UDK 666.973.6


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HIGH-STRENGTH HEAT-INSULATING COMPOSITES

ВИСОКОМІЦНІ ТЕПЛОІЗОЛЯЦІЙНІ КОМПОЗИТИ

ВЫСОКОПРОЧНЫЕ ТЕПЛОИЗОЛЯЦИОННЫЕ КОМПОЗИТЫ

Annotation. The results of the study of basic physical and mechanical properties of porous concrete on the basis of tonnage of waste metals. Established dependence of concrete strength cellular structure on the strength of the matrix material. The results of studies of the properties of the microporous aerated. The main operational characteristics of heat-insulating composites are investigated.

Keywords: non-autoclaved aerated concrete, autoclaved microporous aerated concrete, aggregate activity.

Анотація. Наведено результати дослідження основних фізико-механічних властивостей ніздрюватих бетонів на основі великотоннажних відходів металургії. Встановлено вид залежності міцності бетонів ніздрюватої структури від міцності матеріалу матриці. Представлені результати дослідження властивостей мікропористого газобетону. Досліджені основні експлуатаційні характеристики теплоізоляційних композитів.

Ключові слова: неавтоклавний газобетон, автоклавний мікропористий газобетон, міцність матеріалу матриці, активність заповнювача.

Анотация. Приведены результаты исследования основных физико-механических свойств ячеистых бетонов на основе крупнотоннажных отходов металлургии. Установлен вид зависимости прочности бетонов ячеистой структуры от прочности материала матрицы. Представлены результаты исследования свойств микропористого газобетона. Исследованы основные эксплуатационные характеристики теплоизоляционных композитов.

Ключевые слова: неавтоклавный газобетон, автоклавный микропористый газобетон, прочность материала матрицы, активность заполнителя.

Proceeding from the fundamental tenets of the concept of sustainable development, aerated concrete can be considered as one of the most promising structural materials that provide a significant reduction in energy consumption for space heating at low cost of wall material per square meter of envelope structures.

But, allowing significantly reduce of buildings heat loss, the conventional aerated concrete, in its production requires the presence of high-temperature processes (autoclaving) and the use of initial materials, the production of which is accompanied by the formation of a large amount of CO_2 (greenhouse gas). The composition of the feed mixture enters AAC has up to 40% wt. of Portland cement and lime. The production of these binders is accompanied by emission of a large amount of CO_2 in the atmosphere. Greenhouse gas is generated not only at limestone decarbonation (up to 300 kg per tonne of Portland cement and 780 kg per tonne lime), but also during combustion of fuel, which is used for burning the feedstock mixtures. Taking into account the carbon dioxide formed during the transportation of the finished product, experts believe that the creation of one ton of cement is accompanied by the emission of one ton of carbon dioxide into the atmosphere [1].

In addition to the above mentioned, it should be noted that the traditional autoclaved aerated concrete is characterized by the presence of operational restrictions in damp conditions (for premises with a relative humidity of 75%), which leads to the need to protect the surface of the envelope structures from water sorption. The macroporous structure of the material does not allow efficient hydrophobic coating and causes the need of surface protection with a variety of plasters.

The purpose of the scientific research complex was the creation of new technologies for the production of non-autoclaved aerated concrete on the basis of large industrial wastes and microporous autoclaved aerated concrete manufacturing technologies of low density.

Non-autoclaved aerated concrete manufacturing echnology on the basis of large industrial wastes

The generalized dependence of the porous materials strength (Rp) on the strength material matrix (Rm), which has been obtained by analysing the results of rock tests [2]:

$$R_m = R_p\,(\rho_m/\rho_p)^2, \qquad (1)$$

On the basis of this dependence a similar dependence for autoclaved concretes was obtained experimentally [3], which has the form:

$$R_p = R_m\,[1 - 1{,}105 \cdot (1 - \rho_p/\rho_m)^{0{,}33}], \qquad (2)$$

where: R_m – strength of matrix material with density of ρ_m;
R_p – strength of porous material with density of ρ_p.

The authors experimentally [4] set the view of similar dependencies for non-autoclaved aerated concrete based on Portland cement and an alkali cement:

$$R_m = R_p\,(\rho_m/\rho_p)^{2{,}28}, \qquad (3)$$

$$R_p = R_m\,[1 - 1{,}105 \cdot (1 - \rho_p/\rho_m)^{0{,}47}]\,, \qquad (4)$$

The reliability of the obtained exponents values is confirmed by statistical analysis of test results, which are presented in the Table 1.

