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Protective Coating for Wooden Structures

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Abstract

The production technology and properties of decorative coating, protecting wood from flammability and rotting, are described. Liquid silicate glass is used as a binder and diatomite as a filler and pigment. The coating is fire- and bio- efficient, resistant to moisture and acids. The coating is easy to produce. It dries rapidly and has a varied color palette.

Keywords: protective coating,, liquid glass, diatomite, fire-resistant efficiency, bio-resistance, adhesion, moisture resistance.

1. Introduction

Wood is a natural durable, easily treated material. However, the rotting and inflammability of wooden structures decrease their durability and reliability. Decreasing the inflammability and increasing the bio-resistance of wood are essential in various economic activities, e.g. conservation of wooden architectural monuments. Wooden monuments, located in remote areas, are damaged by lightning, fires, unfavorable climate and human activities.

Coating which protects wood from inflammation and rotting and makes it aesthetically attractive is described. The goal of our project is to study the protective and technological properties of the coating. The properties of the coating depend largely on its composition. The known liquid silicate glass was used as a binder for the coating. Diatomite, which is amorphous siliceous rock of sedimentary origin, acts as a filler and pigment. The coating easy applied to the surface of a product solidifies rapidly forming a protective film. The natural colors of diatomite or the colors acquired upon treatment allow to create a variety of tints of the coating.

2. Composition and properties of coating constituents

Liquid silicate glass commonly use for fire-proof paints. When mixed with filler and pigment, this glass forms homogeneous consistency, which creates over the surface of the product a solid layer. Potassium liquid glass use more commonly than sodium glass, because less salt is formed on its surface in a humid environment. To make the product less inflammable, fire-proof fillers, whiting, color pigments and special additives are added to the paint. Vermiculite, perlite, talc, kaolin wool and asbestos filaments are common fillers. The compositions of well-known fire-resistant paints are shown in Table1 [1].

Table 1. Technical specifications of fire-resistant paints

Paint	Silicate-vermiculite	Silicate-asbestos	Silicate-clay	Silicate-perlite
Composition	Liquid potassium glass, titanium whiting, ground vermiculite	Liquid glass, asbestos, short-filament talc, whiting	Liquid glass, ground brick, clay	Liquid glass, swollen perlite, kaolin wool filaments
Consumption, kg / m^2	1	1	1.5	1.2
Thickness, mm	~1	~1	~1	1
Fire resistance limit, min	45	30	30	30

Potassium glass with a silicate modulus of 2.4-3.0 and a density of 1.36 — 1.50 g/cm3 was used as a binder for the coating developed. Diatomite of lacustrine origin, consisting of the opal valves of diatoms microscopic algae, was used as a filler (Fig.1).

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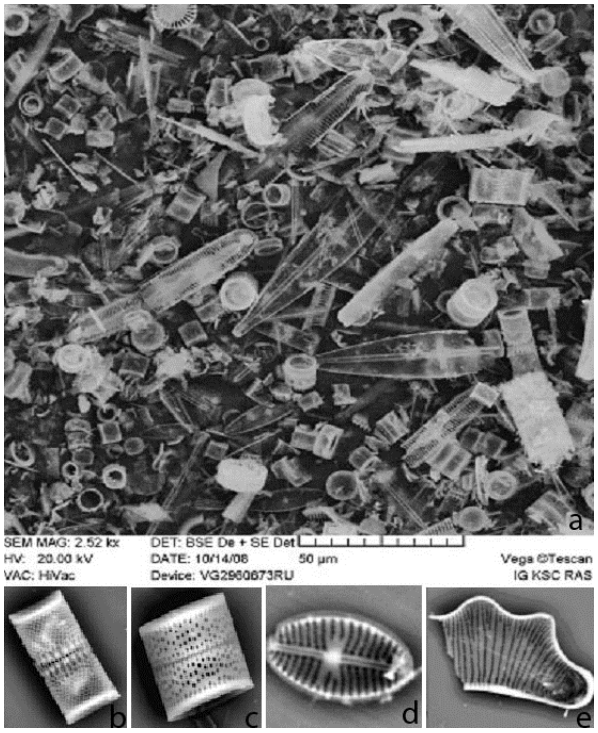

Fig. 1 Electron image of the sedimentary rock of diatomite (a) and some of its constituent species: b, c - *Aulacoseira italica var. valida*, d — *Cocconeis sp.*, e - *Eunotia polygliphis*.

