

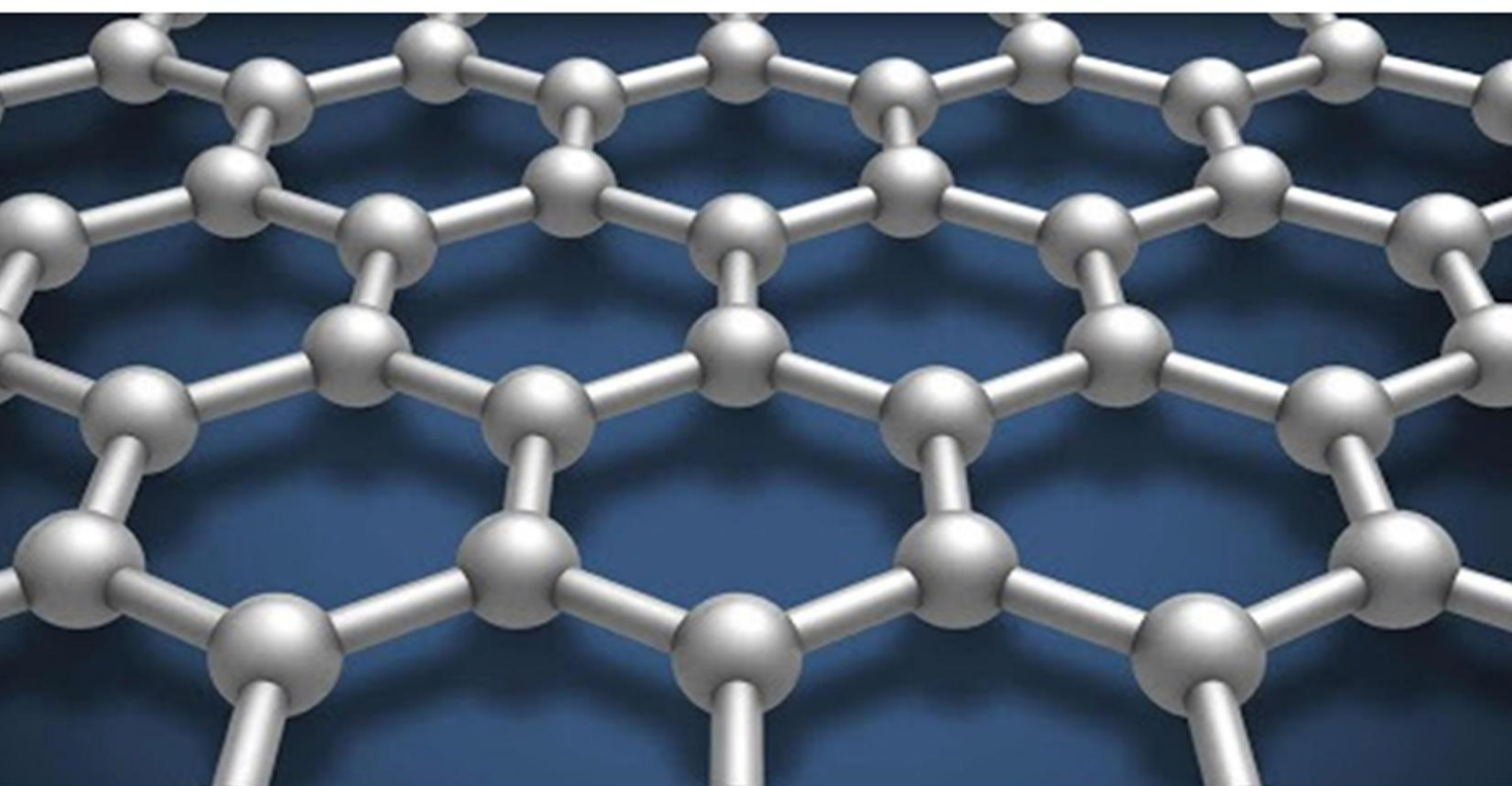
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INVESTIGATION OF THE PHYSICOCHEMICAL PROPERTIES OF ROAD BITUMEN OBTAINED FROM LOCAL BITUMINOUS ROCKS

