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Research paper

Obtaining and study of physical-mechanical properties of paint materials on the basis of domestic petroleum bitumen

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Abstract

The article is devoted to the study of obtaining and study of physical and mechanical properties of paint materials on the basis of domestic petroleum bitumen. The expansion of the fields of application of bituminous materials is becoming more relevant due to the methods of regulation and physico-mechanical and adhesive-strength properties. The study of physical and mechanical properties of bituminous paint materials showed that water absorption changes in almost 3.5 times (from 0.03% to 0.11%), and their viability in the studied temperature range remains sufficient for the application of several layers of film from the prepared compositions. At the same time, all of them far exceed the known compositions in terms of impact strength and the magnitude of water absorption. Heat resistance of coatings does not reduce. And its value is within the permissible limits of temperatures used in technological processes.

Keywords: *Oil Bitumen; Paint Materials; Viscosity; Water Absorption; Swelling; Strength; Adhesion.*

1. Introduction

Kazakhstan within innovation and industrial policy covers a wide range of petrochemical development, providing a set of tasks that will allow to rapidly increase the deep processing of products for related branches of oil and gas industry. This procedure will undoubtedly accelerate the development of the economy of the Republic of Kazakhstan in the future, as defined in the Developments Strategy RK-2050.

The paint materials industry produces a broad range of paints and varnishes (varnishes, enamels, paints, primers, fillings, various auxiliary materials), which are widely used in various industries, construction, transport and everyday life.

The range of paint materials has considerably expanded in recent years. Paint materials are more and more widely used in the oil and gas industry. This is explained by the presence of a number of valuable properties that allow coatings to perform numerous functions, such as to protect the equipment surfaces from corrosion of operating environments, to prevent the formation of deposits of paraffins and salts, to protect the equipment from hydroabrasive and corrosion-mechanical wear, to reduce hydraulic losses, to increase the tightness of detachable fixed joints, to reduce the metal content of constructions [1].

Analysis of the volume of production of paint materials in Kazakhstan in 2017 increased in comparison to the year 2015 on 15 037 tonnes. Increase over the last three years was 55.7%.

Today, the main suppliers of paint materials for Kazakhstan are Russia, Germany, Finland and Denmark. One of the main problems of the industry is the lack of construction materials of domestic production.

However, the import volume of paint materials in Kazakhstan continued to decline. The trend that experts pay attention to is a decrease in the share of supplies of building materials to Kazakhstan from Europe, Japan, the United States and the growth of goods from Russia and Belarus. Experts explain this behavior of the market by integration processes. At the same time, the demand for local paint materials due to their low cost has increased significantly. Most of the domestic paint materials producers, which are potential competitors on the market, are small.

In Kazakhstan, the production of paint materials tends to increase. This is evidenced by the data of the Agency of Kazakhstan on Statistics shown on Fig.1.



Fig. 1: Annual Growth Rate of Paint Materials Production in Kazakhstan, %.

Thus, the figure shows that the volume of production of paint materials in Kazakhstan in 2016 increased by 44 % compared to 2015. The increase in the last five years was 50 %. From here it is possible to make the following conclusion: production of paint materials was and remains one of perspective and favorable investments. Paint materials are the most widespread and one of the most available finishing materials. Despite of the fact that the domestic industry is actively developing in this segment, however,

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the competition is not yet high and the new business has a chance for success.

2. Material and method

The following materials are used for the production of bitumen varnishes: plant-based oils (vegetable oil, flax oil), rosin derivatives, which are represented by calcium and zinc rubber, ester gum, oil special bitumen, solvents. All these components are basic. They are the basis of any varnish brand of this type. Currently, there are about forty brands of varnishes of bitumen type [2].

Table 1 shows the grades and specifications of bituminous varnish. Along with film-forming material, pigments, fillers, plasticizers, as well as some auxiliary substances are used as raw materials in the production of varnishes and paints.

In the process of evaporation of solvents from the pain material film its viscosity increases to such an extent that the stresses arising in the film as a result of shrinkage on an almost rigid undeformed substrate do not have time to relax, which usually leads to cracking of the coating.

