INVESTIGATION OF THE ACRYLIC ARTIFICIAL STONE PROPERTIES

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Abstract: The article is devoted to the research of the acrylic artificial stone properties, which has wide application in the production of furniture, in particular for the bathroom (sinks, baths), kitchens (sinks, countertops, bar counters, table tops for dining tables) and decorative interior elements (window sills, wall panels). In the Ukrainian market there are products of well-known world producers of acrylic artificial stone TM "Corian" (DuPont, USA), "Polystone" (China), LG Chem (South Korea), "Staron" and "Tempest" (Samsung Cheil Industries Inc , South Korea), HI-MACS (LG, South Korea), GetaCore (Westag & Getalit AG, Germany), and unknown trademarks, whose quality of goods is doubtful for the consumer. Therefore, it became necessary to study the acrylic artificial stone properties of those producers whose products are most in demand in the domestic market.

For the research, samples of five manufacturers of acrylic artificial stone TM Tristone (South Korea) Bitto Dongguan (China), Corian (USA), Polystone (China) and LG Ni-macs (South Korea) were selected. These samples of acrylic artificial stone were tested by standard methods for the following parameters: density, water absorption, compressive strength, flexural strength, impact resistance, wear resistance, Mohs hardness, chemical resistance and compared with standards.

Based on the research results, samples of acrylic artificial stone have been determined that do not meet the requirements of regulatory documentation, and recommendations have been made on the use of the investigated materials, taking into account their intended use, providing high performance, reliability and durability.

Keywords: composite polymer materials, artificial stone, acrylic artificial stone, furniture materials, operational properties, reliability properties, hygienic properties.

1. Introduction

Despite the rapid development of chemical technologies and numerous studies of the properties of polymer composite materials, a fairly wide application, particularly in the field of construction and furniture industry, has acquired an artificial stone. This material favorably differs from traditional construction materials, which allows it to be used not only as a building material, but also for finishing interiors and designing furniture, particularly for kitchens and bathrooms. In addition, the production of polymer composite materials is much cheaper and less energy-intensive than the extraction and processing of natural analogs [1].

Artificial stone is a material that includes about 80 % of mineral raw materials, 20 % of marble or granite chips of various fractions and a polymeric binder (polyester or acrylic resins).

Now the most common in use is acrylic artificial stone, from which the furniture for the bathroom (sinks, baths), kitchen furniture (table tops, sinks, bar counters) and interior elements (window sills, facing wall panels, etc.) are made.

Such wide application is primarily due to a number of factors: a good balance between value and consumer properties, a wide palette of colors, the presence of decoration, imitating natural stone, simple processing technology and limitless possibilities for design.

Modern acrylic stone is a high-tech material, featuring special properties and excellent performance characteristics. It is made from a mixture of several components at once, among which the main are aluminum oxide and special acrylic resins. A variety of color solutions is provided by the addition of pigments.

The structure of the artificial stone is dense and homogeneous, it lacks pores, microcracks and voids. Due to this, the surface is well protected from penetration of dirt, grease, moisture and bacteria. This ensures the hygiene of products made of artificial stone.

With a smooth, pores-free surface of acrylic stone, any stains and dirt are easily removed. Acrylic artificial stone is a durable, hard material with high wear resistance.

Products made of acrylic stone are easily restored: accidental scratches can be got rid by polishing the surface at home. A wide range of artificial stone gives a wide choice for interior design of premises.

All these factors, according to experts, contribute to the further growth of the popularity of acrylic artificial stone.

The products of almost all world producers of acrylic stone TM "Corian" (DuPont, USA), "Polystone" (China), "LG Chem" (South Korea), "Staron" and "Tempest" (Samsung Cheil Industries Inc. , South Korea), HI-MACS (LG, South Korea), GetaCore (Westag & Getalit AG, Germany).

Despite the saturation of the Ukrainian market of acrylic artificial stone, it became necessary to study the properties of these materials and establish their compliance with the requirements of regulatory documentation.

