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Investigation of hydrated portland cement structure formation by means of small angle neutron scattering

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Abstract

Investigation of the process of structure formation of samples of hydrated cement compositions on the nano level is conducted with the help of the method of small angle neutron scattering (neutron wavelength is λ=0.3 nm) both on the basis of Portland cement without additives and that modified by various nanoadditives and nanomodifiers of artificial (alpha aluminium oxide, gamma aluminium oxide) and technogenic (sludge) origin, as well as by complex additives containing surfactants. Dynamics of changes of structural parameters of samples of cement compositions depending on time is analyzed. Changes of correlation functions of scattering objects and fractal dimensions are observed. It is substantiated that Portland cement compositions are fractal clusters.

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*Keywords:*portland cement; portland cement compositions; small angle neutron scattering; additives; modifiers; surfactants; fractal dimensions.

1. Introduction

Anhydrous mineral components of cement clinker form crystalline hydrates during the hydration process. Formation of particles of calcium silicate hydrate (C-S-H) is of decisive importance in this process. Particles C-S-H are compounds of variable composition complying with the conditional formula $x\mathrm{CaO}*y\mathrm{SiO_2}*z\mathrm{H_2O}$ and having variable molar fractions *x*, *y* and *z* of calcium oxide, silicon oxide and water, as well as basicity C/S = 0,5 variable on

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a large scale. Complex gelatinous framework is formed from particles C-S-H as a result of formation of hydrated cement. Structural parameters of particles C-S-H and the cement matrix itself change when passing from the nano level to the micro level in accordance with the size of the cement particles formed and affect the properties of the resulting hydrated cement. Strength, durability, water resistance, cold resistance and other properties of hydrated cement depend on the distribution of nano particles C-S-H according to their shape and size, as well as on the ratio of free and bound water filling the space between solid particles of hydro silicates, availability of pores and their distribution according to their shape and dimensions, i.e. the former are determined by the structural parameters of materials on the micro- and nano level. Description and understanding of structural changes is an important prerequisite of managing hydration processes of Portland cement compositions [1].

Various additives (fillers and modifiers) of both artificial (e.g., carbon materials, γAl_2O_3, etc.) and technogenic (e.g., sludge) origin are used for the purpose of forming cement compositions possessing certain desired properties [2-5]. The additives used affect the structure of the original materials and their performance characteristics [6-9] primarily due to the presence of the nano dispersible component [1-3].

In this paper the research of structure formation of Portland cement compositions on the nano level modified by additives of artificial and technogenic origin is conducted by means of smallangle neutron scattering, dynamics of changes of structural parameters of samples of cement compositions over time is analyzed as well.

Nomenclature

λ	wavelength of neutrons
q	scattering vector; transmitted neutron pulse
θ	scattering angle
$I(q)$	intensity of small angle neutron scattering
R	particle size
D	fractal sizes
$\sigma(q)$	neutron scattering cross section
$G(R)$	distribution function of substance density according to distances
$\chi(R)$	correlation function

2. Materials

Both artificial (αAl_2O_3,γAl_2O_3) and technogenic (sludge) materials were used as additives (fillers and modifiers).Sludge is a product resulting from dispersion and adsorption processes, chemical reactions, the processes of mixing, settling and coagulation of solid particles from an oversaturated solution whilst purifying and dispensing wastewater, or in the process of water softening at industrial metallurgical and metal processing enterprises, petrochemical, oil refining and thermal power plants. As a rule sludge is a suspension characterized by stability of structure, homogeneity and consistency of composition [10]. Conditions of sludge formation fit into the concept of nanotechnology sol-gel, which allows treating it as a nanotechnogenic raw material [11].

Chemical composition of sludge indicates its hierarchy as a mineral or organo-mineral material [10]. Sludge can be subdivided into filling components (in which s- elements predominate) and structure-forming ones (containing p-elements and d-elements) according to the method of usage as an additive in Portland cement compositions.

Sludge is not a monodispersed system. One of the important factors affecting its properties is distribution of solid particles according to their dimensions. In many cases sludge may be classified as a nanotechnogenic raw material, as it contains a nano dispersed component [1-3].

Nano technogenic raw materials may be classified in compliance with the following main points: formation conditions, chemical and mineralogical composition, particulate composition, structural and rheological properties, chemical and surface activity [1].

Chemical composition of sludge is largely dependent on the type of technological process and the conditions under which it is formed [10]. Composition of sludge is shown in Table 1.