Table 1: The Brands and Technical Characteristics of the Bitumen Varnish

Brand	Viscosity on VZ-4 at 20° C, not less than, sec	Content of non-volatile substances, not less than, %	Temperature, °C	Drying time
BT-99	39-60	42-47	20±224	15 min
BT - 123	30-70	38-42	200±10	50 min
BT - 142	120-180	55-58	120	2 hrs
BT - 566	—	38-44	90	1 hr
BT - 569	50-90	40-50	200±3	50 min
BT - 577	18-35	37-41	20±2	24 min
			100-110	20 min
BT - 783	60-100	45-55	20±2	48 hrs
			100	2.5 hrs
BT - 980	30-60	40	100-110	10 hrs
BT - 987	30-60	40	105-110	6 hrs
BT - 988	30-60	40	105-110	3 hrs
BT - 5100	25-40	43-48	20±2 60	2 hrs 30 min

In this case, plasticizers are used as a modifying component.

The most effective plasticizers are those, which are along with providing elastic-plastic properties cause the least reduction in structural and mechanical properties of the composition.

The main plasticizers for bituminous coatings are petroleum oils: green transformer, axial, spindle; polymers: polyisobutylene, polyisobutylene solution in green oil, low molecular polyethylene; low molecular synthetic rubbers: polydiene, octol, etc.

Fillers are introduced in the composition coating compositions based on petroleum bitumen to improve the physical and mechanical properties, reduce shrinkage during curing and reduce the cost of [3].

The main requirements for fillers are fine dispersion, low moisture saturation, hydrophobic nature, resistance to various aggressive media.

Currently, quite a promising direction is the use of modified chromatic pigments for the production of pain materials based on petroleum bitumen in order to improve the protective and decorative properties of coatings.

Bituminous varnishes are used for various purposes. The first of them is the protection of metals from corrosion. There are many different methods to deal with the formation of rust on metal surfaces. The varnish coating is quite effective. Varnish covers the metal with a thin layer and restricts access to moisture and air, which lead to oxidation of iron and other metals.

The second purpose of the varnish bituminous type is its adhesive property. It has excellent adhesion to some substances. It works as glue to some of materials and in many situations is used for this purpose. Very often this method of bonding is used in the construction industry. Roofing materials can be glued thanks to varnish.

The third purpose of using bituminous varnish is to use it as a substance that gives the surface resistance to moisture. Very often with the help of it becomes possible to protect the wooden surface from moisture. As a result, the moisture resistance of the material and products is longer.

There is a large number of applications of this material. It is widespread due to its low cost and acceptable composition. In addition, it is ideal for decorating surfaces of various types. Varnish based on bitumen component has universality. It is suitable for household and industrial purposes.

As the foreign practice shows, the additional costs of making the pigments of commercial dye are not only economically justified, but also allows to significantly reduce the need for deficient pigments. Currently numerous of companies are engaged in the production of bitumen varnishes. They use different components in production. Today, the composition of bituminous varnish can be various. In many ways it depends on the manufacturer and the purpose of the varnish. In the initial version of this type of product natural resins and bitumen are used [4-6].

Petroleum road bitumen grade BND 70/100 is used in the process of obtaining a bituminous varnish. BND 70/100 is a large-capacity product of oil refining, has a complex of valuable technical properties.

The resulting bituminous varnish in its physical parameters is a brown or colorless substance that has an oily texture. The substance is quite liquid. Therefore, while usage, a special care should be taken for not to apply an excessive amount on the surface of individual materials.

Sampling was carried out according to GOST 9980.2. Samples for testing are prepared according to GOST 8832. The material of the painted surface, the method of applying the varnish, the thickness of the coating, the number of layers, the conditions and the drying time of the varnish indicate in ND or TU on a specific brand of varnish.

Table 2: Physical and Mechanical Properties of BND 70/100

№	Indicator	Значение
	The depth of needle penetration, 0.1 mm:	
1.	at 25 °C	75
	at 0 °C	22
2.	Softening temperature by the ring and ball, °C 48	48
3.	Expansibility at 25°C, cm	115
4.	Brittleness temperature, °C	-20
5.	Flash point, °C	240

The following characteristics of the chemical properties of bituminous varnish can be distinguished [5]:

- Drying speed. Usually it is not less than twenty hours.
- Viscosity of the coating material. At room temperature, the level of viscosity of the varnish is maintained from 35 to 45.
- Mass fraction of non-volatile substances. This indicator is very important. It should not exceed 45 %. On average, in varnish products it is at the level of 39 to 45 %.
- The level of interaction strength of the material. It should not be less than 0.2.
- The degree of elasticity of the film during bending should not be less than 1.
- Average consumption per m^2. This parameter is different for all the polishes. However, on average it is about 200 milliliters per square meter.