In Ukraine and abroad, significant research has been made on the properties of artificial stone for construction purposes, namely materials based on concretes and cements [2–4]. Foreign researchers conducted a number of studies on the properties of artificial stone based on polymer composite materials, in particular, the possibility of using a casting artificial stone for the production of various technological equipment and equipment for the space industry was considered, a technique for conducting experiments to determine the mechanical characteristics and properties of this material was developed [5]. However, despite the extensive use of acrylic artificial stone, in particular for the production of household furniture (furniture for the bathroom, kitchen, facing materials), it became necessary to assess the properties of this particular material.

The aim of research is investigation of the acrylic artificial stone properties. To achieve this aim, it is necessary to perform the following tasks:

– to choose samples of acrylic artificial stone from different manufacturers;

– to establish indicators of consumer properties that have the most significant impact on the quality of finished products;

– to choose methods of research of quality indicators of acrylic artificial stone;

– to conduct a study of selected samples of acrylic artificial stone in order to determine the compliance of their characteristics with the requirements of regulatory documents;

– to develop recommendations for the use of samples of acrylic artificial stone, depending on their properties.

2. Methods

Five samples of acrylic artificial stone from different manufacturers are chosen for research. They are the most popular in the Ukrainian market. The characteristics of the test samples are given in **Table 1**.

Table 1
Characteristics of the test samples of acrylic artificial stone

No.	Trademark	Manufacturer	Material composition	Purpose
1	Tristone	Lion Chemtech (South Korea)	1/3 of the composition – acrylic resin, 2/3 – natural mineral fillers	Kitchen furniture (countertops, bar counters), sinks, bathroom furniture, window sills, office racks, reception desks.
2	Bitto	Dongguan (China)	93 % – artificial quartz, 6 % – acrylic resin, 1 % activators and pigments.	Kitchen furniture (countertops, bar counters), bathroom furniture, window sills, office racks, reception desks.
3	Corian	DuPont (USA)	2/3 of the composition –aluminum trihydrate, 1/3 – acrylic resin and food pigments.	Kitchen furniture (countertops, bar counters), sinks, bathroom furniture, window sills, office racks, reception desks, stair railing, wall cladding materials.
4	Polystone	Polystone (China)	Composition based on aluminum trihydrate, acrylic resin and pigments.	Kitchen furniture (countertops, bar counters), sinks, bathroom furniture, window sills, office racks, reception desks.
5	LG Hi-macs	LG Chem (South Korea)	1/3 of the composition – acrylic resin, 2/3 – natural mineral fillers	Kitchen furniture (countertops for dining tables, work surfaces), bathroom furniture, furniture for public premises (waiting rooms for airports, stations, public catering facilities, etc.).

The following parameters are determined in the test samples: density, water absorption, compressive strength, flexural strength, impact resistance, wear resistance, Mohs hardness and chemical resistance. The norms of the investigated indicators are given in **Table 2.**

Table 2
Norms of indicators of artificial acrylic stone properties in accordance with regulatory documents

No.	Indicator	Units	Norm according to RD [6]	RD for research method
1	Density (bulk density)	kg/m^3	2200–2400	GOST 12730.1 [7], ISO 1183 [8]
2	Water absorption	%, not more than	0,05	GOST 27180 [9], DIN EN 438-2-2016 [10], GOST 12730.1 [7]
3	Compressive strength	MPa, not less than	36	GOST 10180 [9]
4	Flexural strength	MPa, not less than	50	GOST 27180 [9] GOST 4648-2014 (ISO 178:2010) [11]
5	Impact resistance	cm, not less than	50	GOST 30629 [12]
6	Wear resistance	g/cm^2, not more than	0,097	GOST 27180 [9]
7	Mohs hardness	not less than	6	GOST 27180 [9]
8	Chemical resistance	admissible solutions	No. 1, 2, 3	GOST 27180 [9]

The density of the samples of acrylic stone is determined by measuring the mass (by weighing with an error of not more than 0.1 %) and the volume of samples of the correct shape, taking into account their geometric dimensions. The result is calculated by the formula (1):

$$\rho = \frac{m}{V} \cdot 1000, \quad (1)$$

where m – the sample mass, g; V – the sample volume, cm^3.