To implement the research objectives for the development of manufacturing technology for high-strength non-autoclaved aerated concretes on the basis of large industrial waste, alkaline cements [5] were used, developed in the 70s of the last century in Ukraine. The peculiarity of this type of cement, is that they are made on the basis of large-scale wastes of metallurgy – blast furnace granulated slag and are characterized by a high branding strength (up to 100 MPa), durability (F1000) and corrosion resistance [6].

Characteristics of alkali cement that was used for the development of non-autoclaved aerated concrete on the basis ground blast furnace slag are shown in Table 2. Specified results indicate that the level of alkali cement strength at the age of 7 days corresponds to strength of grade conventional Portland cement (48 ... 63 MPa). Grade of alkaline cement, aged 28 days, is significantly higher than grade conventional Portland cement, and, depending on the type and density of the alkali component is in the range of 77 ... 108 MPa.

Test results of non-autoclaved aerated concrete (Table 3) samples, which were made using an alkali cement without filler and of compositions based on alkali cement with a filler in the form of graded quartz sand and not ground granulated blast furnace slag, indicate that the presented non-autoclaved aerated concrete aged 7 days is characterized by high levels of compressive strength, at the level of the national standard requirements for non-autoclaved concretes aged 28 days (table 4). Branded strength of test compositions at the age of 28 days, in all cases, exceeds the requirements of national standard grade and aerated concrete humidity is in the range of normalized values of temper moisture, i.e. not more than 25%.

A distinctive feature of non-autoclaved concretes of similar compositions autoclaved is the increase of compressive strength in the subsequent hardening for 90 days.

High alkaline media of alkali cement allows chemical reaction of its hydration products with filler surface – quartz sand. The absence of such reactions in compositions based on Portland cement causes a noticeable decrease in the compressive strength of aerated compositions (table 4). When introducing quartz sand into the aerated concrete composition in an amount of 25% by weight of Portland cement, strength is reduced to 68% of the strength of compositions without filler. With increase in the proportion of filler to 43 and 67%, the strength is reduced to 66 and 54%, respectively. At the same time, the introduction of quartz sand in the compositions of alkali cement in an amount of 50 and 100% of the slag weight, the strength reduction is 10 and 20%, respectively.

Test results obtained for non-autoclaved concretes based on alkali cement show that developed compositions have resistance levels within the parameters regulating the characteristics of aerated concretes strength with national standards, not only in the area of non-autoclaved compositions, but for AAC (Table. 5).

High physical and mechanical characteristics of the non-autoclaved aerated concrete D600 have been implemented with the release of pilot batch of aerated concrete wall panels with dimensions of 3300 × 1500 × 500 mm (Figure 1 & 2) which were used in the construction of a residential two-storey building [8].

Table 1.

The results of statistical analysis of test results

Parameter	Designed values of the exponent for expression	
	(3)	(4)
Arithmetic mean value	2.281	0.472
Value of the empirical standard	0.1427	0.0366
Error of values at confidence probability 95 %	±0.041	±0.011
Relative error of the arithmetic mean value	1.8%	2.3%

Table 2.

Key features of alkali cement

Type of alkaline component	Density of the solution, kg / m^3	Setting time, min.		Brand of alkali cement, MPa, aged	
		start	end	7 days	28 days
sodium metasilicate	1200	36	45	63.0 (5.6)*	107.8 (7.6)
	1250	37	48	59.2 (7.1)	93.0 (6.5)
sodium disilicate	1300	56	70	48.3 (4.6)	77.3 (6.3)

* note – flexural strength is stated in parentheses

Table 3.

