2025. Volume 9, Number 2 Pages 157-160

UDC: 614.842.61:674.048
DOI: https://doi.org/10.30546/2521-6317.2025.02.534

SYNTHESIS OF A FIRE-RETARDANT EUF MODIFIER FOR WOODEN STRUCTURAL CONSTRUCTIONS AND INVESTIGATION OF THE PROPERTIES OF A LIQUID GLASS-BASED COMPOSITION

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ARTICLE INFO

Article history:
Received: 2025-06-13
Received in revised form:2025-06-21
Accepted: 2025-07-19
Available online:2025-12-25

Keywords:
organic modifier, liquid glass, extraction, composition, oligo(poly)mer, DMSO, modification, diurethane, formaldehyde.

ABSTRACT

This article presents the analytical results of a scientific study devoted to one of the most relevant current problems, namely the fire protection of wooden building structures and the synthesis of compositions based on organic modifiers for this purpose. The modification of liquid glass, which makes it possible to significantly change its main properties, was studied in accordance with the SST standard, based on the modifier extraction method and the results of testing its thermal properties, which demonstrated a decrease in mass.

1. INTRODUCTION

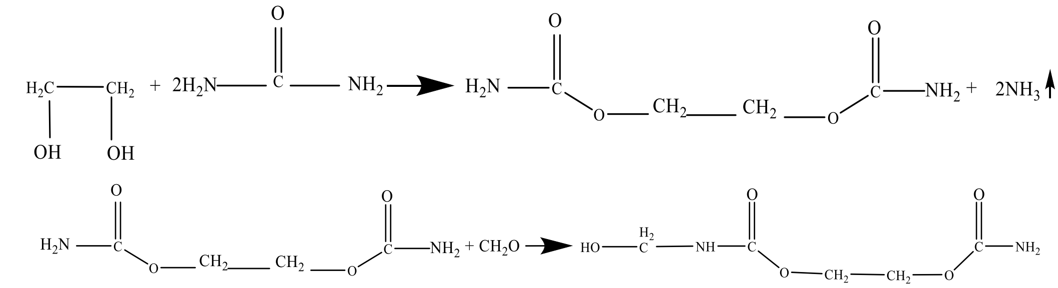
The global construction industry is developing rapidly, primarily due to the growing demand for modern building and structural systems, which stimulates the improvement of their fire protection efficiency. Fire statistics clearly show that fires on a global scale have a negative impact not only on the economy but also on human life. Therefore, preventing the ignition of building structures, especially wooden materials, is of great importance. The use of local raw materials in the development of thermal insulation compositions leads to the creation of new products capable of replacing imported materials. The selection of liquid glass as a base material and the utilization of its properties as a coating make it possible to obtain coatings with localized thermal insulation properties.

To regulate the properties of liquid glass, it is modified using specific additives employed in the synthesis of its components. The modification of liquid glass, that is, the introduction of new organic bonds and changes in the composition of Na2SiO3, makes it possible to significantly expand its field of application. All additives used for the modification of liquid glass are divided into six types: acidic, precipitating, saline, hydrophilic, binding, and organic modifiers. Acidic additives reduce the alkalinity of the system and promote the formation of polysilicate ions, which increases the elastic modulus of liquid glass. Their advantage lies in the fact that, in addition to binding alkali, they release silicic acid during decomposition, which significantly densifies the hardening system [2].

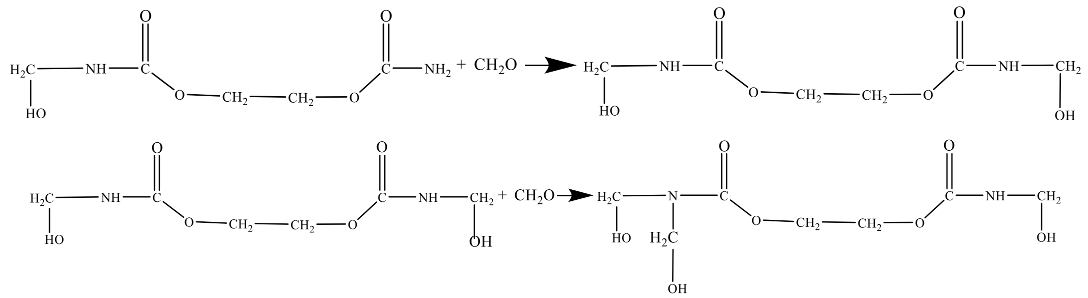
The selection of an organic modifier in the system primarily leads to a significant increase in the adhesion of liquid glass to various surfaces, which is considerably higher than that achieved with inorganic modifiers, thereby expanding its range of applications. In general, without compromising the operational characteristics of the material, this makes it possible to improve not only thermal properties but also adhesion, elasticity, plasticity, and viscosity. However, organic modifiers are not without disadvantages, namely their tendency toward coagulation, and this problem is resolved through the use of an emulsifier.

2. EXPERIMENTAL PART

During the synthesis process, appropriate reagents were selected, and the resulting product was synthesized under specified temperature and time conditions. The correct selection of reaction conditions is essential for the formation of an oligo(poly)mer with the desired thermal properties.



The formed diurethane reacts with formaldehyde to produce an oligo(poly)mer in accordance with the following reaction equation. Depending on the amount of formaldehyde, mono-, di-, or highly methylolated derivatives are formed. The ratio of the components is selected based on the intended application of the resulting derivative.