The water absorption index is determined by saturation by boiling in water samples of an artificial stone, which were previously dried in an oven to constant weight and weighed. The results are calculated by the formula (2).

$$W = \frac{m_2 - m_1}{m_1} \cdot 100, \quad (2)$$

where m_1 – the sample mass dried to constant weight, g; m_2 – sample mass saturated with water, g.

Determination of the strength of artificial stone samples is the measurement of the minimum force at which material samples are destroyed. At the same time, the forces are obtained from a static load with a constant rate of its growth and further calculations of the loads are made with these forces. Universal rupture machines are used for this study. The results are calculated by the formula (3).

$$R = \alpha \frac{F}{A} K_w, \quad (3)$$

where F – the breaking load, N; A – the cross-sectional area of the test sample, mm^2; Kw – the correction factor, taking into account the moisture content of the test sample.

The flexural strength is determined similarly, the results are calculated by the formula (4).

$$R = \frac{3Fl}{2bh^2}, \quad (4)$$

where F – the breaking load, H; l – the distance between the support axes, mm; b – the sample width, mm; h – the sample thickness, mm.

The impact resistance of the test samples is determined by measuring the minimum height of the weight drop, at which cracks appear on the sample or the specimen breaks down. For the study, a hardness tester is used. The values of the impact index take the minimum height of the weight drop, at which the sample formed cracks or its destruction occurred. The exponent is expressed in cm.

The wear resistance of the test samples is determined by determining the loss of mass or volume of the sample, which is subjected to abrasion in a cycle of 600 m. The laboratory abrasion circle *ЛКИ*-3 is used for the study. The results are calculated by the formula (5).

$$R = \frac{m - m_1}{S}, \quad (5)$$

where m – the sample mass before the test, g; m_1 – the sample mass after the tests; S – the area of the reference surface of the sample, cm^2.

When determining the hardness index of the front surface according to Mohs, a standard technique is used that included comparing the hardness of the samples to the known minerals: talc, gypsum, limestone, fluorite, apatite, feldspar, quartz, topaz, corundum. The hardness of the sample face corresponds to the hardness of the test mineral, which preceded the mineral, damaged the surface of the test sample. The chemical stability of the surface is determined by standard treatment with a solution of hydrochloric acid, a solution of potassium hydroxide, and a solution consisting of a solution of sodium carbonate (33 %), sodium tetraborate (7 %), sodium silicate (7 %), soap flakes of sodium oleate (2.6:18.5 %) and distilled water (23 %). Samples of artificial stone are kept in these solutions for 7 days. Stability of the surface to the action of these solutions is determined organoleptically. If a surface has not undergone any changes then it is considered as steady.

3. Results

Selected samples (**Table 1**) are investigated in terms of indicators, which have the greatest influence on the quality of products made of acrylic artificial stone. Results of the study are given in **Table 3.**

4. Discussion of the results

The conducted studies have established that only the sample of TM "Bitto" (China) does not meet the requirements of the current regulatory documents on the chemical resistance index: there is a significant loss of gloss and smoothness of the surface as a result of exposure to a solution of hydrochloric acid. Also this sample has the highest water absorption degree, which significantly reduces its operational and hygienic characteristics, low strength – from the obtained values of the compressive strength and flexural strength index, is characterized by low impact strength, which makes it unstable to chips and heavy loads.

Thus, it should be borne in mind that the obtained characteristics make this material unsuitable for use in the production of furniture for the bathroom, where the humidity is high, and for the production of furniture for public premises requiring high strength and durability.

The quality indicators of the other samples are normal. High values of strength and impact resistance have the samples of TM Tristone (South Korea) Corian (USA) and LG Ni-macs (South Korea). The investigated sample of TM Corian has the highest wear resistance and hardness, which allows it to be used not only for household furniture, but also for public premises (airports, railway stations, hospitals, public catering establishments).