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Abstract. This study investigates the physicochemical, structural, and operational properties of road bitumen obtained from local bituminous rocks and compares them with commercial 60/90 penetration-grade petroleum bitumen. FTIR analysis revealed characteristic absorption bands at 2920 and 2850 cm⁻¹ for aliphatic -CH₂- and -CH₃ groups, around 1600 cm⁻¹ for aromatic C=C bonds, and at 1455, 1375, 1100-1000, and 870-720 cm⁻¹ for hydrocarbon, oxygen-, sulfur-containing, and aromatic structures. SEM-EDS results confirmed a carbon- and sulfur-rich matrix containing minor Mg and Ca components, while the rock-derived sample exhibited a rougher and more heterogeneous microstructure. The obtained bitumen showed penetration values of 73 × 0.1 mm at 25 °C and 25 × 0.1 mm at 0 °C, a softening point of 52 °C, a breaking temperature of -16 °C, a flash point of 235 °C, and ductility values of 58 cm at 25 °C and 3.7 cm at 0 °C. Its adhesion reached 92%, exceeding the 80-85% range of standard bitumen.

Keywords: local bituminous rocks, road bitumen, physicochemical properties, functional groups, morphological characteristics.

Introduction. Road bitumen is one of the principal binding materials used in the construction, repair, and maintenance of asphalt pavements [1]. Its performance is largely determined by its physicochemical composition, rheological behavior, adhesion to mineral aggregates, resistance to temperature fluctuations, and stability under traffic loads [2-3]. The increasing demand for road-building materials, together with the limited availability and relatively high cost of conventional petroleum bitumen, has stimulated research into alternative local raw-material sources for producing bituminous binders [4-5].

Natural bituminous rocks are promising mineral-organic raw materials containing native bitumen distributed within sandstone, limestone, clay, and other rock matrices [6]. Depending on their origin and geological formation conditions, these rocks may differ significantly in bitumen content, mineral composition, density, moisture, ash content, and the structural characteristics of their organic fraction [7]. Appropriate processing of such raw materials makes it possible to separate or concentrate the bituminous component and obtain a binder suitable for road-construction applications [8]. The use of local bituminous rocks may reduce dependence on imported petroleum products, improve the utilization of regional mineral resources, and decrease the production cost of road-binding materials [9-10].

Materials and methods. Bitumen obtained from local bituminous rock was investigated and compared with commercial 60/90 penetration-grade road bitumen. Before analysis, both samples were heated to a homogeneous fluid state, thoroughly mixed, cooled, and stored in sealed containers. Functional groups were analysed by FTIR spectroscopy in the mid-infrared region, while surface morphology, elemental composition, and element distribution were examined using SEM-EDS and elemental mapping. Operational properties, including penetration, softening point, ductility, flash point, density, water content, solubility, and adhesion, were determined using standard laboratory methods and calibrated equipment. All analyses were performed under identical controlled conditions, and repeated measurements were averaged.

Results and discussion. The physicochemical and structural characteristics of the bitumen obtained from local bituminous rock were evaluated and compared with those of standard 60/90 road bitumen. The comparative analyses were performed to determine the similarity and differences between the two bituminous materials.

The FTIR spectra of the standard 60/90 road bitumen and the bitumen obtained from local bituminous rock are presented in Figure 1.

