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 (sink, 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.

MATERIAL SCIENCE

INVESTIGATION OF THE ACRYLIC ARTIFICIAL STONE PROPERTIES

Ludmila Andrievsksa
PhD, Associate Professor
knteu.mila@ukr.net

Natalia Marchuk
PhD, Associate Professor
marchuky@ukr.net

1Department of Commodity Science and Customs Affairs
Kyiv National University of Trade and Economics
19 Kyoto str., Kyiv, Ukraine, 02156

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), kitchen (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).

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.
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

| No. | Indicator                  | Units            | Norm according to RD [6] | RD for research method |
|-----|----------------------------|------------------|--------------------------|------------------------|
| 1   | Density (bulk density)     | kg/m³            | 2200–2400                | GOST 12730.1 [7], ISO 1183 [8] |
| 2   | Water absorption           | %, not more than | 0,05                     | GOST 27180 [9], DIN EN 458-2-2016 [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/cm², 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):

$$\rho = \frac{m}{V} \times 1000,$$

where \(m\) – the sample mass, g; \(V\) – the sample volume, cm³.

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):

$$W = \frac{m_2 - m_1}{m_1} \times 100,$$

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).

$$R = \frac{F}{A} K_w,$$

where \(F\) – the breaking load, N; \(A\) – the cross-sectional area of the test sample, mm²; \(K_w\) – 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).

$$R = \frac{3Fl}{2bh^2},$$

where \(F\) – the breaking load, N; \(l\) – 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 JKH-3 is used for the study. The results are calculated by the formula (5).

$$R = \frac{m - m_1}{S},$$

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, cm².
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 tetaborate (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 Tristine (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                      | Tristone | Bitto | Corian | Polystone | LG Ni-macs | Norm according to RD [6] |
|-----|---------------------------------|----------|-------|--------|-----------|------------|--------------------------|
| 1   | Density (bulk density) kg/m³    | 1600     | 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/cm²          | 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 |

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