Research results should be taken into account by furniture manufacturers who use artificial acrylic stone for the proper selection of materials according to its intended purpose. This will ensure reliability and performance at a high level during the specified service life.

Table 3

Indicators of consumer properties of samples of acrylic artificial stone of different manufacturers

No.	Indicators	Investigated samples of acrylic stone					Norm according to RD [6]
		Tristone	Bitto	Corian	Polystone	LG Hi-macs	
1	Density (bulk density) kg/m^3	1800	1750	1780	1750	1650	2200–2400
2	Water absorption, %	0,034	0,042	0,030	0,030	0,036	Not more than 0,05
3	Compressive strength, MPa	65,1	37,5	49,5	64,3	70,1	Not less than 36
4	Flexural strength, MPa	70	65	75	85	68	Not less than 50
5	Impact resistance, cm	125	62	90	66	120	Not less than 50
6	Wear resistance, g/cm^2	0,038	0,067	0,011	0,045	0,035	Not more than 0,097
7	Mohs hardness	8	6	9	8	8	Not less than 6
8	Chemical resistance	resistant	non-resistant	resistant	resistant	resistant	Resistance to solutions No. 1, 2, 3

References

1. Metyuz, F., Rolings, R. (2004). Kompozitnyie materialyi. Mehanika i tekhnologiya. Moscow: Tehnosfera, 408.
2. Ershova, A. Yu., Martirosov, M. I. (2004). Osobennosti i preimuschestva ispolzovaniya litevogo iskusstvennogo kamnya. Dinamicheskie i tehnologicheskie problemyi mehaniki konstruktsiy i sploshnyih sred. Moscow, 1, 145–146.
3. Kryvenko, P. V., Kovalchuk, O. Yu., Hrabovchak, V. V. (2013). Keruvannia protsesamy strukturoutvorennia luzhnykh zolovmisnykh tsementiv dlia pokrashchennia vlastyvostei shtuchnoho kamenia. Budivelni materialy, vyroby ta sanitarna tekhnika naukovo-tekhnichnyi zbirnyk, 49, 21–27.
4. Merezhko, N., Zolotarova, O. (2016). Fizyko-tekhnichni vlastyvosti prosochenykh kremniiorhanichnymy spolukamy porystykh nerudnykh materialiv. Tovary i rynky, 2, 73–82.
5. Ershova, A. Y. (2010). Eksperimentalnyie issledovaniya mehanicheskih svoystv melkozernistyih kompozitov na osnove nenasyischennyih poliefirov. Moscow, 109.
6. GOST R 56207 2014 (2015). Plityi i plitki iz iskusstvennogo kamnya na osnove prirodnogo kvartsa. Tehnicheskie usloviya. Data vvedeniya 01.01.2016. Moscow: Standartinform, 19.
7. GOST 12730.1-78 (2007). Betonyi. Metodyi opredeleniya plotnosti. Data vvedeniya 01.01.1980. Moscow: Standartinform, 4.
8. ISO 1183-1:2012 (2012). Plastics. Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pyknometer method and titration method. Publication date: 05.15.2012. ISO 2012, 10.
9. GOST 27180 (1987). Plitki keramicheskie. Metodyi ispyitaniy. Data aktualizatsii 2017.10.08. Moscow: Izdatelstvo standartov, 18.
10. DIN EN ISO 1183-1-2013 (2013). Plastics – Methods for determining the density of non-cellular plastics – Part 1: Immersion method, liquid pyknometer method and titration method (ISO 1183-1:2012). German version EN ISO 1183-1:2012, 15
11. GOST 4648 2014 (ISO 178:2010) (2014). Plastmassyi. Metod ispyitaniya na staticheskiy izgib. Data vvedeniya 01.03.2015. Moscow: Standartinform, 19.
12. GOST 30629 (2012). Materialyi i izdeliya oblitsovochnyie iz gornyih porod. Metodyi ispyitaniy. Data vvedeniya 01.10.2012. Moscow: Standartinform, 29.