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INFLUENCE OF VEGETABLE FATS ON CONCRETE OF AGRICULTURAL STRUCTURES

The object of the study was concrete samples with different penetration depths of vegetable oil. For the experiment, concrete samples were taken from the foundation for the oil pan equipment, in the form of cylinders with a diameter of 100 mm and a height of 200 mm. It was found that the experimental sample No. 1 has a decrease in compressive strength of about 6 %, sample No. 2 has a decrease in strength of about 19–20 %, sample No. 3 has a decrease in strength of about 48 % from the control sample No. 4. The study using scanning electron microscopy showed the presence of a layer of solidified oil and plant residues on the surface of the concrete samples. Mycelium of microscopic fungi was detected at a depth of 2 cm from the surface. The study of concrete samples using TPD MS showed that CO was intensively released at a temperature of 583 °C from samples 2 – 0.03 and 3 – 0.05. At a temperature of 552 °C, CO_2 was released with an intensity of 0.1 from sample 2 and 0.18 from sample 3. In other samples, carbon was not released, which is associated with biochemical corrosion of concrete. At a temperature of 100 °C, H_2O was released from concrete samples 2 – 0.8 and 3 – 0.4. Sulfur was released when heated to 90 °C from sample 4_2 in insignificant quantities – 0.0035. SO was released from samples 2 (0.014), $t=764$ °C and 3 (0.012) $t=809$ °C. Sulfur dioxide was released at a temperature of 794 °C with an intensity of 0.005 from samples 2 and 3. The conducted study is distinguished by the fact that correlations were established between the depth of oil impregnation of concrete and loss of strength. Destructive changes in concrete samples, the presence of a layer of solidified oil and microscopic fungi were detected. The presence of carbons, sulfur and its oxides in concrete samples that were least damaged by corrosion processes is associated with the composition of sulfur concrete to give it greater strength. The practical significance of the results obtained is that the negative influence of vegetable fats on concrete is proven, namely a decrease in strength, destruction of the microstructure and the growth of microscopic fungi.

***Keywords**: vegetable oil, loss of strength, corrosion of concrete, thermal properties, microscopic structure.*

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1. Introduction

Organic oils have a negative effect on the strength and structure of concrete structures. The corrosive effect is due to the chemical and physical properties, composition of the oil, temperature and duration of exposure to concrete structures. At enterprises related to the production of vegetable fat (oil), the issue of the influence of these oils on the destruction of concrete structures of buildings and structures is acute.

Research [1] showed the influence of aircraft working fluid, namely lubricants, on the mechanical properties of airport concrete pavement. The results of testing samples of such concrete showed a decrease in its compressive strength by 7.2 %, and tensile strength by 3.6 %.

In [2], the negative influence of petroleum products (gasoline, gas oil, kerosene) on the mechanical properties of concrete was also proven, a decrease in compressive and creep strength was recorded. Concrete based on polyester resin was developed, which showed greater resistance to the influence of lubricants, compared to concrete of classical composition. However, the issue of concrete stability at different temperatures and its performance characteristics remained unresolved.

At the same time, in [3] it was shown that antiseptic oils were developed to protect concrete structures of building facades and structures from corrosion. The study used modified organic oils, but their effect on concrete was limited to laboratory studies. Therefore, more thorough studies are needed, prolonged in time, to determine the effect of organic oils on concrete structures.

Studies were conducted on the effect of glycerin and a mixture of microorganisms to form a protective film on the concrete surface [4]. The results obtained proved the formation of a barrier that reduces capillary water absorption by up to 20 %. The laboratory studies conducted were not implemented in production with the large-scale application of this method of protection in construction.

Scientists in work [5] investigated the permeability of concrete depending on the composition and modification. Agriculture and transport are among the main sources of pollutants containing gases, liquids, oils and greases [6].

Experimental studies conducted in papers [7, 8] are devoted to the influence of chemical harmful gases, alkalis and acids on the strength and durability of concrete. Only a small number of experiments in the works were devoted to determining the long-term influence of lubricants and oils on concrete of structures.

The authors of papers [9, 10] are concerned with the issues of increasing the strength of concrete of structures at the stage of development of production facilities. In [11], when developing hydrophobic additives to the concrete mixture, tests were conducted that should improve such characteristics as water absorption capacity, porosity and heat resistance.

