The Use of Quickly Slaking Lime in Production of Cellular Concrete

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The article presents research data on the use of quick-slaking lime (up to 5 min) in production of cellular concrete. It has been observed that, in burning limestone in a rotating furnace, while it is staying for a short time under isothermal conditions in a combustion zone, small highly hygroscopic lime crystals are formed. After grinding, some inclusions were found in the lime, which showed themselves as white spots in cellular concrete, a product for which it was used. It has been found that lime slaking may be prolonged by adding from 1 % – to 3 % gypsum or a similar amount of triethanolamine. The formation of white lime inclusions in cellular concrete may be avoided if lime is treated with an antistatic unit "Ekofor", or high-speed mixers are used for production of cellular concrete mixes.

Keywords: quickly slaking lime, retarders, cellular concrete, white inclusions, macro- and microstructure, electrostatic charge.

INTRODUCTION

In production of cellular concrete, moderately slaking lime of 85 % ± 5 % reactivity is commonly used [1, 2]. Usually, the time of slaking is from 8 min to 15 min [3]. In Lithuania, calcite lime is produced by a joint-stock company "Naujasis Kalcitas". There, limestone is burned in a rotating furnace and then ground. In currently used cellular concrete standard LST 1469:2000, the reactivity of lime is specified as being not less than 79 %, while the time of slaking given is from 5 min to 10 min. However, the slaking time of the lime calcined in the rotating furnace of "Naujasis Kalcitas" is about 5 min. It is well-known that major characteristics of lime largely depend on the limestone used, as well as on lump size and a burning mode, i.e. the temperature and time of the lime stay under isothermal conditions in a combustion zone [4, 5]. Higher temperature of lime calcining promotes the growth of calcium oxide crystals [6 – 8] which directly affects the time of lime slaking.

However, raising the temperature of lime calcining and prolonging its stay in a combustion zone are power consuming. Moreover, special rotating furnaces of higher length are needed. There are some techniques of prolonging the slaking time of lime by adding various admixtures [3, 9]. These admixtures may be added when the burnt limestone is being ground or cellular concrete is being made. In the latter case, they are added directly into the formation mix. Besides, finely ground lime (over 600 m^2/kg of specific surface) is highly hygroscopic, with its particles being charged and forming the aggregates. This makes it difficult to mix them properly in forming various products, including cellular concrete [10].

The aim of the present investigation is to analyse the structure of cellular concrete for which quickly slaking lime is used as well as to select the admixtures prolonging lime slaking and to find the ways of eliminating white spots on the surface of cellular concrete resulting from lime accumulation.

RAW MATERIALS AND RESEARCH TECHNIQUES

Cellular concrete samples were formed by using quartz sand from the Gariunai sand-pit satisfying the requirements of the standards LST 1273-92 and EN 196-6, as well as Portland cement of the grade CEM II/A-L 42.5N from a joint-stock company "Akmenes Cementas" satisfying the requirements of LSTEN 197-1:2001 standard, and ground lime from the "Naujasis kalcitas" satisfying the requirements of the European standard EN 459-2 to lime of CL90 type.

Chemical composition of the raw materials used is presented in Table 1.

Table 1. Chemical composition of raw materials

No	Raw material	Amount, %							Loss on ignition, %
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	R_2O	SO_3	
1.	Portlandcement clinker	22.41	4.20	4.76	63.00	2.50	–	1.65	1.33
2.	Lime	4.04	2.20	0.87	89.23	2.37	0.36	–	0.86
3.	Sand	87.03	3.51	0.71	4.05	0.49	1.40	–	2.79

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Table 2. Fineness of raw materials

No	Raw material	Fractions, mm				
		<0.09	0.09 – 0.063	0.063 – 0.032	0.032 – 0.02	> 0.02
1.	Lime	4.11	4.16	9.01	82.72	
2.	Sand	5.08	9.14	26.78	11.72	47.28

Sand was ground in a laboratory ball mill by dry grounding. Its specific surface is 362 m^2/kg. The fineness of raw materials according to the size of fractions is given in Table 2.

The reactivity of the ground lime is 81.44 %, slaking time – 2.5 min, and slaking temperature – 59 °C. The initial setting time is 2 h 45 min, and the final setting time – 5 h 50 min. Mineral composition of clinker expressed in % is as follows: C_3S from 50.38 % to 54.74 %; C_2S from 20 % to 24.53 %; C_3A from 4.30 % to 4.37 %; C_4AF from 14.32 % to 14.77 %.

