Structure formation of hyper-compacted and modified concrete

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Abstract. Production of axisymmetric products - pressure and non-pressure pipes, rings, wells, bridges and drainage elements represents one of the main branches of construction industry in water and wastewater industry of Uzbekistan and Central Asian republics. However, positive tendencies of its development are only emerging and still do not meet the potential of progressive, competitive and economical modern technology, capable of providing significant shifts in reduction of resource intensity of new products, expansion of raw material base of construction industry and involvement of technogenic products into its balance, as well as solution of important economic and environmental problems.
Prospects for further development of high-efficiency tubular goods production and scientific and technological progress of their production are largely determined by the importance of regularities and methods of controlling technological processes of structure formation with regard to given high level of product quality and criteria of resource intensity of production.
In this regard, the analysis of general regularities of material structure formation in the complex process of hypercompaction and cementations modification in axisymmetric concrete is of primary importance.

1 Introduction

From the most general point of view, the structural formation of cement stone hyper compacted with modified concrete (HCMC) can be imagined as a transformation of the "system of addition" of initial mineral components "system of growth" of new substances arising at different stages of technology (the terms system of addition and system of growth are proposed by L.V. Radushkevich [1-7, 16].
A stacking system with an appropriate structure is formed by the arrangement and contacting of mineral components and aggregate grains during the process of water mixing, mixing and shaping. The stacking system is created from "ready-made" structural elements

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with the continuous emergence of "new" structural elements as well as inter-grain pores and inter-particle contacts.

Analysis of the formation of stacking systems and their parameters is performed by the mechanics of granular media [17]. The content of this analysis is determined by the requirements of obtaining data on the regularities and nature of the packing of particles in connection with their particle size distribution. In technological terms, this is expressed in the form of problems for selecting the optimum particle size distribution of components, the optimum ratio of their volumes by the packing density criterion, and the minimum water content of the mixture. At the stage of grinding of the initial components, the task of analysis of the mixing system may be to determine the degree of agglomeration of particles, homogeneity of distribution of components in each micro-volume of the product during grinding. The task of mixture homogeneity is typical both for the preparation of the moulding mass, and especially for its compaction and modification.

In the case of hypercompaction, the content of the task includes the phenomena of over-packing of particles due to the application of peristaltic mechanical influences and the squeezing out of excess mixing water [18].

When solving these tasks, the optimal conditions for the formation and development of the growth system (structure formation) are also "prepared" at the same time [11, 19, 20].

2 Methods

The growth system with its inherent structure is created by a combination of different mineralogy, morphology and size of dispersed particles of new formations arising in the process of hydration, accompanied by hypercompaction and modification of the cementations matrix. At the same time, the growth system is created not out of ready-made, but out of newly formed particles in the course of the developed technological process. And that is its fundamental difference from the stacking system.

The development of the growth system reflects, above all, the process of cementations substance accumulation with its qualitative changes occurring under conditions of physical modification. The analysis of the formation and parameters of the growth system is based on the physical chemistry of heterogeneous processes of new disperse phase emergence. The content of this analysis is stipulated by necessity of obtaining information about kinetics and dynamics of hydrate compounds formation, about indices of their composition, dispersity degree, peculiarities of contact in crystal interlock, as well as about evolution of pore space of cementing substance in hypercompaction. In practical terms, this information, correlated to the modes of technological processes, is necessary to control them in accordance with the goal of obtaining products with an extremely high level of quality [8,9].

The growth system develops on the basis of and within the stacking system, transforming it, interacting with it and being influenced by the physical layer of peristaltic hypercompaction and hydraulic modification of the binder. This is expressed in the fact that the system of compaction growth and modification, as the cementations substance accumulates, occupies part of the "disappearing" volume as a result of hydration, as well as a sharp narrowing of the intergranular space of the initial stacking system. The results are as follows. Firstly, the initial value of intergranular hollowness of the addition system is not conserved at synthesis of new formations. The hollowness of the initial stacking system (without growth system) does not increase as usual, but sharply decreases under the action of peristaltic hypercompaction. In this case the volume of cementations substance necessary for monolithization of aggregate particles turns out to be larger than the volume of voids formed in it [21]. The "new" volume of intergranular space is almost entirely filled with cementing material, with its characteristic volume and pore-size distribution. And, thus, the porosity structure of the modified hyper compacted concrete is fundamentally changed.