To study the varnish films, the coating was applied with a brush on one or two sides of the sample, placed in a drying cabinet and kept at 100° C for one hour, or air-dried for 48 hours. After drying, the second and third layer of the coating was also applied. Then the coating was cured. After visual inspection of samples and quality control of the coating they were subjected to various studies.

Determination of the thickness of the coating on the steel sample was carried out with a digital thickness gauge TT-220 (TIME GROUP Inc), the principle of which is based on the principle of magnetic induction. Measuring range-0-1250 μm. The resolution is 1 μm.

Determination of the impact strength was carried out with the standard method (GOST 4765-73) on the device U-2M. Hardness and adhesion (GOST 15140-78) can be characterized at the same time.

Determination of coating adhesion (GOST 15140-78) to carbon steel (ST.20) conducted by the method of uniform breakage of heads on the breaking machine MR-05-1. The maximum possible load is 30N. The speed of movement of clips is 20 mm/min.

The adhesion value was calculated by the formula [7]:

$$\sigma = F / S, \text{ MPa}$$

Where:

F - Load at which the rupture occurs, kg;

S - Contact area of the coating with the substrate, m^2.

The type of separation was characterized as follows:

- Adhesion - separation between metal and polymer:
- Cohesive - on polymer layer:
- Adhesion-cohesive - part of the metal is coated with a polymer.

Determination of water absorption was carried out on a free film, which was immersed for 24 hours in distilled water at 20° C and was calculated by the formula [8]:

$$X = (b - a)100\% / a,$$

Where:

a -Weight of the sample before the test, mg;

b - The mass of the sample after the test, mg.

Determination of coatings swelling was produced on cylindrical samples of carbon steel (ST.20): L=100 mm, d=10 mm, the surface of which was cleaned with abrasive paper to a purity of ∇ 7 and degreased with acetone in ethyl alcohol.

Samples with a coating thickness of 270-300 μm, cured at room temperature, were placed in 0.5 liter jars with aggressive media. The media was being refreshed 1 time in 10 days.

The change in the mass of samples was controlled after 1,3,5,10,20 and 30 days, then once a month for 10 months.

The degree of swelling was calculated by the formula:

$$X = \frac{(m_1 - m_0)}{m_0} 100\%$$

Where:

m_0 – Weight of steel sample before test, g;

m_1 – Weight of the steel sample after the test, g.

Determination of drying time of varnishes is carried out according to GOST 19007. For hot drying paints the degree and temperature of the drying point is shown in ND or in TU of the particular brand of varnish.

Oil-free bitumen varnishes are prepared by heating the bitumen or its mixture with the resin at 250° C. Oil-bituminous and oil-bituminous-resin varnishes are produced by hot or cold method (Fig. 2) till a homogeneous alloy is obtained. After adding the required amount of solvent and stirring, the solution is pumped into the mixer 2 for typing, and then into the pressure tank 3 and centrifuge 4. After purificatin, the ready varnish is packaged in a container.