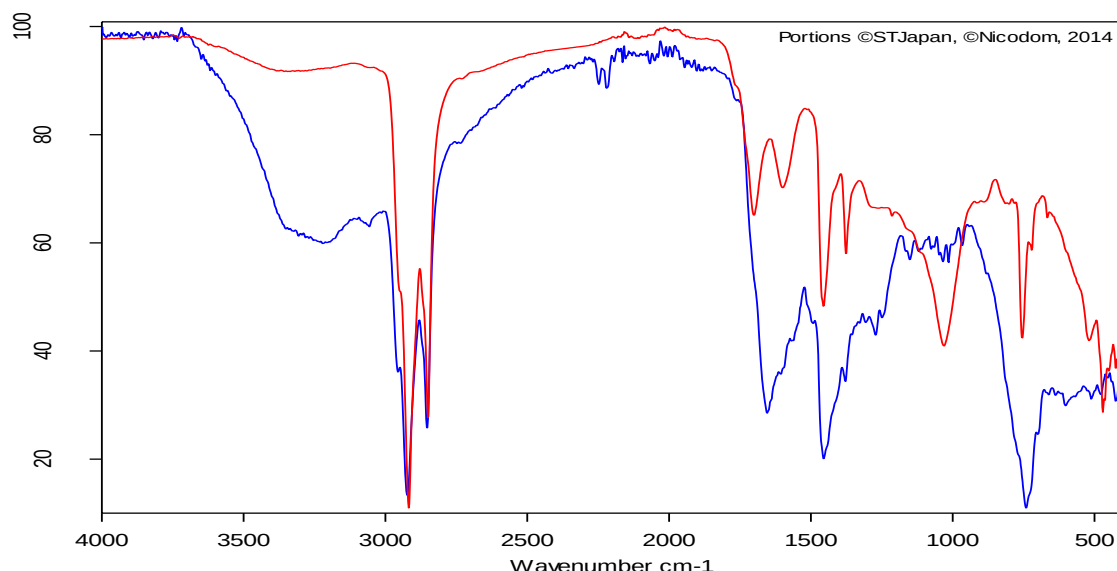


Fig. 1. FTIR spectra of standard 60/90 road bitumen and bitumen obtained from local bituminous rock

The FTIR spectra of both samples showed characteristic bituminous hydrocarbon bands at 2920 and 2850 cm^{-1} for aliphatic $-\text{CH}_2-$ and $-\text{CH}_3$ groups, near 1600 cm^{-1} for aromatic $\text{C}=\text{C}$ bonds, and at 1455-1375 cm^{-1} for methyl and methylene vibrations. Bands at 1100-1000 and 870-720 cm^{-1} indicated oxygen-, sulfur-containing, and aromatic structures.

The close similarity of the spectra confirms that the rock-derived bitumen has a molecular structure comparable to standard 60/90 road bitumen.

The SEM images and elemental mapping results of the standard 60/90 road bitumen and the bitumen extracted from local bituminous rocks are presented in Figure 2.

