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Furfural-based binder for composite construction materials

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Abstract

The paper considers the possibility of furfural hardening by oligomeric acid, which is both a hardener and a direct participant in processes of polymerization and polycondensation. Low viscosity furfural-based binders, which gelling time is 40-60 minutes were developed. They can be used to produce highly filled materials having high physical and mechanical properties and chemical resistance to water and aggressive acidic media. Use of the developed binder as a protective compound for concrete structures is very promising. The coating partially contacts with the concrete surface forming insoluble phosphates. Thus, the protected structure becomes waterproof and can work in an aggressive environment for a long time.

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Keywords: furfural; three-dimensional polymer; hardening; chemical resistance; water absorption; mastic composition; fillers; adhesion; protection of concrete structures

1. Introduction

Furfural is the product of vegetable raw material hydrolysis reproduced by nature. It represents a very promising object of research. Interest to furfural is caused by the fact that heterocyclic aldehyde is characterized by high reactivity, which is due to the presence of a carbonyl group and a conjugated double-bond system in its structure as well as the possibility of ring opening[1-4]. These properties determine furfural ability to form high molecular products resistant to aggressive environments.

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Furfural-acetone, phenolfurfural oligomers and compositions based on furfuryl alcohol produced by furfural reducing reaction are widely known[5-11]. To produce these products, oligomeric compounds are usually obtained, which then form hardened three-dimensional polymers under the influence of certain agents and usually as a result of heat treatment.

Attempts to harden furfural itself resulted mainly in production of brittle materials with unstable properties [12-14]. Data concerning production of composite materials based on furfural, carbamide and ferric chloride as hardening agents are available [15]. However, carbamide and ferric chloride are poorly soluble by furfural and can be in excess supply as a result of a high rate of composition hardening. Being water-soluble substances, they can be washed out during use and serve as centers of material destruction.

2. Experimental section

We developed new binders based on furfural and an acid agent, which is both a hardener and a direct participant in processes of polymerization and polycondensation. The hardener represents an oligomeric sulfonic acid produced by condensation of sulfonated phenolic carbamide and formaldehyde in an acid medium. The reactants are well mixed to form a homogeneous mass that hardens at room temperature in 40-60 min depending on the ratio of initial components and the ambient temperature. The reaction of furfural hardening is accompanied by heat production, so temperature increase by even 5-7°C results in the acceleration of the hardening process.

The resulting three-dimensional polymer has high physical and mechanical properties; it is characterized by a significant increase in strength during six months of exposure. At the same time breaking compression stress reaches 120-130 MPa and bending stress exceeds 40 MPa (see Table 1).

Table 1 Physical and mechanical properties of polymer compositions based on furfural

Hardener to furfural ratio in a binder	Gelling time, min	Breaking compression stress, MPa, in			
		7days	14days	30days	90days
0.25	300	Gel	Gel	3.5	7.2
0.50	60	24.8	51.2	70.7	77.5
0.60	55	27.9	59.6	79.0	112.5
0.75	50	34.2	60.6	77.5	108.6
1.00	50	43.7	69.9	75.0	98.4

It follows from Table 1 that an increase in the amount of hardener facilitates more rapid strength generation during the first day of hardening. After three months of air exposition samples containing 60% and 75% of hardener show the maximum composition strength. Similarly, the bending stress of compositions containing high amounts of hardener increases within the same time and reaches maximum values (27-35 MPa). The resulting polymer has high stability in water and acidic aggressive environments.

Experimental data confirm high stability of the binder, in particular, in hydrochloric acid, which has reducing properties and a destructive effect on many polymer materials (Table 2).

Table 2 Resistance to chemical attack of a hardened binder based on furfural

Hardener to furfural ratio in a binder	Water absorption in 3 days,%	Weight loss during boiling water extraction, %	Resistance to chemical attack after 30 days of exposition			
			Water	10% HCl	10% H_2SO_4	10% NaOH
0.25	36.5	4.1	0.58	0.42	0.56	0.21