The water absorption capacity of concrete directly depends on the structure and porosity of concrete. The penetration of oil into the pores of unsaturated concrete leads to its gradual absorption into the structure [12, 13].

Also, prolonged exposure to high temperatures [14, 15], as well as temperature drops [16], can cause destruction in the form of splitting and microcracks in concrete structures. Therefore, it is relevant to evaluate the long-term effect of vegetable oil on the chemical and mechanical characteristics of concrete.

Existing studies in this area have been reviewed, but the following issues remain unresolved: the effect on the physical, chemical characteristics and structure of concrete.

The aim of research is to determine the effect of organic oil on the strength of concrete, its structure and thermal resistance.

2. Materials and Methods

The object of research is concrete samples with different penetration depths of vegetable oil.

In the experimental part, a study was conducted on the effect of prolonged exposure to organic oil on concrete of reinforced concrete structures of the building in which the process of its manufacture took place. The following characteristics of the concrete of the control samples were subject to analysis, such as the structural structure of the material, strength and heat resistance.

To achieve the aim and conduct the relevant research, the following objectives were solved:

- the strength of concrete was determined by the control samples by the direct method, respectively, with different degrees of penetration of organic oil along the height of the sample;
- the effect of organic oil, depending on the depth of its penetration, on the microstructural changes of the concrete of the samples was investigated using scanning electron microscopy;
- the effect of organic oil, depending on the depth of its penetration in concrete samples, on the heat resistance of concrete was investigated using the method of thermally programmed mass spectrometry.

Samples for the study were obtained directly from the building where the process of manufacturing organic sunflower oil takes place. The agricultural enterprise building was built in the 1980s and is located in the village of Hrakovo, Kharkiv region (Ukraine).

Microstructural studies of building material samples were carried out in the interfaculty laboratory of electron microscopy. Determination of concrete strength was carried out in the laboratory of testing and research of building materials and structures of Sumy National Agrarian University. Thermal stability of concrete samples was determined in the laboratory of the Department of Radiation Biophysics of the Institute of Applied Physics of the NAAS of Ukraine (Sumy, Ukraine).

2.1. Determination of concrete strength

The strength of concrete is determined by the direct method, by measuring the forces that lead to the destruction of specially manufactured and drilled samples from the structure when they are loaded at a constant speed.

Accordingly, from the reinforced concrete foundation for the equipment, on which the process of manufacturing organic oil takes place, 3 cylindrical test specimens with a diameter of 100 mm and a height of 200 mm were drilled. Considering that for a long time the concrete of the reinforced concrete foundation for the equipment was soaked with vegetable fats (oil), the samples were taken in different places with different penetration depths of vegetable fat along their height. According to the existing building project, the concrete foundations for the equipment are made of heavy concrete of class C16/20.

To study the effect of oil on the structural structure of concrete and other indicators, control samples were extracted at a distance of 1 m, 0.5 m and 0.2 m from the support of the equipment for the production of vegetable fats to the center of the core. Accordingly, control sample No. 1 has an insignificant penetration depth of vegetable fats, which is within 20–25 % of its volume. In control sample No. 2, penetration of vegetable fats is observed up to 50–60 % of its volume. Control sample No. 3 has penetration of vegetable fats practically throughout its entire volume of 90–100 %. Control sample No. 4 was obtained outside the possible action of vegetable fats.

Testing of control samples by the direct method was carried out in accordance with [17, 18].

Thus, the object of experimental research is concrete of a reinforced concrete structure that is under the influence of vegetable fat (oil).

The study is aimed at determining the effect of vegetable fat (oil) on the strength of concrete of control samples depending on their oil filling.

2.2. Research of microstructural changes in concrete

The samples obtained from the experimental site were examined. The equipment PEM 106 and (OJSC SELMI, Ukraine) was used. The concrete samples were fixed on metal substrates using double-sided carbon tape. To provide electrical conductivity to the samples, silver was sprayed. To study the biofilms of microorganisms, the concrete samples were fixed with 2.5 % glutaraldehyde in 0.2 M phosphate buffer solution, dehydrated in a series of ethyl alcohols of increasing concentration and sprayed with silver [19]. The samples were examined in a scanning electron microscope in the secondary electron mode in the electron-optical magnification range from 200 to 5000 times.