128 high-quality diatomite deposits and manifestations been prospected in Karelia. Their average thickness is 2-3 m and in some water bodies 6-8 m [2, 3].

Natural diatomite, containing 80-85% moisture, is a brown, white, cream or orange-colored gelatinous mass. The composition, structure, physicochemical properties and applications of diatomites are discussed in [3-6]. Most diatomite grains are 15-20 µm in size. Grains having sizes 100-1000 µm, are formed by agglomeration of particles. Quartz and feldspar grains, 0.015 – 0.2 mm in size, occur as mineral impurities. Some of them are brown in color. The presence of organic impurities is set up by the exothermal peaks on the derivatograms of diatomite near 285°C, which attributed to the decomposition of impurities and the oxidation of Fe^{+2}. Diatomite impurities are removed by roasting the samples in a muffle furnace at 700°C for 1.5 hours, using magnetic separation and leaching by boiling in 5% hydrochloric acid for 1 hour.

Diatomite is typically has an amorphous porous structure. As the holes in its valves are about 100 nm in size, diatomite could be considered a biogenic nanomaterial. Because of its high porosity diatomite has a small specific gravity , although the X-ray density of the silica of the diatomite valves is similar to that of amorphous quartz (2300 kg/m3). The size, shape and pores of diatomite particles are determine the specific surface – a characteristic, which controls the behavior of powders in technological processes. The low thermal conductivity of diatomite (0.07-0.10 Wt/(m·K) is essential for the fire-resistant coating.

To produce such a coating, brown-colored D0-diatomite samples from Lake Tedrilampi, located in the Muezersky District, and white D1-diatomite samples from a small nameless lake, 2 km from Lake Tungozero, Louhi District, were used as a filler and pigment. The samples differed in species composition, the degree of preservation, the number of valves in 1 gram of sediment, physicochemical properties and the presence of organic and mineral impurities. After thermal treatment at 700°C, the brown D0-diatomite sample became orange. The chemical compositions of the diatomite samples are shown in Table 2 and their some physicochemical properties in Table 3.

Table 2. Chemical composition of diatomite samples, mas.%.

Sample	D0			D1		
	700°C	HCl	Initial	700°C	HCl	
SiO_2	70.46	86.02	88.28	76.20	88.86	91.2
TiO_2	0.05	0.06	0.05	0.1	0.08	0.05
Al_2O_3	1.96	2.29	2.38	3.82	4.32	4.43
Fe_2O_3	2.27	2.05	0.09	0.22	0.13	0.07
MgO	0.62	1.38	1.62	0.25	0.41	0.92
CaO	0.43	0.51	0.58	0.28	0.37	0.43
Na_2O	0.19	0.24	0.76	0.33	0.29	0.08
K_2O	0.14	0.18	0.33	0.27	0.19	0.03
Igniton loss	23.88	7.27	5.91	18.53	5.35	2.79

Table 3. Physicochemical properties of diatomites.

Sample	D0	D1
Volume mass, g/cm^3	0.45	0.19
Specific surface after HCl treatment, m^2/g	14.8	123
Thermal conductivity, Wt/(m K)	0.10	0.07
True density, g/cm^3	3.4	2.3
Total Fe,%	0.09	0.07
Ignition loss	8.5	3.22
Colour after treatment	Orange	White

The specific surface area of D1 sample is almost one order of magnitude greater than that of D0 sample, indicating its greater dispersion and porosity.