3 Results and discussion

The interaction of stacking and growth systems also consists in the fact that during formation of cementations matter its contact with surface of aggregate grains and other initial components is formed. The influence of the stacking system on the growth system in this case is expressed by the fact that the kinetics of cementitious accumulation and crystallization, dynamics and mechanism of the contact zone formation depend on the crystallographic characteristics of specific surface values, specific surface energy of the stacking system particles, and finally on the parameters of its pore space. As it is proved experimentally, the structure of new material can be considered to be a composition of addition and growth systems at the appropriate stage of their interaction.

The resulting structure depends on the totality of all structure-forming factors, which can be characterised by a certain "structure-forming potential" or "formation limit" of the cementations matrix. The value of the potential is a quantitative expression of the degree of completion of a given structure in relation to the ultimate, ideal structure. Incomplete realization of this potential in the resulting material will be characterized by an appropriate measure (degree) of incompleteness of the structure formation process, which will determine the level of material quality in terms of its construction and technological properties. The degree of structure formation completion can be quantitatively estimated through the ratio of parameters of the structure state fixed under certain technological conditions to the limit state with the maximum possible density of neoplasms and the maximum specific activity of surface bonds in principle achievable with a new technology. Structure completion degree Sc for the whole range of technological conditions will be normalized in the range of values from 0 to 1. We implemented quantitative structure evaluation of various materials with a given controlled plausibility. To check "structural" researches of various concretes, the methodology of sampling and preparation of statistically representative samples of its cement stone has been substantiated and applied. Special studies of the Institute of Physics of Chemistry of the Academy of Sciences of Uzbekistan have shown that statistical reproducibility of composition characteristics, structure parameters, material state parameters corresponds to the error not exceeding 7...9%, and estimates of physical-mechanical properties to 9...14%.

The results are shown in Fig. 1 and 2. While the volumes of hydrate phases and pore space remain practically constant, they undergo qualitative changes in time. In the solid phase, as the exponential accumulation of cementitious matter exponentially decreases the volume of residual grains of the original components, although the cementations matter at various stages of its formation is represented by a set of highly basic forms of hydrate formations, and their structure depends on the technological conditions of structure formation. The dynamics of morphological composition of cementations substance of hypercompact modified concrete is determined by: a continuous decrease in the relative volume fraction of the hidden crystalline component in kinetics of the morphostructure of different types of concrete and structural characteristics of different types of concrete.

