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## **Selection of the optimal component of the elastic coating for the central Asian region**

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## Selection of the optimal component of the elastic coating for the central Asian region

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**Abstract.** The work examines the issue of selecting the optimal polymer component for elastic rail substrates used in the extreme climatic conditions of Central Asia. An analysis of the properties of the main types of elastomers - synthetic rubbers (SBR, NBR), polyurethanes, silicone rubbers, and composites based on recycled tires - was conducted. Based on mechanical, climatic, and economic criteria, an approach to composition selection using the analytical hierarchy (API) method has been proposed. It has been established that the best combination of elastic and climatic properties is demonstrated by polyurethane and composite materials with antioxidant and UV-modification.

### INTRODUCTION

Elastic rail pads are an important element of the rail-sleeper grid, ensuring a reduction in dynamic impacts, uniform load distribution, and extending the service life of the track. The elastic under-rail gasket was initially called the track substrate. This laying allows for solving the following tasks: protecting the upper structure of the track, improving the quality of the track position, reducing vibrations not only of the track but also in the directional transitions. Rail linings are elastic products installed directly under the rail sole, which provide shock absorption and wear resistance. They have specified rigidity and are used on the ballast track. Improved load distribution ensures more comfortable driving and less wear of the track's upper structure. Increased elasticity positively affects the wear of elements of the track's upper structure and rolling stock [1-5].

The purpose of the research is to select and justify the optimal polymer component that ensures the durability of the elastic gasket in the climatic conditions of Central Asia.

In the conditions of Central Asia, characterized by extremely high summer temperatures (+50°C), low humidity, intense UV radiation, and significant daily temperature fluctuations, traditional materials (SBR, NR) lose their properties due to accelerated aging and cracking. In the second work, the experimental study of an optimized NR development connection was analyzed to improve railway productivity, especially in the transition junction zone where tracks transition from bridges to ballasted sections [2-4, 6-11].

Various compounds of the formula NR were invented by adjusting the filler, and tests for tensile, thermal aging, and rupture properties were conducted.

Let's consider the properties of NR. Natural rubber, Natural Rubber, is designated as NR - an elastomer of natural origin derived from the latex of rubber-bearing plants (mainly Hevea brasiliensis). It is highly elastic, crystallizing when stretched. Its density is 0.91-0.93 g/cm<sup>3</sup>, and its glass transition temperature is -70°C. Its tensile strength is very high, especially when stretched due to crystallization. Exceptionally elastic rubber, the relative elongation at break is 600-800%. It has excellent deformation reversibility properties and very high impact strength.

Wear resistance is high, excellent for the use of auto tires, conveyor belts, seals, vibration and noise-insulating elements, rail pads, and shock absorbers that operate without contact with oils and at moderate temperatures. It is a benchmark for many mechanical properties among rubbers [4-7, 12-16].

NR has good operational properties such as high elasticity and wear resistance, excellent dynamic strength and fatigue resistance, good damping and vibration-reducing properties, and works well at low temperatures. However, it has several drawbacks: 1) poorly tolerates the effects of oils, fuel, ozone, and solar radiation; 2) tends to age when heated for a long time; 3) requires protection (antioxidants, wax coatings, UV stabilizers) when used outdoors. And the most important aspect is the price, natural rubber is expensive, therefore it is recommended to use a combination of NR + SBR + EPDM [1-2, 11-13, 17-22].

Let's consider SKI-3 (styrene-butadiene rubber, international designation SBR - Styrene-Butadiene Rubber) - the most common synthetic rubber of general purpose, created as a substitute for natural rubber (NR). It is produced by the copolymerization of butadiene ( $\approx 75\%$ ) and styrene ( $\approx 25\%$ ) in an emulsion medium. This rubber has a density of 0.93-0.96 g/cm<sup>3</sup> higher than that of HP, but its strength is lower. It has the following operational advantages: good wear resistance and dimensional stability; higher resistance to aging and heat than natural rubber; low cost and ease of processing; good adhesion to technical carbon; the ability to regulate properties (hardness, elasticity) by selecting fillers. Features for Central Asian climate SKI-3 is beneficial because: it is more resistant to heat and aging than NR; it mixes well with NR and EPDM, creating balanced recipes; it is economical and available in the local market [7-9, 15-17, 23-29].