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3. Coating production technology

To prepare the fire-resistant coating, diatomite in the amount of 17 – 70 mas. % was weighed and placed into a mixer, where liquid glass, in the amount of 30 – 83 mas.%, was poured [7]. The solution was mixed until a mass, homogeneous in color, was obtained. Then this mass were applied with a roller or brush on the surface of the product and were dried. The coating was spread over the wooden, ceramic or concrete surface as a smooth layer. The consumption of the coating was 0.154 – 0.308 kg/m2, the coating thickness being 0.01-02 mm.

4. Coating testing methods

The fire-resistance of the coating on the base of developed composition was tested using the "fire tube" method [8]. A previously weighed sample was placed on a holder into the center of a steel tube with an internal diameter of 50 mm and a length of 165 mm. A burner was mounted under the sample. The height of its flame was controlled in the interval of 15-25 cm. After the ignition of the sample the burner was removed and fixed the time of independent sample burning. The mass loss of the sample was estimated by additional weighing.

The adhesion of the coating was assessed using the reticulate notch method [9], assuming that result of test is the adhesion value in points, corresponds to the majority of coincident values at all the surface sites of the samples. The values that differed in less than one point were considered coincident.

The time and degree of drying were calculated at (20 ± 2) °C and a relative air humidity of (65 ± 5) % on three samples spaced at least 20 mm apart [10]. The moisture resistance of the coating was estimated from the mass loss of the samples after they stayed in a humid medium. Exploitation time was determined using an accelerated method [11]. The consumption of the coating per square meter was measured experimentally [12]. Acid resistance class was determined in accordance with ASTM C 283-54 International Standard [13]. The thermal conductivity coefficient of the coating was measured using an ITEM-1M instrument [14].

The mold fungus resistance of the coating [11] was tested at V. L. Komarov Botanical Institute, RAS, in St. Petersburg by Senior Researcher E. V. Bogomolova using spores infected by water suspension without adding nutrients and spores infected by water suspension with addition of sugar and mineral substances. Czapek's nutrient medium was selected as an additive [15]. The viability of the fungus spores on the coating was assessed using the replication method [16].

The bio-resistance of the coating was checked in a real environment. Observation of the coated and control samples (7-10 mm thick pine planks) was conducted in the basement of a house infected with the fungi Serpula lacrymans (weeping Serpula) and Coniophora puteana (cellar fungus, stinky Coniophora) [17].

5. Results of the tests

The fire-resistance of the coating is shown in Figure 2 and in Table 4. The figure shows an uncoated control sample kept in the burner flame for 1 minute and a coated sample kept in the flame for 10 minutes (b). The mass loss of the coated sample was 0.34-0.55 %. The mass loss of no more than 9% corresponds the high fire resistance of the coating [8].

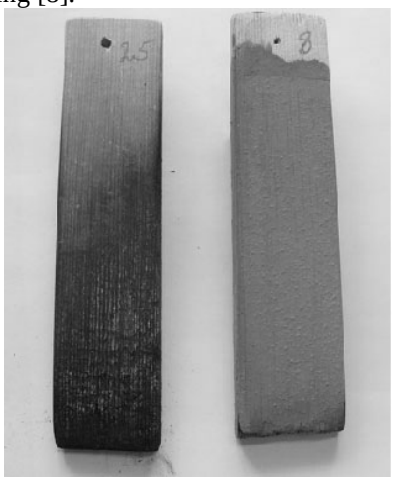

Fig.2. Results of the testing of a control sample and a coated sample in a fire tube after keeping the control sample in the flame for 1 minute and the coated sample for 10 minutes.

Table 4. Properties of fire-resistant coatings.