In making gas silicate, concrete aluminium powder produced in Russia, which was hydrophylized with sulphonol (20 g/kg) was used. Its proper surface was 980 m^2/kg. The water was complied with GOST 3732-79 standard. The admixtures of gypsum and triethanolamine (from 1 % to 3 %) were used as retarders of lime slaking. Triethanolamine, in the amount of 1 %, was used in grinding the lime, while other admixtures were added to the formation mix.

The formation mixes were prepared in the laboratory by using a propeller mixer from 300 rpm to 1000 rpm. The reactivity of the silicate gas concrete mix, depending on the amount of the active CaO and MgO, reached 20 %, while the ratio of water and dry solids was 0.6.

The microstructure of the samples was investigated by a scanning electron microscope (SEM) and an ultrasonic device GSPOKO-2CK14P.

The sample phase composition was analysed by the X-ray diffraction with the diffractometer DRON-5.

RESULTS AND DISCUSSION

At the initial stage, the effect of retarders on lime slaking was investigated. It has been found that lime with no additives is quickly slaking, reaching the maximum temperature of 59 °C in 2.5 min (Fig. 1, curve 1).

The addition of 1 % gypsum ($CaSO_4 \cdot 2H_2O$) increases the slaking time up to 5 min, while 3 % gypsum prolongs it up to 8 min (Fig. 1, curves 2, 3). However, the addition of 1 % triethanolamine retards the slaking up to 6.5 min, while added in the amount of 3 % it retarded slaking time up to 10 min (Fig. 1, curves 4 and 5).

While analysing the curve obtained for lime with no admixtures, another slightly expressed exothermic effect accounted for the hydration of MgO can be observed (Fig. 1, curve 1). MgO hydration takes place at the 5-th minute of lime slaking when the temperature rises up to 60 °C fact, the choice of a particular retarder for practical application depends on its cost, because their retarding effect on lime slaking is nearly the same.

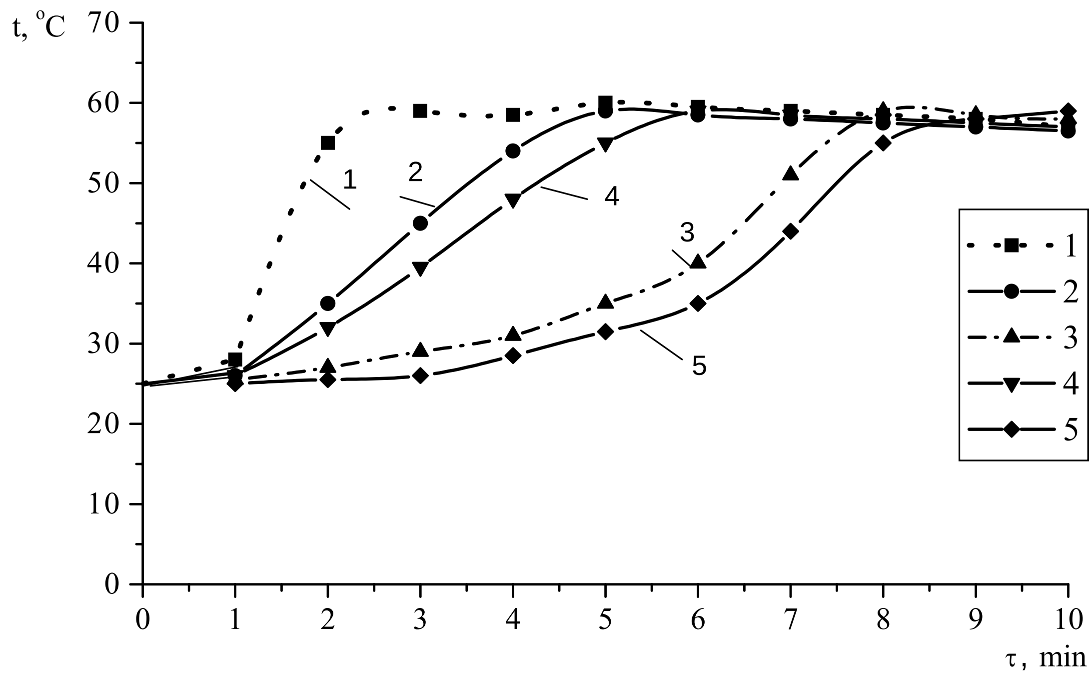

Fig. 1. The effect of retarders on lime slaking temperature: 1 – lime without admixture; 2 – lime with 1 % gypsum added; 3 – lime with 3 % gypsum; 4 – lime with 1 % triethanolamine; 5 – lime with 3 % triethanolamine

The density of moulded and autoclave-cured samples was determined when they were dried. It has been found that the compressive strength of 450 kg/m^3 density samples reaches 2.7 MPa. At the fracture area of the compressed specimens, the accumulation of white inclusions (grains from 2 mm to 5 mm) could be observed (Fig. 2).

