzbekiston temir yullari” with heavy-duty and high-speed train passage.

The experimental section was located in a straight line in the plan; the usual butt zones (4 butt zones) are selected; rails of type P65 with a length of 12.5 m and 25 m without wear and defects; BF-70 sleepers in the amount of 1840 pieces / km (in one rail–sleeper grid - 23 pieces of sleepers), defective sleepers during experimental studies not used; bonded with the brand Pandrol Fastclip (for comparison, KB65); ballast is crushed stone with a thickness of 35-40 sm, standard according to GOST 7392-20214 (with a rubble size of 25-60 mm) and free of contamination; the roadbed must be healthy.

The assessment of the condition of the experimental section along the passage of the computerized track measuring car (PS - 106, PS - 126) before the experimental study is studied and the butt zones are analyzed.

Conducted experimental studies at the pilot site, when trains pass from the butt zones using elastic sleeper gaskets with different thicknesses, the following are proposed below:

a) № 1 butt zone using elastic sleeper gaskets with a thickness of 5 mm.

b) № 2 butt zone with the use of elastic foot pads with a thickness of 10 mm.

c) № 3 butt zone with the use of elastic foot pads with a thickness of 15 mm.

d) № 4 butt zone with the use of elastic foot pads with a thickness of 20 mm.

A mobile engineering seismometric station (MESS), developed at the Institute of Mechanics and Earthquake Resistance of Structures in 2016, is used to measure the transmission of dynamic characteristics from rolling stock to rail and the lower parts of butt zone structures, without the use of elastic sleeper gaskets and with the use of elastic sleeper gaskets.

Detailed information about the structure of the station, the principle of operation, its preparation for operation, the method of calibration of measuring channels, the method of recording vibrations of an object during dynamic processes is provided in the scientific and technical report [9].

Figure 3 shows a block diagram of a two-channel mobile engineering seismometric station. Each measuring channel includes: an input divider, an amplifier, an analog-to-digital converter (ADC) for all channels, a laptop with software. A seismometer is connected to the input of the measuring channel. The input voltage divider limits the input EMF value of the seismometer to a value at which the input signal has no distortion.

The amplifier amplifies the weak signals of the seismometers. The ADC converts analog signals into a digital code for computer operation. The computer program saves the data coming from the seismometers, processes them and presents them in the form of graphs of fluctuations of the studied area – joint zones in real time on the laptop monitor. During measurements, it uses two channels to the inputs that will be connected to the SM-3 seismometers to measure hydrodynamic forces from rolling stock, during operation of the wheel and the structures of the upper structure of the track and embankment.

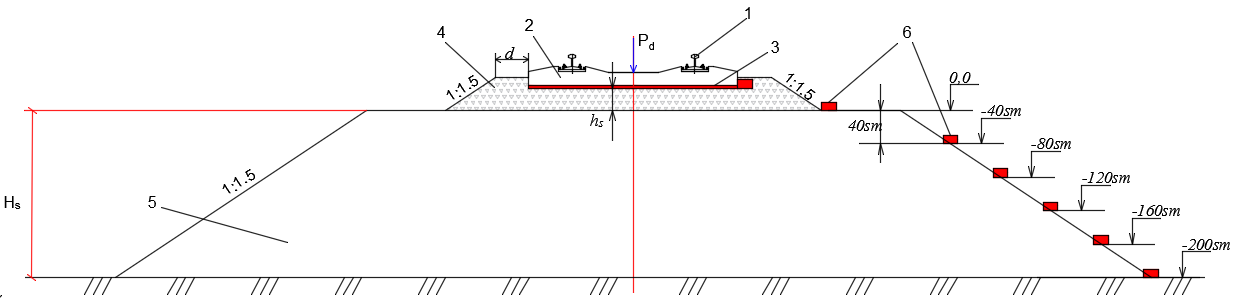
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**FIGURE 3.** Block diagram of a 2-channel mobile engineering seismometric station