Physical and mechanical characteristics of non-autoclaved concretes on the basis of alkali cement

Concrete density grade	Average sample density, kg / m^3	Sample humidity wt. %	Compressive strength, Mpa aged		
			7 days	28 days	90 days
1	2	3	4	5	6
without filler					
D500	520	18.7	2.54	4.07	4.32
D600	610	16.9	3.74	4.75	5.10
D700	680	17.6	5.02	6.09	6.46
filler – quartz sand (fraction 0.25-0.5 mm) 50 % of slag weight					
D500	510	15.5	2.29	2.97	3.16
D600	620	15.7	3.87	4.36	4.55
D700	690	16.1	4.84	5.78	6.17
filler – quartz sand (fraction 0.25-0.5 mm) 100 % of slag weight					
D500	530	12,1	2.38	2.67	2.86
D600	610	13,7	3.74	3.82	4.02
D700	710	13,9	4.86	5.04	5.31
filler – slag non ground (fraction 0.25-0.5 mm) 50 % of slag weight					
D500	500	19,7	2.54	2.87	3.03
D600	620	18,5	4.03	4.47	4.67
D700	700	18,4	4.93	5.14	5.38
filler – slag non ground (fraction 0.25-0.5 mm) 100 % of slag weight					
D500	510	17,4	2.17	2.54	2.61
D600	590	17,5	3.02	3.75	3.90
D700	690	18,0	4.09	4.43	4.57

Table 4.

Strength of non-autoclaved aerated concrete D600 based on Portland cement and alkali cement without filler and with filler, quartz sand, at the age of 28 days

Cement type	Quantity of filler, % by weight of cement	Grade of non-autoclaved aerated concrete, MPa	Strength as% of the strength of the samples without filler
Portland cement	0	4.46	100
	25	3.05	68.4
	43	2.93	65.7
	67	2.41	54.0
Alkaline cement	0	4.75	100
	50	4.36	91.8
	100	3.82	80.4

Table 5.

The requirements of the standard and non-autoclaved aerated concrete strength characteristics of an alkali cement

Concrete grade by density	Levels of aerated concrete compressive strength, Mpa standard [7]		Compressive strength, MPa, based on non-autoclaved aerated alkali cement		
	autoclaved	non- autoclaved	without filler	with filler, unground slag in an amount of	
				50 %	100 %
D500	2.17 – 3.62	1.45 – 2.90	4.07	2.87	2.56
D600	2.90 – 3.62	2.17 – 2.90	4.75	4.47	3.75
D700	3.62 – 7.23	2.90 – 3.62	6.09	5.14	4.43

Figure 1. Residential two-storey house, erected with the use of aerated concrete wall panels

Figure 2. Detail of the interior of a residential two-story house erected using aerated concrete wall panels

Manufacturing technology of microporous AAC of low density

The objective of research in the development of manufacturing technology for microporous AAC was to provide compositions, which can be characterized by the presence of a microporous structure.

Traditional AAC, due to the specifics of their production are characterized by a macropore size of 0.5 – 3.0 mm (Figure 3a.). This structure is completely determined by the spatial arrangement of the particles in the mixture of aluminium powder after mixing and particle size of the gassing agent. The macroporous structure of traditional aerated concrete determines thereafter, its performance, and limits the scope of its use in humid environments. The results of long-term survey [9] found that the use of products made of autoclaved aerated concrete without protective coatings in humid conditions or when exposed to corrosive environments leads to their rapid destruction. Traditional exterior protective coating effectively eliminates this drawback, however, due to the presence of a macroporous structure AAC they require mandatory plastering, which significantly complicates and increases cost of final stage of construction.

Modern hydrophobic coatings can significantly simplify the process of items protection based on the AAC, but due to the specifics of its structure, require increased consumption of expensive water-repellent product.

Developed AAC microporous technology allows obtaining a composition, in which the structure has no large pores both on the surface of the array (Fig. 3 в), and inside it (Fig. 3c).

Physical and mechanical properties of the microporous autoclaved aerated concrete are shown in the Table 6.

The results presented show that the strength properties of the microporous AAC correspond to the standard level of strength. It should be noted that their manufacturing technology allows not only surface hydrophobization, which is performed after autoclaving, but also hydrophobization in an array volume during mixing.

Peculiarity of this technology is the increased proportion of thermal energy consumption, but in the cost structure this overrun is offset by the lack of aluminium powder in process mixture.