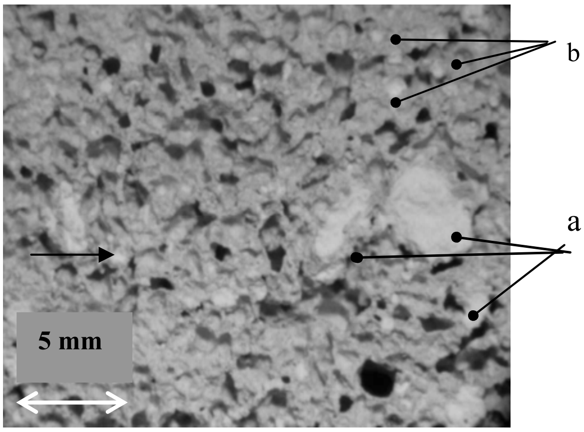

Fig. 2. Cellular concrete structure: a – coarse inclusions; b – fine inclusions

With the above phenomenon investigated, the lime was screened through sieves № 1.25 and № 0.08. It has been found that the amount of lime retained on the sieves was 0.44 % and 0.12 % respectively, while the amount of lime with 1 % triethanolamine was 0.35 % and 0.45 % respectively.

The study of the material retained on the sieves under the microscope has revealed that it consists of cemented together lime particles in the form of small plates (Fig. 3).

In stirring the formation mixes of cellular concrete in the mixer, with the roll rotating with 300 revolution/min, the above mentioned particles glued while slaked only

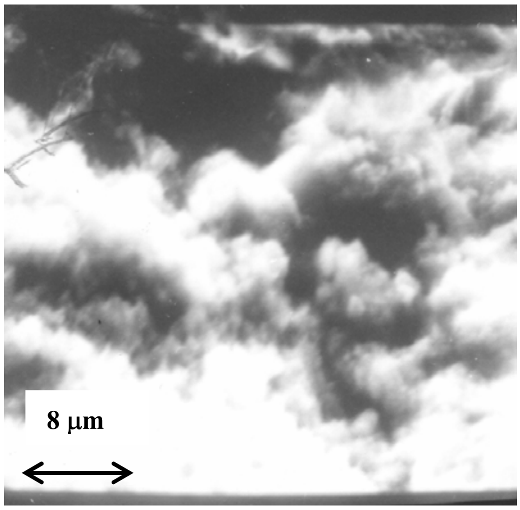

Fig. 3. Structure of lime retained on the sieve

during the autoclave curing. These unbroken particles make white spots of well crystallized Ca $(OH)_2$.

The performed X-ray analysis allowed us to identify the above inclusions (Fig. 4).

In these X-ray diffraction pattern, white inclusions were represented mostly by sharp peaks that can be described by the interplanar distances 0.18 nm, 0.192 nm, 0.263 nm and 0.49 nm. Cellular concrete samples (Fig. 4, curve 1) are characterized by sharp diffraction peaks related to tobermorite as follows 0.281 nm; 0.288 nm and 0.308 nm.

The comparative analysis of the structure of the white spots found on the hardened cellular concrete specimens (Fig. 5) and the inclusions observed in the screened lime (Fig. 3) has shown that the crystall structure in both photographs are similar. Needle-shaped crystals placed close to the lamellar ones can be seen, which prove that different lime crystallization degrees were achieved using