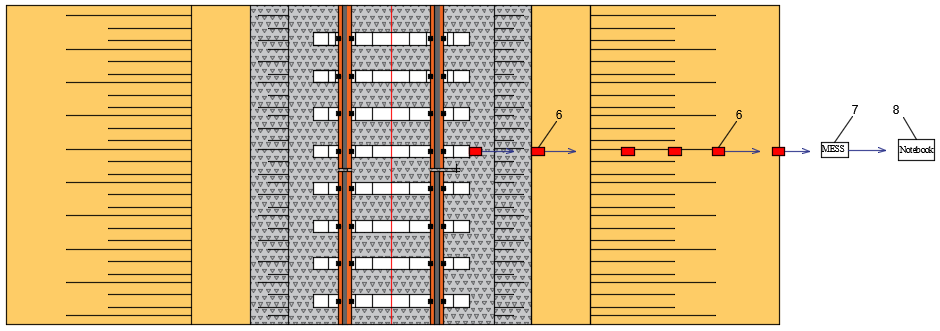
**Selection of measuring points and location of sensors:**

For an experimental study during the passage of rolling stock from the butt zones, it is proposed to measure the revealed dynamic characteristics of vibrations in the structures – MVSP and embankment selected 7 (seven) measuring points as shown in the Figure 4.a, b. The IT-1 measuring point is located in the butt zone at the top of the ballast layer closer to the sleeper, the IT-2 measuring point is located at the end of the ballast prism of the embankment of the main site, the IT-3 measuring point is located from the main site in a 40 sm section on the embankment slope, and the remaining IT measuring points-4-5-6-7 are located on the slope of the embankment with a 40 sm section from each other to the solid ground at the base of the embankment [10].

**а)**



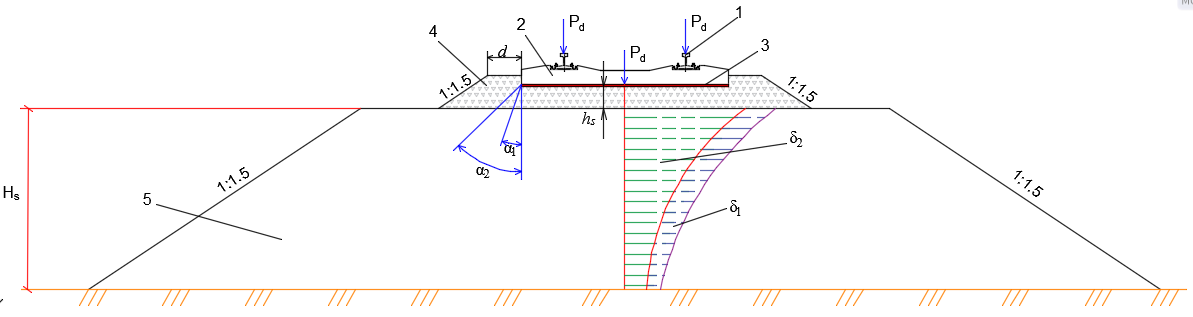
**b)**



**FIGURE 4.** Location of measuring points with seismometers in the butt zone  
a) vertical – transverse locations of points. 1 — rail, 2 – sleeper, 3 – under sleeper pads, 4 – ballast prism, 5 – earth bed,   
6 – SM-3 sensors, hs – the thickness of the rubble under the sleeper, d – the shoulder of the ballast prism;   
b) the location of points from the top of the track, 7 – MESS, 8 – notebook (laptop).

**RESULTS AND DISCUSSION**

During experimental studies, data are taken on dynamic forces and track fluctuations in the butt zones and embankments during the passage of rolling stock using elastic under sleeper gaskets (pads) and without installed under sleeper gaskets (pads) from each 4 butt zones, 7 (seven) measuring points are installed. All data is stored in a laptop and analyzed, as well as a calculation methodology is being developedas shown in the Figure 5 – we can look at the effect of dynamic loads from the wheelset in the lower part of the track with the above diagrams δ1 — without under sleeper pads and the diagram δ2 — with the use of under sleeper pads in the butt zones.



**FIGURE 5.** Diagrams of the plot when using sleeper gaskets, transferring the load from the rail to the track base:  
1 — rail, 2 – sleepers, 3 –under sleeper gasket (pads), 4 – ballast prism, 5 – roadbed, hs – the thickness of the rubble under the sleeper, d – the shoulder of the ballast prism, α1 — the angle of load distribution (pressure) in the ballast layer without under sleeper pads, α2 — is the angle of load distribution in the ballast layer using under sleeper gaskets (pads), δ1 is the load plot without under sleeper gaskets (pads) in the earth bed, δ2 is the load plot using under sleeper gaskets (pads) in the earth bed,   
Pd - dynamic load on the rail, kN

Thus, sleeper gaskets are well suited for applications that are critical in terms of strength and impact resistance, for example, in places where the ballast layer is not sufficient (exposed ends of sleepers, flaws in the sleeper boxes of crushed stone, etc.) and does not provide sufficient elasticity, as well as in places (in the joint zones of link tracks and equalizing spans of a jointless track) subject to very strong horizontal or vertical force impacts resulting from trains running on high-speed or high axle loads. Elastic sleeper gaskets (pads) are also favorable for ballast with a crushed stone layer.