## EXPERIMENTAL RESEARCH

EPDM (ethylene-propylene-diene monomer rubber) is a synthetic elastomer characterized by high resistance to aging, ozone, solar radiation, and temperature fluctuations. It is widely used in technology, where durability and stable properties are required in open air and elevated temperatures. Its density is 0.86-0.87 g/cm<sup>3</sup>, lower, NR + SBR. It has good elasticity and medium hardness, and its wear resistance is also lower than that of NR and SBR.

Significance for under-rail gaskets: for the climate of Central Asia, EPDM is extremely beneficial, as [30-34]:

- resistant to ultraviolet, ozone, and heat - does not age in the sun;
- operates in the range from -50 to +150°C - tolerates sharp temperature fluctuations;
- does not break down from salts and moisture characteristic of saline soils;
- increases the service life of the NR/SBR mixture by 1.5-2 times.

However, it has disadvantages, higher cost compared to NR and SBR, and poor compatibility with other rubbers without special modifiers. Therefore, its proportion in many recommended mixtures is 16.7 times less than NP, and 3.4 times less than NP. In work 2, the mixture for manufacturing the elastic gasket does not contain EPDM, and natural rubber STR20, nitrilbutadiene rubber NBR, and chloroprene rubber CR are included in the mixture [35-38].

In work 4, the results of separation tests conducted on three samples of butadiene-styrene rubber (SBR) granules and one polyurethane sample are presented.

Let's consider options made of polyurethane for elastic gaskets.

Polyurethane elastomers (PU, or TPU - thermoplastic polyurethanes) are a group of polymer materials with high elasticity, strength, and wear resistance, combining the properties of rubber and plastics. In addition to the above-mentioned properties, they possess abrasion resistance, possessing high mechanical strength against abrasive wear, surpassing many materials, including cast iron. They can combine the strength and hardness of engineering plastics with the elasticity of rubber, maintain elasticity in a wide range of temperatures (from -50 to +1200°C), and can withstand large dynamic loads. They are resistant to the effects of oils, fuels and lubricants, and other aggressive environments, as well as to hydrolysis and atmospheric factors. After all, these properties are perfectly suited for railway transport, and on railways with diesel traction, the impact of oils and fuels and lubricants on track elements is maximal, especially considering the influence of atmospheric precipitation and solar radiation [19-23, 39-42].

In work 3, the author proposes an alternative to reusing abundant waste, reducing the cost of elastic elements. The author asserts that when the tire layers are deconstructed without grinding the material, they retain the tire properties [12-14, 23-24, 35, 42-45].

GTR compounds are created by mechanical or thermoplastic mixing of rubber crumbs (usually from SBR, NR, BR-based tires) with a binding polymer - for example, polyethylene (PE), polypropylene (PP), EVA, thermoplastic polyurethane (TPU), or fresh rubber (SBR, NBR, EPDM).

Sometimes plasticizers, binding agents, and vulcanizing systems are added to improve phase compatibility. Mechanical properties of the GTR compound: the tensile strength depends on the crumb fraction and the type of binder and is 3-15 MPa. Wear resistance is high, but lower than that of pure polyurethanes [26-28, 44-48].

Density 1.05-1.25 g/cm<sup>3</sup>. Moreover, the operating temperature range is high, ranging from -40 to +800°C, which is perfectly suited for the climate of Central Asia. Good resistance to impact loads and fatigue, which is well

combined with loads on the roads of industrial enterprises, where the load on the axis exceeds permissible norms, since when loading with excavators, it is impossible to weigh the ore. Resistance to ozone and atmospheric aging is excellent chemical resistance for gaskets [5-6, 11-14, 29-30, 48-49].