2.3. Concrete research using TPD MS

To study the materials, thermally programmed mass spectrometry was used. Samples of old structures weighing 3–5 mg were heated to a temperature of 1000 °C. At the same time, the rate of destruction of the materials and the chemical composition of the gases released during heating were determined. The gases were identified by molecular masses (m/z): H_2O – 18, CO – 28, CO_2 – 44, S – 32, SO – 48, SO_2 – 64 [20].

3. Results and Discussion

3.1. Results of the study of the strength of concrete using control samples by the direct method depending on the penetration depth of vegetable fat (oil)

The process of manufacturing vegetable fat (oil) can occur using imperfect technologies, during which the concrete of structures for production equipment is under their influence. Vegetable fats (oils) can systematically get on the concrete of the structure, impregnating it, penetrating into the deep layers. Vegetable fats (oils) contain high-molecular fatty acids that destroy cement stone, leading to corrosion of concrete.

The process of destruction of concrete under the influence of vegetable oil occurs due to the weakening of contacts between cement stone and aggregates [21]. The degree of influence of oil on concrete can be estimated by determining the strength of concrete depending on the penetration depth and the duration of action.

When testing control samples No. 1–4 (Fig. 1–3), the following initial data were recorded:

- according to the design data, the concrete class of the reinforced concrete foundation for the equipment is heavy concrete C16/20;
- the dimensions of the samples correspond to [18] and are: height 200 mm, core diameter 100 mm;
- samples obtained by cutting a cylindrical core;
- the ratio of length to diameter of the prepared sample is 2:1;
- the compressive strength of the core with an accuracy of 0.1 MPa (N/mm^2).

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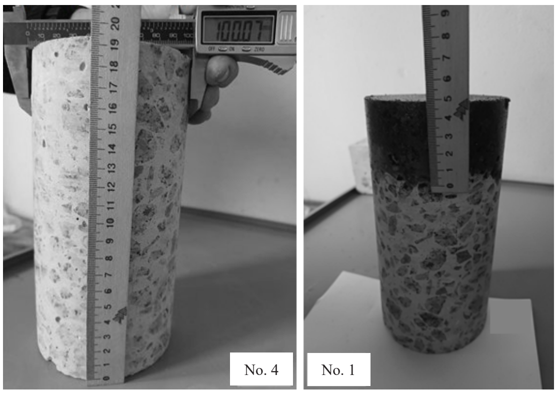
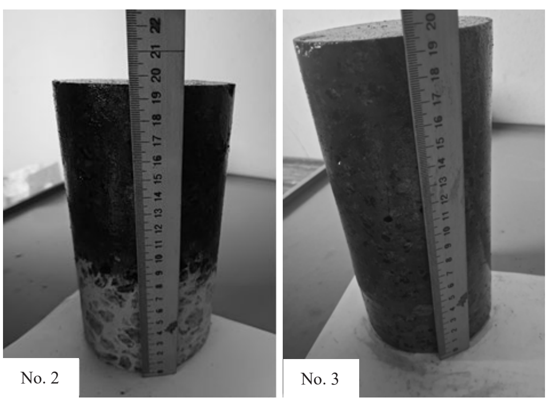
Determination of the strength of test sample No. 1 by the penetration of vegetable fats (oils) from its volume within 20–25 % showed a decrease in compressive strength by 5.4 % compared to sample No. 4 – from 19.76 MPa to 18.7 MPa, Fig. 1.

Determination of the strength of experimental sample No. 2 with the permeability of vegetable fats (oils) from its volume within 50–60 % showed a decrease in compressive strength by 19.5 % – from 19.76 MPa to 15.9 MPa compared to sample No. 4, Fig. 2.



a *b*

Fig. 1. Samples with permeability within 20–25 % of their volume: *a* – control sample No. 4; *b* – experimental sample No. 1

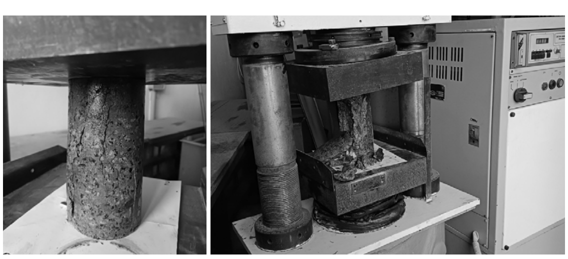


a *b*

Fig. 2. Test specimens with penetration depths within 50–60 % and 90–100 % of their volume, respectively: *a* – test specimen No. 2; *b* – test specimen No. 3

Determination of the strength of test specimen No. 3 with 90–100 % penetration of vegetable fats (oils) from its volume showed that the aggressive effect of high-molecular fats led to a decrease in strength by approximately 48 %, compression from 19.76 MPa to 10.4 MPa compared to control specimen No. 4, Fig. 3.

