Modern Technologies of Nondestructive Testing of Construction Materials

R Fediuk\textsuperscript{1} and A Yushin\textsuperscript{2}

\textsuperscript{1}Senior Lecturer, Engineering School, Far Eastern Federal University, Vladivostok, Russia
\textsuperscript{2}Student, Engineering School, Far Eastern Federal University, Vladivostok, Russia

E-mail: roman44@yandex.ru

Abstract. The article presents the modern methods of research of building materials (such as styrofoam, cement, concrete admixtures, etc.), applied in the Far Eastern Federal University. The latest equipment described for these studies and modern methods of testing.

1. Introduction

In recent years, to determine the processes of formation structure in products from inorganic building materials binders are widely used non-destructive inspection methods. These methods best meet the requirements of continuous monitoring of the properties of construction materials, the study of their physical and chemical properties. This test is not accompanied by the destruction of the structure of the material and do not require bookmarks foreign bodies in the sample, as well as allow individuals to obtain objective indicators, are valid not only for small but also for large samples.

2. Basic information

2.1. Chromatography of destruction polystyrene

To assess the quantitative and qualitative composition of toxic substances released during of destruction polystyrene used PGC-1 – autonomous wearable gas chromatograph using a highly sensitive photoionization detector (PID) (figure 1).

\textbf{Figure 1. Chromatograph PGC – 1.}
For more accurate results, samples were also carried out research on gas chromatography-mass spectrometer Shimatsu QP – 5050A (figure 2).

Flexible quadrupole gas chromatography-mass spectrometer along with electron impact ionization (EI) and the system of positive chemical ionization (PCI) for precise determination of molecular weight also has a system of negative chemical ionization (NCI) for highly sensitive analysis of electrophiles. It has a computer - optimizable ion source and the system of magnetic lenses. Quick and clean (150 liter/sec) turbomolecular vacuum pump provides for chemical ionization and ability to work with packed columns within 5 minutes after the activation. Mass Range – 900 Daltons (1.5 · 10^{-21} g) is achieved by means of a detector with low noise. There is a possibility of direct sample introduction, the use of capillary and packed columns. There is a quick switch from automatic mode negative chemical ionization (NCI) in the electron impact ionization (EI) without replacing the components of the ion source. There is a direct connection Purge-and-Trap (VOC concentrator column) without introducing a jet separator. The scanning speed is 6750AEM / s or 50 scans / s, the concentration dynamic range – 106.

2.2. The study of morphological features of the microstructure using scanning electron microscopy
The microstructure of samples was performed using a scanning electron microscope Carl Zeiss CrossBeam 1540XB (figure 3).
Microstructural studies and quantitative analysis of the microstructure of the samples were carried out using the hardware-software complex, which includes a laser diffraction particle size analyzer "Analysette 22" model NanoTech (Germany) [1].

For the analysis was used specially developed software package automated processing, enabling you to get almost all the morphological parameters of the microstructure (the size and shape of the structural elements, their orientation in space), and to assess the value of porosity and specific surface area.

2.3. X-ray analysis

Study of the qualitative and quantitative composition and properties of the starting materials and composite binder was performed using standard methods. Investigation of the mineral composition and the structure is performed using X-ray diffraction on the powder X-ray diffractometer D8 Advance Company Bruker AXS (figure 4).

![Figure 4. X-ray powder diffractometer D8 Advance.](image)

X-ray diffraction - a non-destructive method for analyzing substances in powder form. It provides the ability to conduct qualitative and quantitative analysis of crystalline phases of establishing the crystal structure of inorganic, organic, organic and metal complex compounds in polycrystalline form, establishing the composition of polycrystalline materials, the degree of crystallinity of polymers [2].

In the study used the database ICDD PDF–2 and Crystallography Open Database. Quantitative phase analysis is possible for 345 industrially important phases contained in the database TOPAS Structure Database, as well as the phase of known structure [3].

2.4. Differential thermal analysis and thermogravimetry

Depending on the latched indicators when heated distinguish the following methods of thermal analysis:

- Differential thermal analysis (DTA) - shows the change in the energy system (sample);
- Thermogravimetry (TG) - change in mass [4].

Derivatograms samples were obtained on a thermogravimetric analyzer, Shimadzu DTG–60H (figure 5). Program heating furnaces from 20 to 1500°C is carried out by electronically heater at 20 °C / min. Platinum thermocouple with an accuracy of 5 ° C temperature measurement (T), the scan speed at 2.5 mm / min a four-channel recorder signal is recorded on the paper. The temperature difference (ΔT) between the studied substance and a standard proportional to the thermal effect is recorded in the form of DTA curve (sensitivity of 0.5 mV). Simultaneously with the DTA curve is being recorded curve of weight loss (TG) and its derivative (DTG) (sensitivity of 0.5 mV), 113 mg sample weight. Weighing accuracy of 0.05 mg [5].
2.5. Determination of radioactive materials

In the literature review, it was found that materials such as crushed granite screenings and ash TPP have some radioactivity. Due to the fact that the concept of the modern building materials science is aimed at creating conditions for the environmental safety of the home, it was necessary to quantitatively check the background radiation of these materials [6, 7].