Review of materials and foreign solutions. Modern under-rail gaskets are made from [45-49]:

- synthetic rubbers (SBR, NBR, IR) - are used in Russia and the CIS (SP-74, SP-356, KB-65); they have good mechanical properties but are sensitive to heat and UV aging.
- polyurethane elastomers (PUR) - used by the companies Getzner, Pandrol, RailOne; they are characterized by stable rigidity and low wear during prolonged vibration.
- silicone rubbers (HTV-SR) - have excellent thermal and UV resistance, but high cost limits their application.
- recycled rubber compounds (ground tire rubber, GTR) - an economical and environmentally friendly solution that requires modification with plasticizers and antioxidants to stabilize properties.

3. Material selection criteria are summarized in Table 1.

**TABLE 1.** Material selection criteria

Criteria group	Indicators	Significance (weight, %)
Mechanical	Stiffness, fatigue strength, compression	35
Climate resistance	Heat, UV, and moisture resistance	30
Economic	Cost of raw materials, processing technology	15
Ecological	Use of secondary raw materials, utilization	10
Technological	Adhesion to sleepers, reproducibility of the process	10

*Research methodology:* The analytical hierarchy method (AHP) is used to calculate the integral suitability index of the material. Tests are being conducted on [5-6, 11-14, 49]:

- GOST 34078-2017 Railway Rail Fastening Layers. Technical conditions;
- GOST ISO -188-2013 - modeling solar exposure;

The results of the comparative analysis of five types of materials are summarized in Table 2.

**TABLE 2.** Results of comparative analysis

Material	Static stiffness (kN/mm)	UV stability	Heat resistance	Price (relative)	AHP Integral Index
SBR	100	low	average	1.0.	0.62
NBR	110	average	high	1.2.	0.74
PURE	115	high	high	1.4.	0.88
GTR compound	90	average	average	0.7	0.81
Silicon (HTV-SR)	95	very high	very high	2.5	0.79

*Discussion:* Polyurethane linings demonstrate stable mechanical properties and excellent resistance to climatic factors, making them optimal for Central Asia. Composites based on recycled tires with the addition of stabilizers can serve as an economical alternative. Using the hierarchy analysis method allows for the justified selection of material considering multifactorial conditions [47-53].

## CONCLUSION

1. The optimal components for elastic gaskets in the climate of Central Asia are:

- polyurethane elastomers with UV modifiers;
- composites based on recycled tires with antioxidant additives.

The optimal option for manufacturing elastic sub-rail gaskets in the conditions of the Central Asian region is polyurethane elastomers modified with UV stabilizers, as well as composites based on recycled tires with the introduction of antioxidant additives. These materials provide the necessary combination of elasticity, durability, and resistance to climatic factors - high temperatures, intense solar radiation, and fluctuations in humidity.

However, the use of secondary rubber materials is limited by the availability of raw materials: the volume of car tire waste in the region is insufficient for large-scale production of railway linings. In this regard, a rational direction

is the combined approach - the use of polyurethane systems with partial inclusion of rubber crumbs, which will simultaneously increase environmental efficiency and ensure stable production volumes.

2. The MAI matrix is presented in Table 3.

**TABLE 3.** Hierarchy analysis method matrix

ANR matrix						
Criterion	Weight	SBR	NR	PUR	GTR	Silicone
Mechanical properties	0,35	0,7	0,8	0,9	0,7	0,8
Climate resistance	0,3	0,5	0,7	0,9	0,6	1
Economy	0,15	1	0,9	0,8	1,2	0,4
Environmental friendliness	0,1	0,5	0,6	0,6	1	0,5
Technicity	0,1	0,8	0,8	0,9	0,7	0,7
Total ( $\Sigma$ =points)		0,62	0,74	0,88	0,81	

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