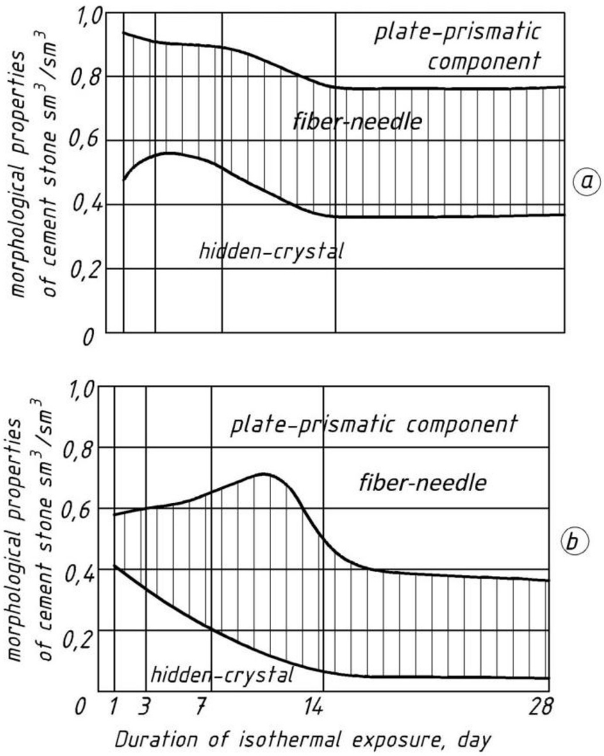

Fig. 1. a) - normal concrete; b) - hyper-compacted concrete

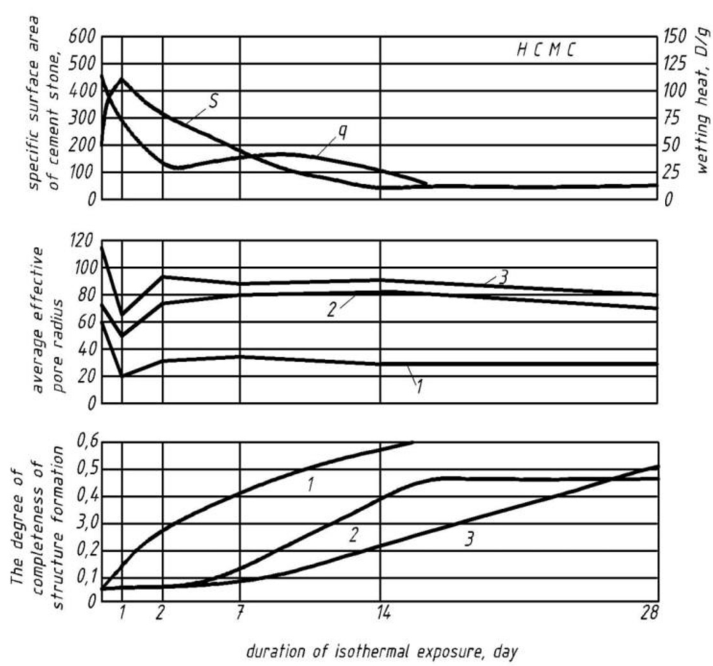

Fig. 2. 1 - hyperdense modified; 2 - Vacuumed; 3 - vibro-compacted

The current increase in the share of fibrous-needle component, decrease in the share of lamellar-prismatic component at the stage of neoplasm accumulation; decrease in the share of fibrous-needle component and increase in the share of lamellar-prismatic component at the stage of neoplasm recrystallisation at the maximum accumulated (practically constant) amount of the latter.

A change in the quantitative content of cementitious matter with the simultaneous development of the process of morphological transformations, crystallization and recrystallization of fusion products determines an ambiguous nature of changes in the value of their total specific surface. The specific surface passes through its maximum anatomy in the first hours of synthesis of neoplasms, and thereafter significantly decreases.

The structure of porosity at practically constant value of material porosity is determined by the change of micro-pore size distribution function in the process of "overgrowth" of inter-grain voids of the system of initial particle addition by cementitious substance and simultaneous change of its mineral and morphological composition, size of crystals. The average effective pore radius as an estimation of the function of their size distribution can decrease by 4...5 times in the period of cementing substance accumulation, and increase again by 1.5...2 times during recrystallization of new formations and enlargement of crystals in the aggregate compared to the minimal value.

The formation of crystalline aggregate occurs through the formation of adjoining contacts, coalescence and germination of individual crystals and their friends. As the hardening progresses, the process of transition from adjoining contacts to intergrowth contacts develops, but with a tendency for individual crystals to become more damaged and defective. Cementitious bonding zones with aggregate grain surfaces are formed as adjacency contact; with increasing duration of isothermal curing the contact may be disturbed and weakened.

The specific experimental data shown in Table 1 also well illustrate the regularities for hyper-compacted modified concrete (HCCP). The quantitative expressions may be different if the technological conditions of compaction or water squeezing are changed, but the general nature and essence will remain the same [10, 11, 22, 23, 24].

Changes in the quantitative characteristics of the structure of the hyper-compacted concrete were also observed when changing the dwell time of the concrete mixture before pressing with the squeezing out of the excess mixing water, Fig. 3. The observed changes in the morphological structure of the cement stone cannot be accidental, as they are confirmed by repeated experiments at yields ranging from 79 to 109%.

In contrast, no such change in the morphology of the neoplasm was observed in normal concrete. The above data show a significant increase in the lamellar-prismatic component in cement concrete which has been cured for 20 to 40 minutes before pressing. With increasing curing time the number of formed crystalline neoformations necessarily increases.