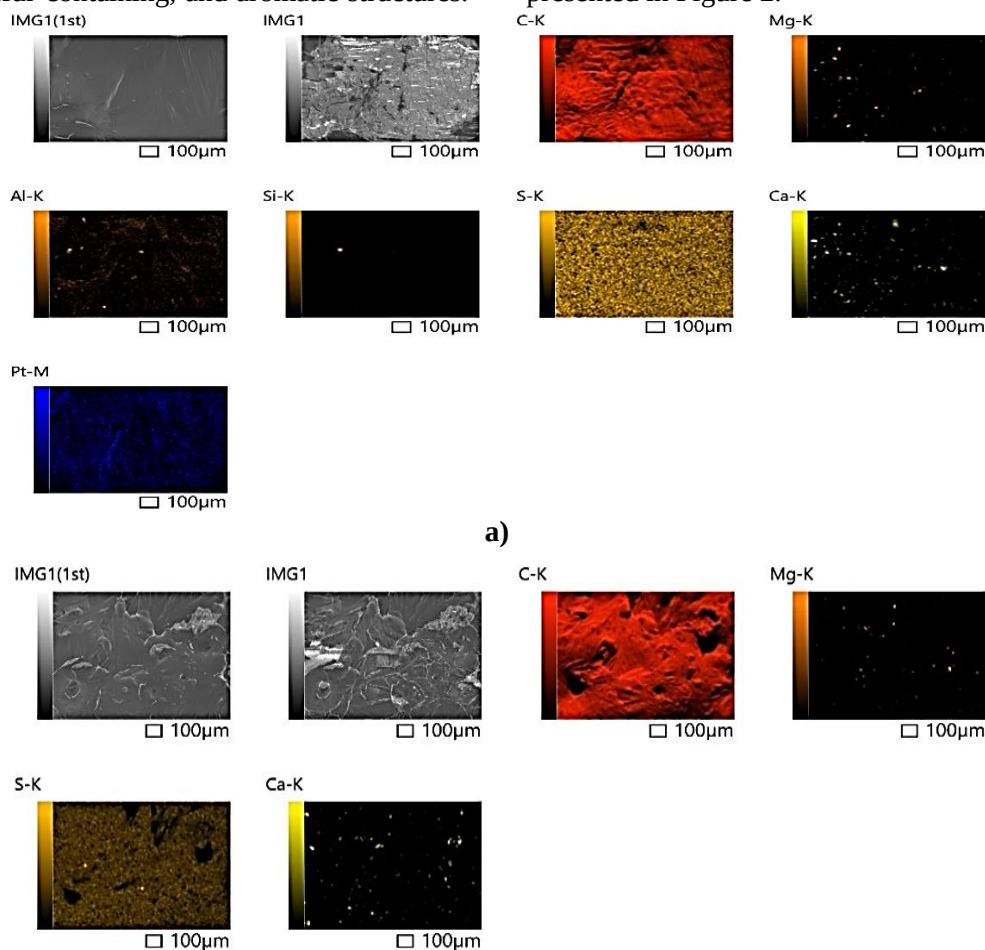


Figure 2. SEM micrographs and elemental mapping of (a) standard 60/90 road bitumen and (b) bitumen extracted from local bituminous rock

The SEM micrographs reveal noticeable differences in the surface morphology of the investigated bitumen samples. Standard 60/90 road bitumen exhibits a relatively dense, smooth, and homogeneous surface with fine directional features. In contrast, the bitumen extracted from local bituminous rock has a rougher and more irregular morphology, characterised by folded, layered, and locally heterogeneous surface regions. Such morphological differences may be associated with variations in the proportions of oils, resins, asphaltenes, and residual inorganic components in the samples.

Elemental mapping shows that carbon is widely distributed throughout the analysed surfaces of both bitumen samples, confirming the predominance of the organic hydrocarbon phase. Sulfur also demonstrates a broad distribution in both samples,

indicating the presence of sulfur-containing compounds within the bituminous matrix. Magnesium and calcium are detected as sparsely distributed localised particles, which may originate from minor inorganic components.

In the standard 60/90 road bitumen, aluminium and silicon signals are also observed in several local regions. Their presence may be related to trace mineral impurities or inorganic particles contained in the sample. Aluminium and silicon maps were not presented for the bitumen extracted from the local rock; therefore, their complete absence cannot be concluded without quantitative EDS data.

The EDS spectra showing the characteristic elemental peaks of the standard 60/90 road bitumen and the bitumen extracted from local bituminous rock are presented in Figure 3.