The results of the research are shown in Table 1, which shows the strength of concrete depending on the permeability of vegetable fats (oils) into concrete.



a *b*

Fig. 3. Test sample No. 3: *a* – concrete sample before destruction; *b* – concrete sample after destruction

Table 1

Strength indicators of control concrete samples

Sample number	Working area of the sample *A*, mm^2	Destructive force *F*, kN	Coefficient used in compression α	Compressive strength $f=\alpha\cdot F/A$, N/mm^2
4	7854	133.8	1.16	19.76
1	7854	126.6	1.16	18.7
2	7854	107.6	1.16	15.9
3	7854	70.4	1.16	10.4

Table 2 shows the characteristics of the samples, namely: its number, the distance at which the sample was taken relative to the equipment support, the penetration depth of vegetable fats (oils) along the height of the sample and the percentage of reduction in the strength of the concrete of the sample.

Table 2

Summary indicators of the impact of reducing the strength of concrete of experimental samples depending on the penetration of vegetable fats (oils)

Sample No.	Distance from equipment support	Percentage of penetration	Reduction in concrete strength
1	100 mm	17–25 %	5.4 %
2	60 mm	50–60 %	19.5 %
3	20 mm	90–100 %	47.3 %

These results indicate a direct aggressive effect of organic vegetable fats (oils) on the reduction of concrete strength. In addition, the mode of obtaining oil by the outdated method from sunflower was accompanied by its heating to a temperature of 60 °C [22]. The effect of high-temperature vegetable oil on concrete increases its destruction, which is confirmed by studies [23]. The absorption capacity of concrete is important [24], which is interconnected with strength characteristics.

To ensure constant strength of concrete during operation of structures, it is necessary to protect concrete surfaces from the effects of oil.

3.2. Research results on the impregnation depth of concrete with oil and determination of microstructural changes using scanning electron microscopy

The studies have established that there is a layer of solidified oil on the surface of concrete structures, which has accumulated over the years (Fig. 4, 5).

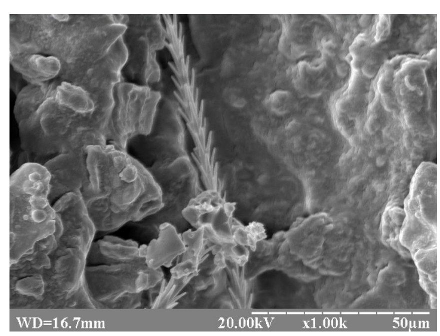


Fig. 4. Electron microscopic image of the concrete surface, on which a layer of oil and plant residues are present

In Fig. 4, one can observe the accumulation of oil and plant residues that have been preserved in frozen masses.

Microscopy of samples at a depth of 2 cm (Fig. 5) shows the presence of mycelium of microscopic fungi [25].

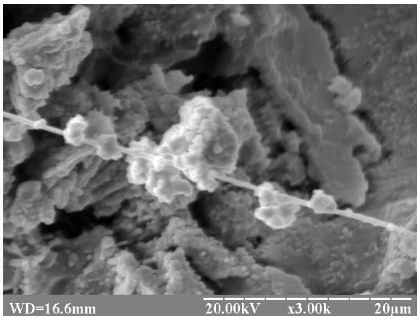


Fig. 5. Electron microscopic image of concrete affected by microscopic fungi

Studies [26] confirm that under favorable environmental conditions and sufficient nutrients, fungal hyphae penetrate microcracks and pores of building materials. Fungal enzymes soften the concrete matrix to facilitate penetration into the substrate.

In addition, researchers in [27] proved the destructive effect of biochemical corrosion on concrete.

As a result of the study, it can be concluded that the concrete structures of the oil press shop were affected by two factors: oil and microscopic fungi.

3.3. Results of concrete research using TPD MS

Concrete samples were obtained at different distances from the equipment support to the center of the core with different degrees of oil penetration (Fig. 6).