This can be explained by the previously proposed systems approach - the morphology of the cement stone structure is the result of the interaction of kinetics of the morphostructure of concrete with curing before compaction.

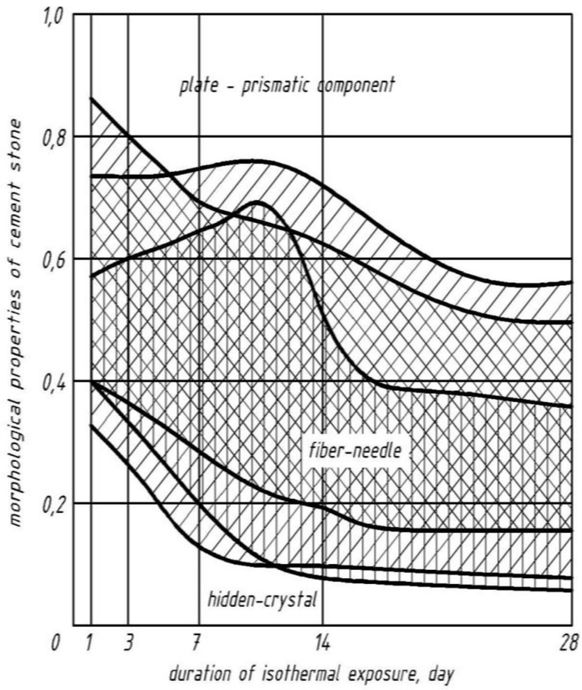

Fig. 3. - hyper-compacted modified; - vacuumed; - vibro-compacted

Table 1. Cement stone morphostructure in hypercompacted modified concrete (HCMC)

1	Morphological structure	Submicrocrystalline	Fibrous-acicular	Lamellar-priamatic
2	Mineralogical composition	Highly basic calcium hydrosilicates (HCS)	Predominantly HCS of the tobermorite group	Tobermorite with long processing times
3	Size of particles and crystals; medium length, micron	$\frac{0.10}{0.15}$ And less than	$\frac{0.10}{1.0} \ldots \frac{0.5}{5.0}$	$\frac{0.80}{2.4} \ldots \frac{1.3}{5.0}$
4	Number of contacts per volume unit, 1/cm3	$\sim 10^7$	$\sim 10^5$	$\sim 10^4$
5	Type of contacts between particles and crystals	globular bulb contacts particles	combination of butt contacts and crystal fusion	a combination of adjoining, intergrowth and sprouting crystals
6	Specific surface, m2/g	500	100...200	30...50
7	Average effective pore radius, nm	5...7 and less	20...40	40...80
8	Wetting heat, J/g	100...120	30...40	15...20
9	Marginal coefficient of heterogeneity The structure of the-% of the total	0.15/46-100-0.4	5/215-100-2.3	5/464-100-1.1

At the same time the growth system (recrystallization and development of structure in time) can develop effectively without sufficiently complete development of the addition system (accumulation of primary hydration products). The developed system of addition of hydration of cement particles under favourable conditions of hydraulic head of surrounding water, due to thixotropic, significantly improves morphology of structural neoplasms. This phenomenon is not observed in conventional concretes where there is no structure modification and low level of compaction. Experimental data based on complex structural examination techniques show that the volume development of related morphological structures can be as much as 20%. At the same time the degree of completion of structure formation increases by 7...12%. The first established influence of the time of keeping of the concrete mixture before its modification and hyper consolidation is an important technological factor. Its implementation in the technological process is not difficult and can be easily realized in normal production conditions.

4 Conclusions

1. Complex methods of chemical, X-ray phase, electron-microscopic, enthalpy-metric, adsorption, porometric and other analyses have established that morphostructure of binder in concrete is characterized by change of quantitative relations of volumes of open-crystalline, needle-fibre and lamellar-primary components of a cement stone at completeness of structure formation in 1,5 times exceeds vibro-compacted and vacuum-compacted concrete.
2. By determining the micro-hardness of the cement paste by indentation of the diamond pyramid, it was found that the strength of the inter-partial layers and contact zones are nearly identical, which gives the HCMC a considerable advantage over conventional concrete.

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