**CONCLUSION**

The use of elastic sleeper gaskets makes it possible to increase the α2 angle of the distributed load, as well as increase the sleeper's support area on the ballast, significantly increase the sleeper's resistance to lateral shear, which in turn is an important factor in ensuring stability during operation of a seamless track. As a result, the stability of the railway track against emissions increases.

The presence of an elastic sleeper gasket (pads) makes it possible to reduce the impact of ↓Pdna dynamic forces and vibrations transmitted from the sleeper to the crushed stone, partially dampening the vibrations of the sleeper.

The received axial loads from the wheelsets are distributed over a larger number of sleepers. The use of elastic sleeper gaskets (pads) reduces the average load on the ballast layer and the roadbed.

The use of elastic sleeper gaskets (pads) on the base of the sleeper in the butt zone reduces the process of wear and defects (17.1, 27.1, 30V.1, 52.1, 53.1, etc.) in the geometry of the rail

The plastic properties of the elastic sleeper gasket do not lead to abrasion and crushing of crushed stone, as in the case of ballast contact with a concrete sleeper, allowing crushed stone particles in the contact zone to be pressed into the gasket material.

**FUTURE SCOPE**

High-Speed Rail Track Stability: With the spread of high-speed railway systems around the world, there is a need to provide more solid and sustainable railway systems. The elastic sleeper gasket provides greater lateral shear resistance and removes the danger of track movement which makes this an important part of the future design of high speed and seamless railway tracks.

Enhanced Vibration Damping of the Passenger Vibration: As passenger comfort becomes more and more of a consideration, particularly when entering and leaving the urban and long-distance trains, elastic sleeper gaskets are able to supply proper damping to vibration. This translates into a smoother ride and less noise pollution nourishing the emergence of quiet, available and comfortable rail transport systems.

Increase Ballast and track life: Elastic sleeper gaskets provide an increase in time between maintenance since they reduce dynamic forces as well as provide a more even dispersion of the load and hence will extend the life of ballast and substructure. The maintenance of future railway networks and systems can incorporate such gaskets in order to limit the deterioration of the ballast and the overall cost of maintaining tracks.

In Smart Railway System: Elastic sleeper gasket could in the future be used together with sensors or intelligent materials to measure pressure, temperature and stress in a real-time scenario. This assimilation will favor predictive maintenance patterns and contribute to enhancing the quality levels of railway safety and effectiveness.

Suitability to Electrified lines and to Heavy Freight Lines: Since the rail systems are becoming more and more electrified and with capacity to carry heavier freights, the elasticity in sleeper gaskets will be of essence in absorbing the higher load weights on the axles and reducing the number of damage on the structural parts. Their application will guarantee better and durable infrastructure in high duty operations.

Sustainability and Environmental Benefits: Reduction of the demands of replacement of ballast and its environmental effects can be increased to a large extent with the use of such elastic materials that minimize the crushing and wearing of the ballast. Potential future trends could be the recyclable or environmentally friendly nature of gasket to adhere to the objectives of having a sustainable infrastructure.

Special Designs in Complex Track Geometries: Future railway construction works can have more complex geometries i.e. tight curves, transition zone, or varying soil. Where this is required, elastic sleeper gaskets can be designed to provide a specific shape, stiffness and material characteristics to satisfy the requirements of particular engineering applications.

Enhanced Preservation of Track Geometry: Elastic sleeper gaskets will have a significant role at the prevention of track geometry wear and impairments in the critical sections of tracks, specifically at rail joints, switches and reduces the regularity of making geometric adjustments.

Long-Term Track Maintenance Costs: Whenever a track is subject to the instalment of elastic sleeper gaskets, the first cost of upgrading the track might be high but, due to wear, others incurred in track maintenance activities, and disappearance of tracks, the cost will be saved within the lifecycle of the track. Such savings are likely to be factored more and more into future economic models of railway investment.

Its Spreading Popularity: With elastic sleeper gaskets showing their utility and strengths, further increases in their popularity are expected as research and practical use multiply and more rail construction standards become built to include elastic sleeper gaskets. This will promote the wider internationalization in the developed and developing railway systems.

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