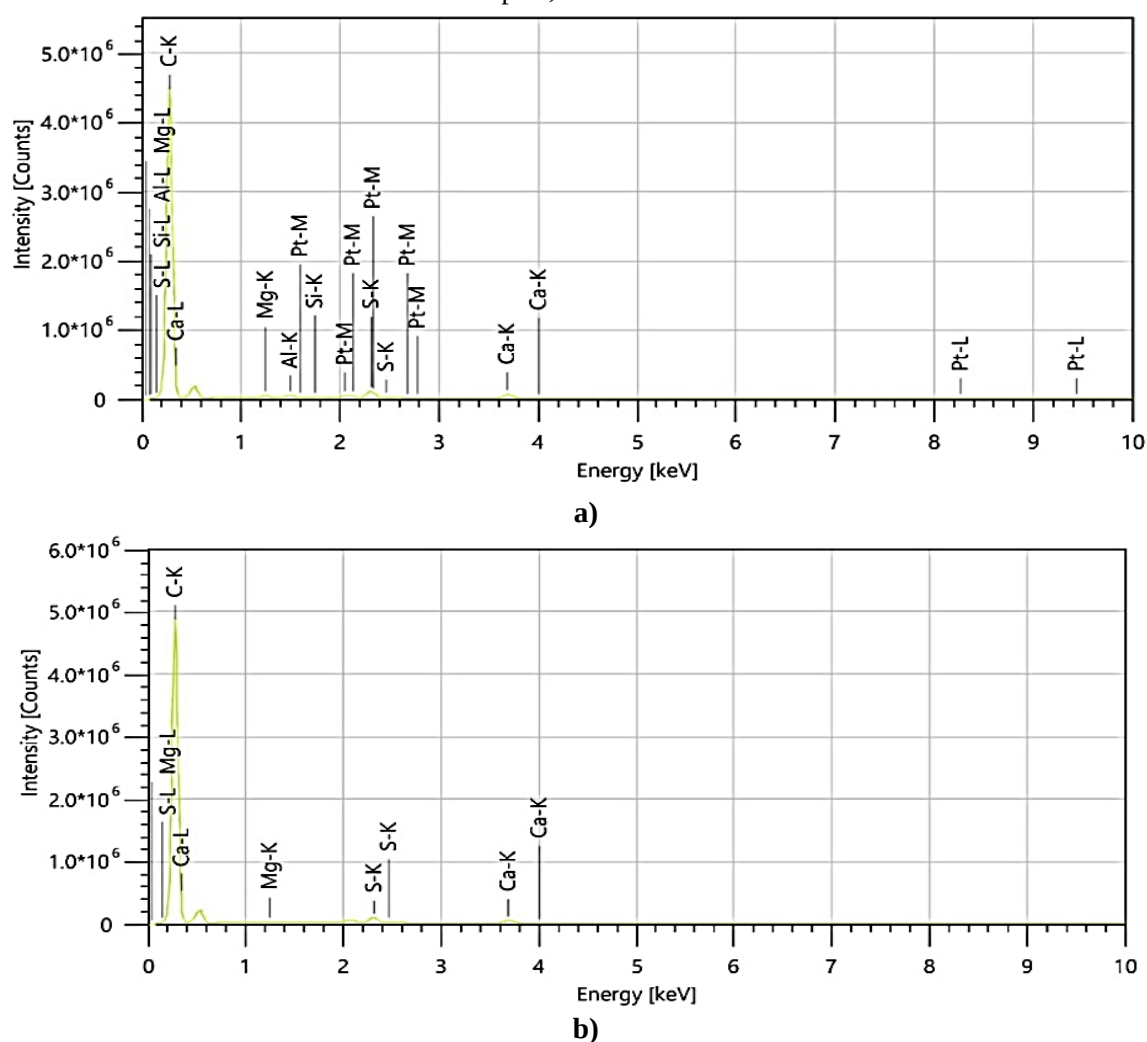


Figure 3. EDS spectra of (a) standard 60/90 road bitumen and (b) bitumen extracted from local bituminous rock

The EDS spectra of both bitumen samples were dominated by carbon, with sulfur, magnesium, and calcium also detected. Standard 60/90 bitumen additionally contained aluminium, silicon, and platinum, the latter originating from the conductive coating. The rock-derived bitumen showed a simpler

elemental composition, suggesting effective removal of most silicate and aluminosilicate impurities during extraction and purification. The comparative results for both bitumen samples are presented in Table 1.

Table 1.

Comparison of the Operational Properties of Standard 60/90 Road Bitumen and Bitumen Obtained from Local Bituminous Rock

Property	Standard 60/90 road bitumen	Bitumen obtained from local bituminous rock
Penetration at 25 °C, 0.1 mm	61–90	73
Penetration at 0 °C, 0.1 mm	20	25
Softening point, °C	47	52
Breaking temperature, °C	–15	–16
Flash point, °C	230	235
Ductility at 25 °C, cm	55	58
Ductility at 0 °C, cm	3.5	3.7
Adhesion, %	80–85	92

The bitumen obtained from local bituminous rock demonstrated operational properties comparable to standard 60/90 road bitumen. Its penetration values were 73×0.1 mm at 25 °C and 25×0.1 mm at 0 °C, indicating suitable consistency and slightly improved low-temperature deformability. The breaking temperature decreased from –15 to –16 °C, while the softening point increased from 47 to 52 °C, suggesting enhanced resistance to both low-temperature brittleness and high-temperature deformation. The flash point reached 235 °C compared with 230 °C for the standard sample. Furthermore, ductility increased from 55 to 58 cm at 25 °C and from 3.5 to 3.7 cm at 0 °C, confirming slightly improved plasticity, extensibility, and thermal stability.

Conclusion. The bitumen obtained from local bituminous rock exhibited physicochemical and structural characteristics similar to those of standard 60/90 road bitumen. FTIR and SEM–EDS analyses confirmed the formation of a carbon-rich bituminous matrix containing sulfur and minor mineral components. The obtained bitumen showed a penetration of 73×0.1 mm at 25 °C, a softening point of 52 °C, a breaking temperature of –16 °C, a flash point of 235 °C, and a ductility of 58 cm. Its adhesion reached 92%, exceeding the 80–85% value of the standard bitumen. These results demonstrate that local bituminous rocks can be considered a promising raw material for producing road bitumen with suitable operational properties.

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