

# INNOVATIVE COMPOSITES MADE FROM RUBBER WASTE

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## Abstract

*In recent years, there has been significant focus on utilizing production and household waste to create polymer composites. These composites can be employed either independently or in a modified form, and can also serve as additives. The aim of our study was to develop composite materials using epoxy resin and household rubber waste and to evaluate their properties. We tested various aspects, including water absorption, flexural strength, and adhesion.*

**Keywords:** adhesive, rubber, composite, ecology, epoxy resin

## I. Introduction

Today, no country is free from issues related to waste management. This is especially true in large nations with high populations, where both domestic and industrial waste can reach enormous volumes. Landfills consume vast areas of land and contribute to soil, air, and water pollution, which often leads to various diseases and epidemics. Thus, a comprehensive approach to waste management is essential to address these challenges. The primary objective is to minimize both domestic and industrial waste. People often dispose of garbage in landfills, rivers, or valleys, making waste a significant source of environmental pollution. Typically, waste is "disposed of" by being dumped in landfills, where it is then crushed and covered with layers of soil. It may seem as though the waste has "disappeared" once buried, but this is not the case. Waste is just hidden underground and remains a significant environmental concern. Decomposing waste generates harmful gases that are released into the atmosphere, and rainwater infiltrates the waste, becoming contaminated with its harmful substances. If a landfill lacks a system to collect and treat this contaminated runoff, the polluted water can eventually mix with groundwater or rivers, leading to severe pollution. Additionally, some waste decomposes very slowly, taking decades to break down while continuously polluting air and water. On a positive note, silicon-containing compounds can enhance the properties of composite materials. Epoxy resins, known for their excellent physical, mechanical, and technological characteristics, are widely utilized in creating various materials, including heat-sensitive adhesives and composites designed for extreme conditions [1-10].

Our objective is to develop new construction materials using recycled rubber waste, epoxy resin, and ethyl silicate. By incorporating rubber waste, we not only recycle household waste but also contribute to environmental improvement. These materials stand out from other options due to their

cost-effectiveness, user-friendly technology, and resistance to microorganisms. Additionally, they meet all contemporary standards for building materials.

## II. Experimental part

**Processing.** In a specialized mixer, we combine epoxy resin, ethyl silicate, and rubber waste in varying proportions. After adding a stabilizer, we thoroughly mix the components. The mixture is then poured into specific molds and left to set overnight. The following day, we remove the material from the molds, conduct a thermostatic treatment, and proceed with testing.

**Fourier transform infrared spectra** were determined with a Varian 660-IR FT-IR Spectrometer. The KBr pellets of samples were prepared by mixing (1.5–2.0) mg of samples, finely grounded, with 200 mg KBr (FTIR grade) in a vibratory ball mixer for 20 s.

Microstructure of the samples was studied by NMM-800RF/TRF type of optical microscope SEM and EDS observations were conducted. Measurements were performed under a microscope - Tescan Vega 3, LMU, LaB 6 cathode. Maximum accelerating voltage was 30 kV, resolution 2.0 nm. The microscope was also equipped with an energy dispersive spectrometer of X-ray-induced electron beam specimens (EDS, Oxford Systems). EDS was used to analyze the sample compositions.

**Impact viscosity** determination, also called *shock viscosity* determination, is a technique applied to soft solids and is essentially a drop impact test. The drop height  $h$  is the vertical distance between the upper surface of the tested material ( $h_1$ ) and the bottom surface of the drop hammer at the end of the impact event ( $h_2$ ). With the sample mass  $m$  and the acceleration  $g$ , the work performed by the falling hammer is  $mg(h_1 - h_2)$ , anormalized with respect to the horizontal cross-section of the specimen.

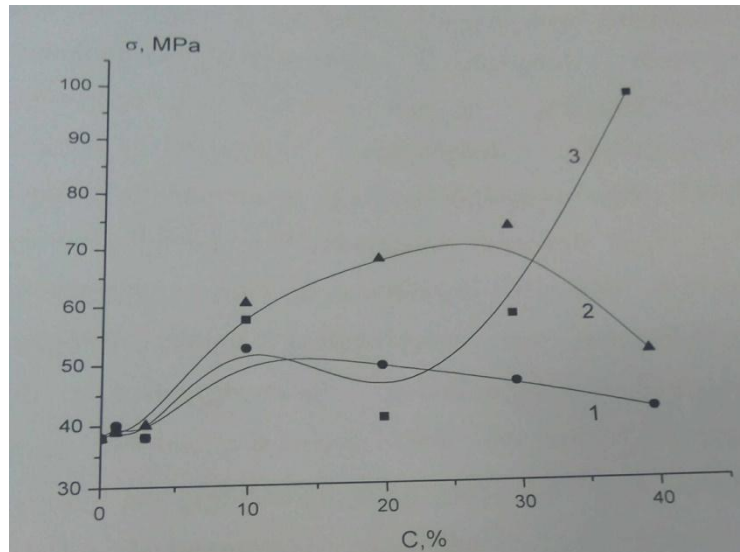
**Vicat softening depth** consists in the determination of the depth of the indentation with respect to the top surface caused by a flat ended indenter with the cross-section of 1 mm<sup>2</sup>. The load applied is 10 or 50 N and the cross-section of the indenter end is circular. The term *Vicat hardness* is also in use – really confusing since larger values correspond to lower hardness.