Sample no.	1	2	3	4
Adhesion to wooden surface, points	1	1	1	2
Mass loss upon inflammation, %	0.55	0.50	0.34	10
Non-flammability group	1	1	1	2
Drying time, min.	15	10	17	6-12 hrs
Moisture resistance, mass loss, %	1.7	2.2	2.5	-
Acid resistance, ASTM C 283-54 class	AA	A	AA	-

The numbers 1-3 are coated samples and number 4 is coating prototype [18].

It follows from Table 4 the coating studied is 18 times better the liquid glass-, ground vermiculite- and quartz sand-based coating in terms of drying indices [18]. The study of the adhesion of the coating to a wooden surface

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has shown that the edges of the notches are smooth and display no signs of flaking. Flaking took place after the samples were kept in a humid medium for one month. This is not surprising because the samples were not impregnated prior to coating. The coating is moisture-resistant. The mass loss upon moisture impregnation of the samples is 1.7-2.5%. The coating corresponds to class AA in chemical resistance.

The coating resists the overgrowing of the wood with mold fungi. In the absence of organic contamination the coating
is of PG_{0X1}-PG_{0X2} fungus resistance classes. Weak fungicidal activity, indicated by the emergence of scarce small mold fungus colonies, was displayed by one of the four samples analyzed.
Figure 3 shows samples infected with fungi in a real environment. In the absence of light and at high above-ground air and soil humidity the fungi Serpula lacrymans and Coniophora puteana rapidly destroyed the wood of the control samples. After a week they had white spots which passed into silvery interweaving and growing fruit bodies. The surface of the coated samples remained clean for a long time, but after a month some white spots on it were noticeable.

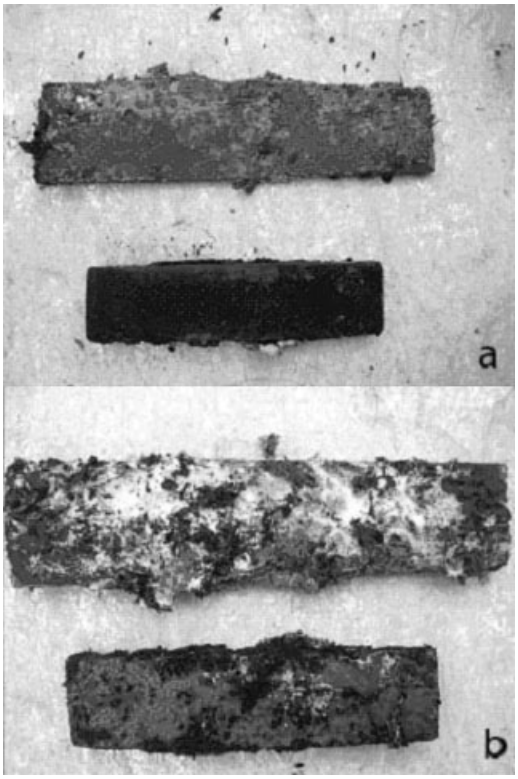

Fig.3. Photos of control (top) and coated (bottom) samples after keeping them for one month on the earth floor in a zone affected by the fungi Serpula lacrymans and Coniophora puteana: a) upward surfaces, b) surfaces near the ground.

The natural colors of diatomite and those obtained by treatment can easily add various tints to the coating .

6. Conclusion

The coating developed for wooden structures has a high fire, moisture and fungus resistance. It contains no toxic components and can be produced in various colors. The use of diatomite as a filler improves the properties of the coating in comparison with common fillers because of its high silicon dioxide and low iron content, high dispersion, amorphous structure, the presence of pores and low density and thermal conductivity.

The application of diatomite is economically efficient because it has a finely disperse structure and thus needs no expensive crushing, displays a variety of colors and can be used as a filler and pigment. As diatomite has a porous structure, extra additives could be added in smaller concentrations and protection against external effects is provided.

The coating is easy to produce. It is readily applied to wooden surfaces, dries rapidly and protects wooden products against fire, atmospheric precipitation, moisture and rot.

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