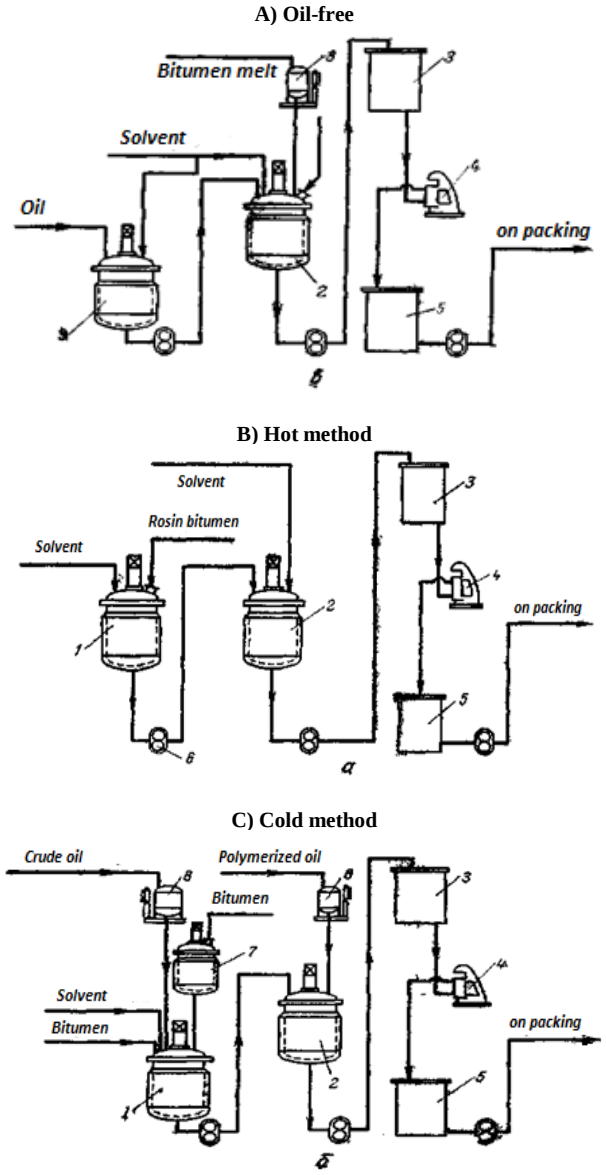


Fig. 2: The Scheme of Production of Bituminous Varnishes: 1 - Reactor; 2 - Mixer; 3 - Pressure Tank; 4 - Super-Centrifuge; 5 - Receiving Tank; 6 - Pump; 7 - Melter; 8 Gauges on Scales; 9 - Polymerizer.

3. Results and discussion

The study of physical and mechanical properties of bituminous paints and varnishes is presented in (Table 3)

Table 3: Physical and Mechanical Properties of Samples of Bituminous Paints and Varnishes

Indicator	Covers 1	2	3	4	5	H
Drying from "dust", min	20	20	20	20	20	20
Complete drying, hour	3	3	3	3	3	3
Impact strength, N. M	3,8	5	5,5	5	5,4	3
Elasticity	1	1	1	1	1	2
Hardness by pendulum device	0,5	0,7	0,8	0,8	0,8	0,8
Water absorption, % mass	0,03	0,08	0,037	0,051	0,037	0,17
Viability, days	+25°C	>7	>7	>7	>7	>7
	+60°C	>7	>7	>7	>7	>7

So water absorption changes almost 3.5 times (from 0.03% to 0.11%), and their viability in the studied temperature range is sufficient for applying several layers of film from the prepared compositions.

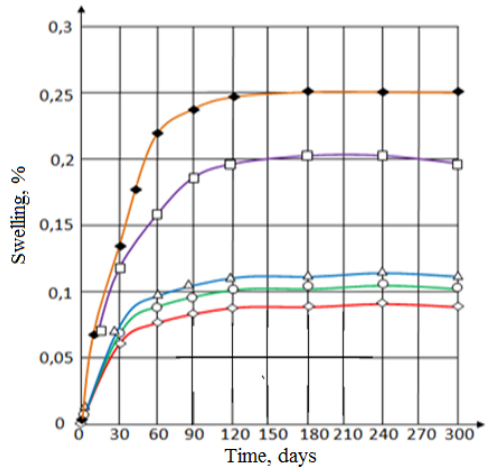


Fig. 3: Swelling of Bituminous Coatings in Water at 25^{0}C.

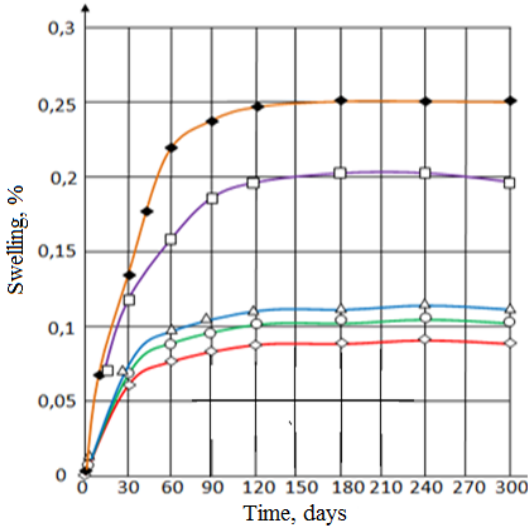


Fig. 4: Swelling of Bitumen Coatings in Water at 50^0 C.