**Water absorption** is determined simply as the percentage weight change of the sample after submersion in water. We have performed such measurements after 3 hours and 24 hours exposition to water

## III. Results and discussions

Composites were produced using epoxy resin, rubber waste, and ethyl silicate, and were subjected to testing. We determined the strength limit of the composites and examined how it depended on both the content of rubber waste and its modification with ethyl silicate. Based on the curves shown in Fig. 1, we observed an increase in the strength limit of the epoxy resin-based composites with varying concentrations of rubber waste. The three curves presented in the figure exhibit both qualitative and quantitative differences. The first curve represents the strength limit as it relates to the amount of unmodified rubber waste. This curve displays a broad peak, illustrating the well-known relationship between composite strength and filler concentration. The mechanical strength of composites containing unmodified rubber waste peaks at relatively low concentrations (10-20%). In contrast, rubber waste modified with ethyl silicate (3-5%) significantly enhances the mechanical strength of the composite, shifting the maximum strength to higher concentrations of rubber waste (as shown in curves 2 and 3). This finding is practically important: the more mineral fillers a polymer composite includes, the lower its intrinsic cost. Curve 3 shows an interesting trend: a single peak is observed at relatively low filler concentrations, while at higher concentrations, the curve becomes disrupted. This disruption occurs because achieving high filler content in composites is

technically challenging, primarily due to difficulties in uniformly distributing the filler within the polymer matrix.



**Figure 1:** Dependence of the strength limit of ED-20 + rubber residue composites on the content of rubber residue for

The curves indicate that finely dispersed rubber tire powder significantly enhances both the mass density and strength of the composites compared to those with the same concentrations of unmodified rubber. The addition of ethyl silicate, a modifier, greatly impacts the mechanical properties of the composites. The siloxane compound on the rubber grain surfaces activates them, and during heat treatment, ethyl silicate likely forms bonds with the macromolecules of the epoxy resin. It fills the gaps between polymer blocks and creates a "buffer" zone between the rubber and the polymer. This interaction between the epoxy resin and ethyl silicate results in the formation of additional physical, Van der Waals, sorption, and chemical bonds, which collectively enhance the mechanical strength of the composites compared to their unmodified counterparts. Epoxy resin composites filled with modified rubber powder demonstrate better compatibility compared to those with unmodified rubber, as evidenced by superior mechanical strength indicators. The mechanical stresses in the composite, whether from compressive or tensile forces, are effectively absorbed by the relatively soft siloxane phase. This phase helps to limit and contain the development of microdefects within the carbon chain matrix, thus reducing the overall thickness of the composite. These structural improvements are also reflected in the thermo-mechanical properties of the materials. Composites with rubber residues modified with ethyl silicate exhibit a higher and more consistent softening temperature compared to those with unmodified rubber residues. This behavior correlates well with the mechanical strength values, suggesting that the modified filler has a stronger interaction with the polymer molecules through the modifier than the unmodified filler.

The enhanced compatibility of rubber residues in the carbon chain matrix of the composite, facilitated by ethyl silicate, is evident from the water absorption properties. Table 1 reveals that increasing the filler concentration generally leads to larger microstructures and the formation of interconnected or isolated microvoids, resulting in higher water absorption rates. However, composites with rubber residues modified by ethyl silicate exhibit significantly lower water absorption rates compared to those with unmodified rubber residues. This reduction can be attributed to the well-known hydrophobic nature of siloxane compounds, which greatly decreases water absorption in composites with modified fillers.

**Table 1:** *Dependence of Composite Water Absorption on Ethyl Silicate Content*

Rubber Residue Content	Ethyl Silicate Content	% of water absorption after 3 hours	% of water absorption after 24 hours	Density
10	0	0	0	1.1252
20	0	0.08	0.12	1.2332
40	0	0.14	0.36	1.2546
10	3	0.053	0.108	1.2198
10	5	0.032	0.100	1.2341
20	3	0.062	0.116	1.2455
30	5	0.072	0.266	1.2678

It has been established that ethyl silicate enhances the hydrophobicity of the composite by a factor of four at a 10% concentration, while also increasing both the softening temperature and mechanical strength. The modification of rubber residues with 3% and 5% ethyl silicate leads to a significant increase in the composite's mechanical strength up to a certain concentration of rubber residues. The strength dependence curve for these modified composites shows a peak much higher than that of composites filled with unmodified rubber waste. Specifically, composites with 5% ethyl silicate-modified rubber waste exhibit substantially greater maximum strength compared to those with 3% ethyl silicate-modified rubber waste. All composites incorporating ethyl silicate-treated rubber waste demonstrate notable hydrophobic properties.

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