The specific (volumetric) activity of beta- and gamma-emitting nuclides in the samples was determined by counting spectrometric method using a universal spectrometer complex USC “Gamma Plus” (figure 6).

The study was conducted according to the requirements of the following standard documents: GOST 27451-87 "Means of measuring ionizing radiation. General technical conditions", GOST 26864–86 "Spectrometers of energies of ionizing radiation. Methods of measurement of basic parameters", TU 4362-002-46554900-06 (PLUS 412131.002TU) "complex universal spectrometry USC” Gamma Plus. "Specifications".
The principle of operation is based on the complex transformation in the working volume of the detector of gamma rays and beta particles in the flashes of light (scintillation), the intensity of which is proportional to the energy lost by the gamma-quantum or beta-particle detector. Lights flash, falling into a photoelectron amplifier tube (PMT), converted into a stream of electrons, which multiply under the influence of the applied potential difference, resulting in at the output of the PMT generated pulses of electric current, whose amplitude is proportional to the particle energy lost in the detector. This fact provides the fundamental ability to measure the energy spectrum of the detected gamma - or beta radiation.

2.6. Determination of particle size materials

Particle size was determined by laser particle size distribution of powder materials, allows you to determine the particle size and the percentage of their content in the analyzed material. For these purposes, used laser diffraction particle size analyzer "Analysette 22" model NanoTech (Germany) (figure 7).

![Figure 7. Laser diffraction particle analyzer "Analysette 22" NanoTec.](image)

Analyzer for determining the particle size distribution by laser diffraction employs the physical principle of scattering of electromagnetic waves. Particles in a parallel laser beam scatter light at a constant solid angle, which depends on the particle diameter. The lens collects the scattered light annularly detector, which is mounted in the focal plane of the lens. Non-scattering light always converges at the focal point on the optical axis.

With complex mathematics of the intensity distribution of the scattered light can calculate the particle size distribution of the scattering particles in the team. The result is a laser diffraction particle diameter, the diameter of which is equivalent to a sphere with the same distribution of scattered light. Measured volume mean diameter and the resulting particle size distribution, this is distribution volume.

2.7. Determination of the specific surface

Specific surface area binders and mineral additives used were measured according to GOST 310.2-81, using an instrument PSC-11, which operates on the principle of air permeability through the layer previously compacted material (figure 8).
All measurements and calculations in the PSC-11 automated, eliminating the factor of human error. The measurement results are displayed on the display. The unit of analysis of variance PSC-11 is used internationally accepted method gas permeability Kozeny and Carman. Coefficient of permeability of samples with open porosity or powder layer is determined by the duration of the filtration air therethrough at a fixed initial and final vacuum in the working volume of the device.

The test particulate material is introduced into the sleeve layer of a certain thickness, after a vacuum is created by means of a water jet pump. Using the regulator device when the cock is open, a vacuum is created in which the fluid in the closed knee gauge aspirator begins to move from the closed knee open due to the level difference, thus there is the passage of air through a bed located in the liner material. The duration of the passage of a certain volume of air through a bed of particulate material is dependent on the value of its specific surface area, which allows to calculate its value.

The calculation is made using equation 1:

\[ S = K \frac{M \sqrt{t}}{m} \]  

where \( S \) – the value of specific surface area, \( K \) – constant of the device (the device is indicated in the passport); \( M \) – value depending on the height of the powder layer and the ambient temperature (determined by the table); \( t \) – time of passage of fluid between the risks; \( m \) – mass of sample [g].

3. Summary
According to the results of series of experiments the amendment of the well-known Fuchsiun equation is calculated for calculation of the resistance of fibrous air filter with regard to form and surface defects of the fibers.

References
[1] Boukherroub N et al 2012 EPJ Web of Conferences 29 00010
[2] Kezrane M et al 2012 Journal of Alloys and Compound 536 304–307
[3] Predescu C et al 2012 Metalurgia International 18 65–68
[4] Akkouche K et al 2011 Journal of Magnetism and Magnetic Materials 323 2542–2548
[5] Nicolicescu C et al 2011 Materials Science Forum 672 219–222
[6] Nicolicescu C et al 2010 Optoelectronics and Advanced Materials, Rapid Communications 4 1408–1414
[7] Hales S J and Vasquez P 2003 Gamma Titanium Aluminides 305–310