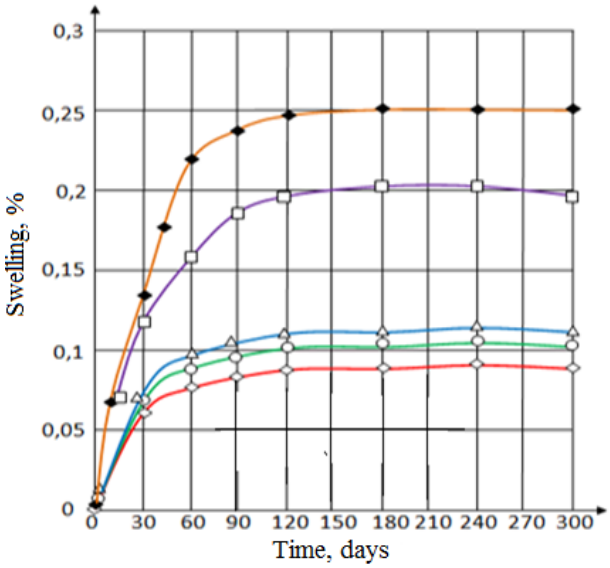


Fig. 5: Change in Impact Strength of Bituminous Coatings in Water at 25^{0}C.

At the same time, all of them in terms of impact strength and the magnitude of water absorption far exceed the known samples.

Heat resistance of coatings is not reduced, and its value is within the permissible limits of temperatures used in the conduct of technological processes.

Thus, the obtained bitumen varnish which meet Standards 5631-79 and 312-79 are capable of withstanding cyclic atmospheric loading with no loss in physical, mechanical, adhesion, strength and hydrophobic properties.

The use of bitumen acquires its primary actuality in the production of protective coatings due to many of its valuable properties (water resistance, hydrophobic protective properties in highly concentrated acids and alkalis). There is a clear need to expand the fields of application of bituminous materials due to methods of regulation of physical-mechanical and adhesive-strength properties.

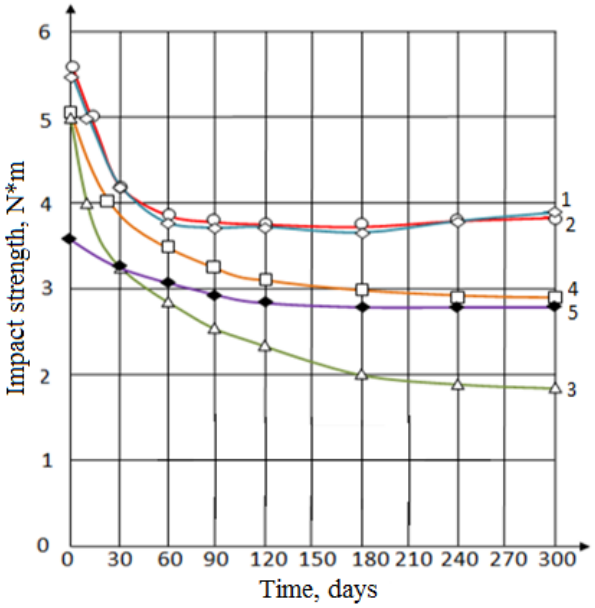


Fig. 6: Change in Impact Strength of Bituminous Coatings in Water at 500°C.

The study of the protective properties of modified coatings showed their high protective properties both at 25°C and at 60°C.

4. Conclusion

The expansion of the fields of application of bituminous materials is becoming more relevant due to the methods of regulation and physico-mechanical and adhesive-strength properties. The study of physical and mechanical properties of bituminous paint materials showed that water absorption changes in almost 3.5 times (from 0.03% to 0.11%), and their viability in the studied temperature range remains sufficient for the application of several layers of film from the prepared compositions. At the same time, all of them far exceed the known compositions in terms of impact strength and the magnitude of water absorption. Heat resistance of coatings does not reduce. And its value is within the permissible limits of temperatures used in technological processes.

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