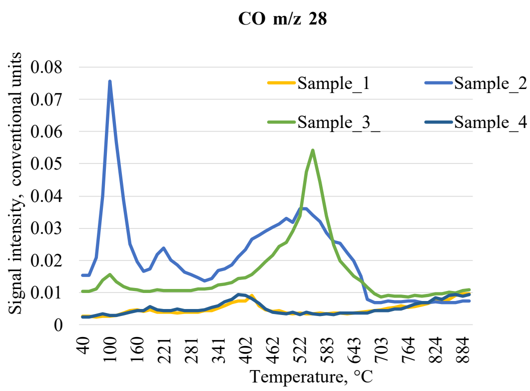


Fig. 6. Thermograms of CO release ($m/z=28$) from samples obtained at different distances from the core

As a result of the study, it was found that CO was released most intensively from samples 2 – 0.03 and 3 – 0.05 at a temperature of 583 °C. Other concrete samples were destroyed by corrosion and contained a small amount of CO throughout the entire heating period.

The CO_2 content in concrete samples was similarly high in samples 2 and 3 (Fig. 7).

Carbon dioxide was released at a temperature of 552 °C with an intensity of 0.1 from sample 2 and 0.18 from sample 3. In other samples, carbon loss occurred, which can be attributed to biochemical corrosion due to the growth of microscopic fungi in the concrete. The obtained result is confirmed by studies [27, 28].

Also, studies of concrete by TPD-MS show that carbons (CO, CO_2) are destroyed at a temperature of 583 °C.

Fig. 8 shows the release of water with an intensity of 0.8 from sample 2 and 0.4 from concrete sample 3 at a temperature of 100 °C.

The specified samples of building materials had a significant amount of bound moisture in the structure, so when heated to 100 °C, the water evaporated.

Fig. 9 shows a negligible sulfur content of 0.0035 at a temperature of 90 °C in test sample 2.

In other experimental samples, sulfur was practically not released during the entire experimental period. Unlike sulfur, SO was released quite intensively (Fig. 10).

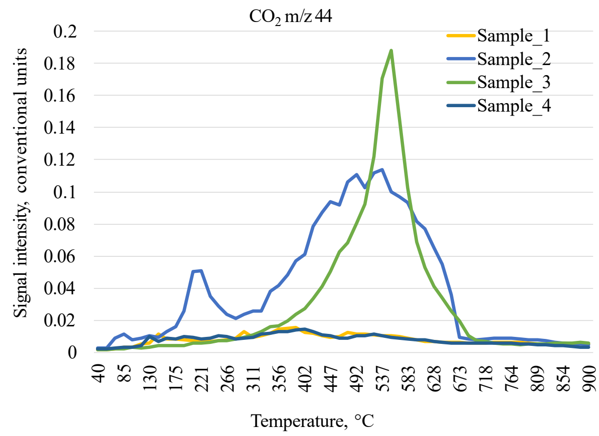


Fig. 7. Thermograms of CO_2 release ($m/z=44$) from samples obtained at different distances from the core

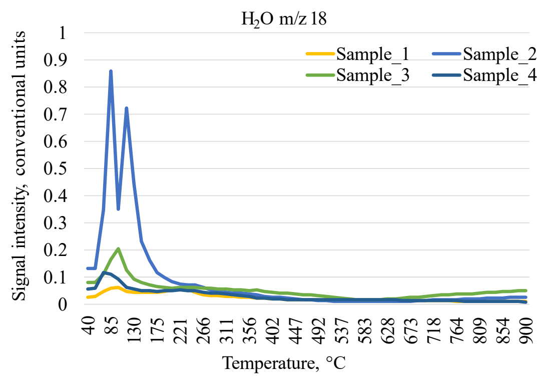


Fig. 8. Thermograms of H_2O release ($m/z=18$) from samples obtained at different distances from the core

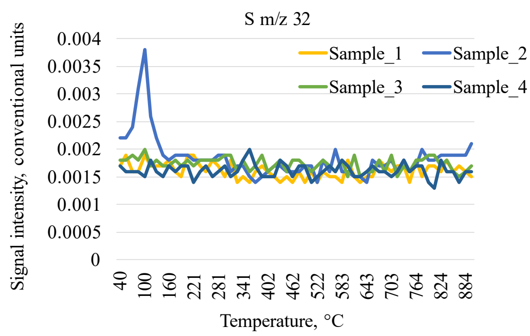


Fig. 9. Thermograms of the S release ($m/z=32$) from samples obtained at different distances from the core