At the end of the process, a ready-to-use EUF modifier with a white–brown color and viscous consistency was obtained. The isolation of the synthesized compounds was carried out using the conventional extraction method. The resulting oligo(poly)mer was purified by extraction using various solvents. In particular, when dissolving the reagent and the synthesis product in alcohol, ethylene glycol and formaldehyde were dissolved, urea dissolved in small amounts, while the EUF modifier remained insoluble. A similar procedure was performed using other solvents. The extraction results are presented in the following table (Table 1).

Table 1. Solubility of Reagents and Products in Solvents

Solvents	Reagents and Products			
	Ethylene glycol	Urea	Formaldehyde	EUF
Water	dissolved	dissolved	dissolved	dissolved at 70-80 ^{0}C
Ethanol (Alcohol)	dissolved	partially dissolved	dissolved	partially dissolved
Benzene	insoluble	insoluble	insoluble	insoluble
Hexane	dissolved	insoluble	dissolved	partially dissolved
Dimethylformamide (DMF)	dissolved	insoluble	dissolved	partially dissolved
Decane	dissolved	insoluble	dissolved	dissolved
Octane	dissolved	insoluble	dissolved	insoluble
Acetone	dissolved	dissolved	dissolved	partially dissolved
Diethyl ether	dissolved	dissolved	dissolved	dissolved

DMSO	dissolved	dissolved	dissolved	insoluble
Isopropyl alcohol	dissolved	insoluble	dissolved	partially dissolved
Tetrahydrofuran (THF)	dissolved	dissolved	dissolved	dissolved
Benzene + DMSO	insoluble	insoluble	insoluble	partially dissolved
4 ml acetic acid + 4 ml ethanol + 2 ml butanol	dissolved	dissolved	dissolved	dissolved

Based on the obtained data, it can be concluded that the insolubility of the EUF substance in DMSO makes it possible to use this solvent in the extraction process to isolate the required synthesized compound. Particular attention should be paid to the purity of DMSO. Based on the determination of the solubility of the substance in various solvents and the results of the conducted experiments, it can be confidently stated that DMSO is used as the solvent after the extraction process.

It was established that one layer of the extraction mixture contains unreacted substances and compounds dissolved in the solvent (ethylene glycol, urea, and formaldehyde), while the second layer contains the synthesized reaction product, EUF, which is insoluble in the solvent. By applying the solvent replacement method, the oligo(poly)mer was isolated in a pure form, after which its structure, morphology, and composition were investigated using modern analytical methods.

3. Results and Discussion

To investigate the thermal properties of the oligo(poly)mer synthesized from the selected reagents, samples were prepared in a modified form using liquid glass solutions of varying concentrations. Wooden samples were treated by impregnation with the prepared liquid glass-based composition. According to fire safety regulations, the critical temperature for metallic structures, at which they lose strength, is 500 ^{0}C.

Aqueous solutions of the synthesized compounds with concentrations ranging from 1 to 10 % were prepared, and pine wood samples were impregnated in a specialized bath at 40–50 ^{0}C for 1–1.5 hours. As a result, it was established that the fire resistance of the treated wooden materials increased significantly. These findings were analyzed in accordance with SST 16363-98 (Table 2)

Table 2. Test results obtained for evaluating the thermal performance of liquid glass-based coatings (6 % modified composition).

№	Sample Mass, g		Temperature, ^{0}C		mass loss, g		Note
	Before	Before	T_{Start}	T_{End}	g	%	
1% Na_2SiO_3 solution	155,2	153,8	220	380	1,4	0,9	no complete destruction observed
2% Na_2SiO_3 solution	155,4	153,9	220	380	1.5	0,96	no complete destruction observed
3% Na_2SiO_3 solution	157,3	155.6	220	380	1,7	1,08	no complete destruction observed.
4% Na_2SiO_3solution	156,2	155.8	220	380	0,4	0,26	no complete destruction observed.
5% Na_2SiO_3solution	155,2	154,4	220	380	0,8	0,52	charring
6% Na_2SiO_3solution	155,5	154,5	220	380	1	0,64	charring
7% Na_2SiO_3solution	157,7	156,5	220	380	1,2	0,76	charring
8% Na_2SiO_3 solution	157,9	156,4	220	380	1,5	0,95	charring
9% Na_2SiO_3solution	157,9	156	220	380	1,9	1,2	charring
10% Na_2SiO_3solution	156,7	154,5	220	380	2,2	1,4	charring

Based on the results presented in Table 2, it can be concluded that, according to the requirements of SST 16363-98, as the concentration of the modified liquid glass increases, its degree of penetration into the wood decreases. Consequently, the thermal stability initially increases and then decreases, with the maximum value observed for the 4 % solution.

4. CONCLUSION

In conclusion, it can be noted that an EUF modifier with the desired properties was successfully synthesized using the selected reagents. To isolate this compound in a pure and individual form, a suitable solvent for extraction was selected, ensuring the purity of the obtained modifier.

The next key step in achieving the study objectives involved preparing solutions of modified liquid glass, testing them on wood samples, and conducting experiments in accordance with SST standards to evaluate the significant improvement in the fire resistance of the treated wooden materials. According to Table 2, the best performance for the selected 6 % modified composition and its corresponding Na_2SiO_3 was observed at a concentration of 4 %. This is primarily due to the low mass loss of 0.4 % and the absence of complete destruction, which supports the conclusion that the study's objectives have been successfully achieved.

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