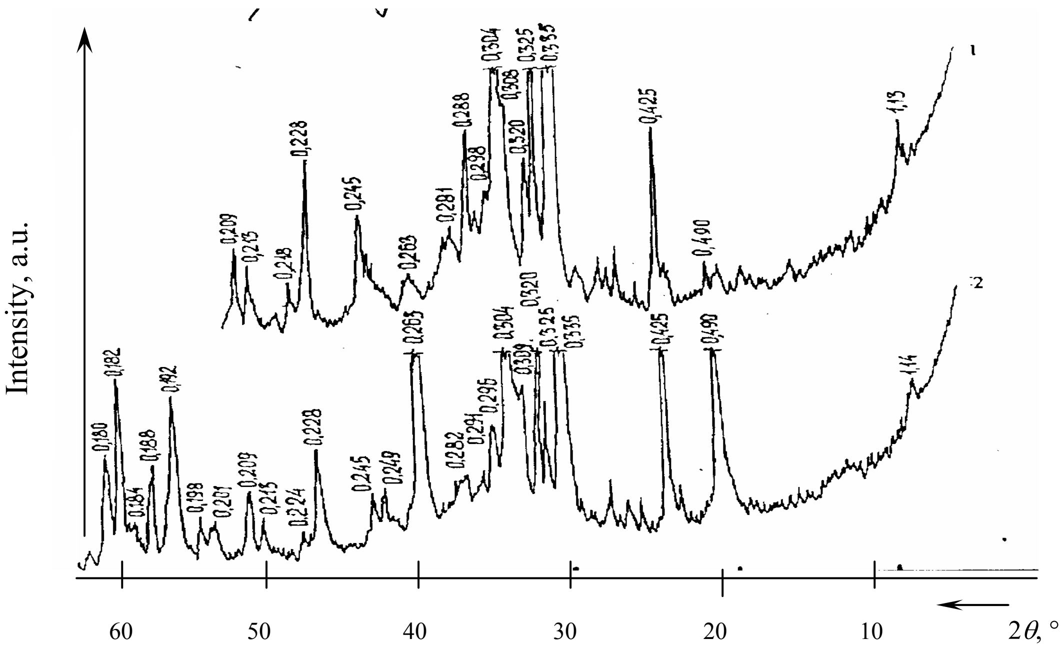

Fig. 4. The X-ray diffraction patterns of autoclaved cellular concrete specimen: 1) cellular concrete; 2) white inclusions in the cellular concrete

different modes of limestone burning in the rotating furnace.

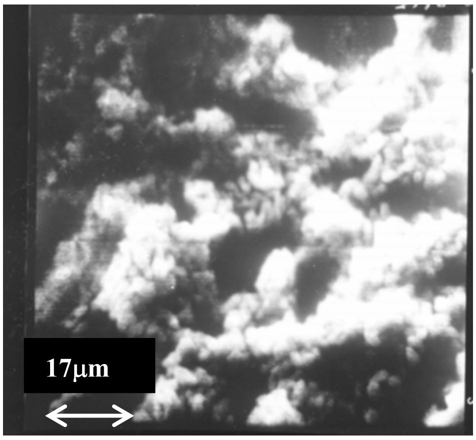

Fig .5. The structure of inclusions

The effect of lime inclusions on the propagation of ultrasonic waves in cellular concrete and properties of the specimens have been investigated as well. It has been found that the sound velocity in various directions does not vary much in both specimens (v_1 – 1748 m/s, v_2 – 1560 m/s, respectively). However, the compressive strength of specimens free of white spots has been found 10 % higher. This may be explained by a higher crystallization degree of calcium hydrosilicates as well as by its increased amount due to the completion of the lime reaction.

The methods of eliminating lime inclusions in cellular concrete have also been tested. Good results were achieved when ground lime was treated with "Ekofor", unit eliminating the electrostatic charge in the crystals of calcium oxide produced in Russia. In the specimens treated in this way, the accumulation of inclusions has not been observed. However, in the specimens formed by using the above lime, white spots were found after 6 months of curing. To develop the technique for their elimination, the effect of mixing rate on the mix quality has been studied. By adjusting the revolutions of the laboratory mixer's roll (from 300 revolution/min to 1000 revolution/min), positive results have been obtained. The white spots (lime inclusions) could not be observed in a formed specimen when the speed of rotation of a mixing roll reached about 1000 revolution/min.

CONCLUSIONS

When calcite lime obtained by burning limestone is used for making cellular concrete, the following rules should be observed. It is advisable:

1. To use the admixtures retarding lime slaking, e.g. from 1 % to 3 % amount of gypsum ($CaSO_4 \cdot 2H_2O$) or a similar amount of triethanolamine, by the lime mass, depending on its reactivity.
2. To reduce the electrostatic charge of calcium oxide crystals (for example, by using a special agent "Ekofor").
3. To use high-speed mixers to stir the formation mix.

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