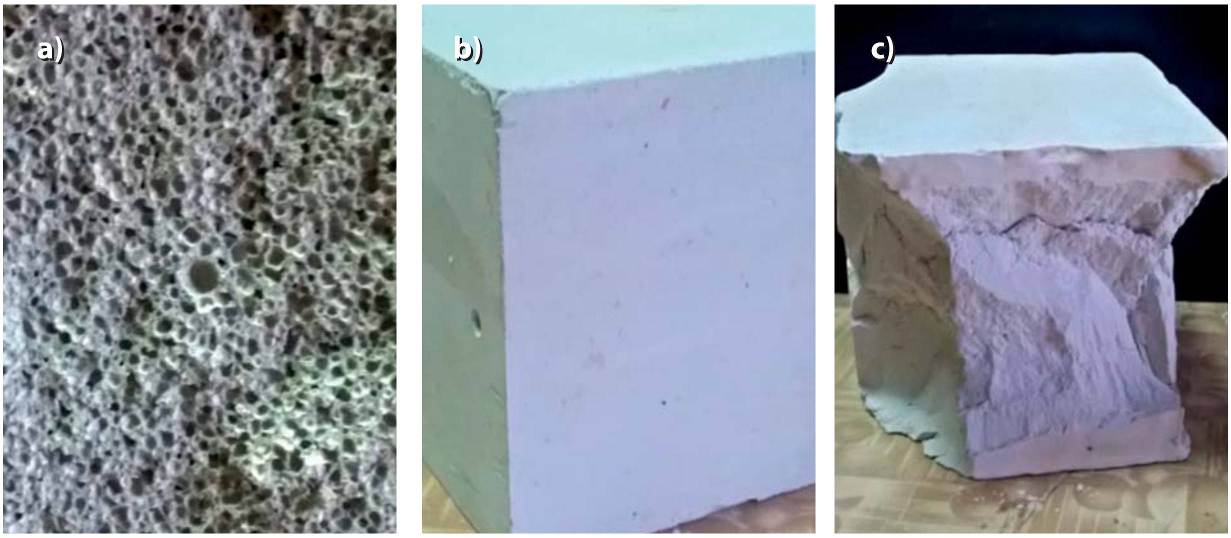

Figure 3. Structures of conventional AAC (a), microporous autoclaved concrete outside (в) and the internal structure of the sample after testing (c)

Table 6.

Physical and mechanical properties of the microporous AAC

Concrete grade by density	Levels of autoclaved aerated concrete strength, MPa, standard [8]	Density of the sample, kg / m^3	Compressive strength, MPa
D250	0.72	280	0.86
D350	1.45	370	1.70
D400	1.45	400	2.08
D500	2.17 – 3.62	550	2.28
D600	2.90 – 3.62	630	4.60

УДК 666.973.6

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ВЫСОКОПРОЧНЫЕ ТЕПЛОИЗОЛЯЦИОННЫЕ КОМПОЗИТЫ

ВИСОКОМІЦНІ ТЕПЛОІЗОЛЯЦІЙНІ КОМПОЗИТИ

HIGH-STRENGTH HEAT-INSULATING COMPOSITES

Исходные положения

Исходя из основных положений концепции устойчивого развития, газобетон можно рассматривать как один из наиболее перспективных конструкционный материалов, обеспечивающих существенное сокращение энергетических затрат на отопление помещений при низких расходах стенового материала на квадратный метр ограждающих конструкций.

Но, позволяя существенно сократить тепловые потери зданий, традиционный газобетон, в своем производстве предполагает присутствие высокотемпературных процессов (автоклавирование) и использование исходных продуктов, производство которых сопровождается образованием большого количества CO_2 (парникового газа). В состав сырьевой смеси автоклавного газобетона входит до 40 % по массе портландцемента и извести. Производство этих вяжущих сопровождается выделение в атмосферу большого количества CO_2. Парниковый газ образуется не только при декарбонизации известняка (до 300 кг на тонну портландцемента и до 780 кг на тонну извести), но и при сжигании топлива, которое используется для обжига исходных сырьевых смесей. С учетом углекислого газа, образующегося при транспортировании готового продукта, специалисты полагают, что создание одной тонны цемента сопровождается выпуском в атмосферу одной тонны углекислого газа [1].

Кроме вышеизложенного, необходимо отметить, что традиционный автоклавный газобетон характеризуется наличием ограничений по эксплуатации во влажных условиях (для помещений с относительной влажностью воздуха не более 75 %), что обуславливает необходимость защиты поверхности ограждающей конструкции от сорбции воды. Макропористая структура данного материала не позволяет использовать эффективно гидрофобные покрытия и обуславливает необходимость защиты поверхности с помощью разнообразных штукатурных растворов.

Целью комплекса научных исследований явилось создание новых технологий производства неавтоклавного газобетона на основе крупнотоннажных отходов промышленности и технологий изготовления микропористого автоклавного газобетона низкой плотность.