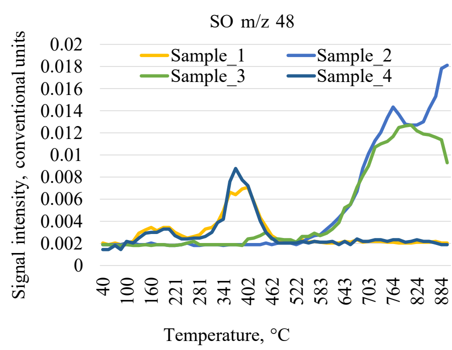


Fig. 10. Thermograms of SO release ($m/z=48$) from samples obtained at different distances from the core

The release of sulfur oxide occurred from sample 1 – 0.08 at a temperature of 402 °C, 2 – 0.014 at a temperature of 764 °C, 3 – 0.012 at a temperature of 809 °C, and 4 – 0.09 at a temperature of 402 °C. The obtained data confirm the presence of bound water in the concrete samples.

Sulfur dioxide was released from the concrete samples less intensively when heated (Fig. 11).

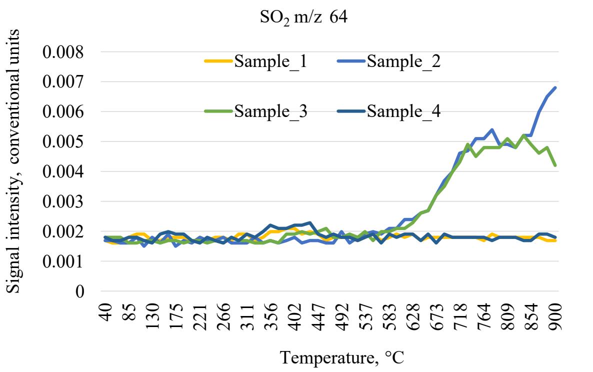


Fig. 11. Thermograms of SO_2 release ($m/z=64$) from samples obtained at different distances from the core

Sulfur dioxide was released with an intensity of 0.005 at a temperature of 794 °C from samples 2 and 3.

As a result of the study using the TPD-MS method, it can be concluded that carbons (CO, CO_2) and H_2O were intensively released from concrete samples 2 and 3. Sulfur was released when heating sample 2 in insignificant quantities. Sulfur oxide and dioxide were also released most intensively from samples 2 and 3. The presence of sulfur and its oxides in concrete samples that were least damaged by corrosion processes is associated with the composition of sulfur concrete to give it greater strength. When designing the oil pan, the builders took into account the negative impact of vegetable oils on the surface of building materials.

The practical significance of the results obtained is that a long-term negative effect of vegetable fats on concrete was established.

The limitation of research is that the experiment was conducted on the scale of one object.

The impact of martial law is that the oil pan was studied after destruction as a result of the blast wave, so the studies conducted at the object became possible.

The prospect of further research is the development of concrete with reduced absorption capacity.

4. Conclusions

When determining the strength of concrete by the direct method of testing experimental samples, the aggressive effect of high-molecular fats on concrete structures was confirmed with the following results: experimental sample No. 1 has a decrease in compressive strength of about 6 %, sample No. 2 has a decrease in strength of about 19–20 %, sample No. 3 has a decrease in strength of about 48 % from the control sample No. 4.

Electron microscopy established a layer of solidified oil and plant residues on the surface of concrete samples. In addition, at a depth of 2 cm, the mycelium of microscopic fungi was found, which use concrete as a matrix for growth.

The study of concrete samples using TPD MS showed that carbon monoxide was intensively released at a temperature of 583 °C from samples 2 – 0.03 and 3 – 0.05. CO_2 was released at a temperature of 552 °C with an intensity of 0.1 from sample 2, and 0.18 from sample 3. In other samples, carbon was not released, which is associated with biochemical corrosion of concrete. Water was released from concrete samples 2 – 0.8 and 3 – 0.4 at a temperature of 100 °C. Sulfur was released when heated to 90 °C from sample 2 in insignificant quantities – 0.0035. Sulfur oxide was also most intensely released from samples 2 (0.014), $t=764$ °C and 3 (0.012) $t=809$ °C. SO_2 was released at a temperature of 794 °C with an intensity of 0.005 from samples 2 and 3.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

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The study was performed without financial support.

Data availability

Manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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