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Charcterization of Autoclaved Slag Concrete for Stowing the Vertical Mine Workings under Liquidation

Andrey V. Uglyanica, Kirill D. Solonin and Ekaterina A. Strukova
Kuzbass State Technical University, Vesennyaya St. 28, 650000 Kemerovo, Russia

Abstract: Performance analysis of the vertical mine workings showed that hardening unshrinkable and waterproof backfill is the main guarantor of long-term sustainability of the earth's surface in the vicinity of the vertical mine workings under liquidation and ecological safety of territories. The study presents the results of the experimental laboratory studies of filtration and compression properties of the autoclave materials, based on the fuel and energy industry slag waste and lime for stowing the vertical mine workings under liquidation. The results of the study show the dependence of changes in the properties of autoclaved slag concrete on the stowing slag lime mixture parameters and its autoclaving. The obtained results allow determining the rational parameters of autoclave slag lime mixture for the production of shrink-proof and impervious stowing slag concrete in the vertical mine workings under liquidation. The regularities allow to develop the technology of backfill vertical mine workings under liquidation water-resistant low-shrinkage mining slag lime autoclave concrete and rational method for determining its parameters. Studies on the mechanisms of a process of forming the vertical mine workings under liquidation unshrinkable and waterproof filling mass autoclave method based on slag waste of fuel and energy companies are relevant to the solution of environmental problems areas liquidated mining enterprises and disposal of slag dumps. In addition, developed as a result of this study, non-shrink and waterproof slag-lime autoclave concrete will be used in the construction industry as an alternative to cement concrete.

Key words: Autoclaved slag concrete, stowing slag lime mixture, filtration properties, compression properties, mixture parameters, autoclaving parameters, vertical mine workings

INTRODUCTION

The present study was performed to investigate the compression and filtration properties of autoclaved slag concrete, on the basis of cheap cement from ground slag and lime and the possibility of its application for stowing the vertical mine workings under liquidation.

MATERIALS AND METHODS

The filtration and compression properties of autoclave materials are affected by the following parameters of slag and lime mixture: the type of lime (slaked lime, unslaked lime, lime grade); dispersion degree of cement components; water cementitious ratio; basicity coefficient (ratio that takes into account the content of different chemical elements involved in the formation of new compounds). In addition, the filtration and compression properties of autoclave materials may be influences by their autoclaving parameters-duration: pre-autoclaving cure, water vapor pressure buildup, cure under maximum water vapor pressure and water vapor pressure lowering (Bozhenov, 1978).

The analysis of chemical composition of the slags of Kuzbass power plants has shown that they can vary significantly depending on the places where they are obtained. Accordingly, formulating the mixture one can not operate with absolute weight or bulky components of mixture. In this case, it is advisable to use the basicity ratio which characterizes the ability of the mixture to fix into calcium monosilicate and it is calculated according to the formula:

$$K_{main} = \frac{(CaO + 0.93MgO + 0.6R_2O) - (0.55Al_2O_3 + 0.35Fe_2O_3 + 0.7SO_3)}{0.93SiO_2},$$

where $(CaO+0.93MgO+0.6R_2O)$ is the total “conditional” CaO, %; $(0.55Al_2O_3+0.35Fe_2O_3+0.7SO_3)$ the amount of CaO, bound by various oxides, non involved in the silicatization, %; $0.93SiO_2$ the amount of CaO for fixing SiO_2 into calcium monosilicate, % (Ashmarin *et al*., 1975).

Corresponding Author: Andrey V. Uglyanica, Kuzbass State Technical University, Vesennyaya St. 28, 650000 Kemerovo, Russia

In the lab tests, the samples were prepared in the laboratory autoclave, designed for the physical-chemical treatments of various substances and materials with neutral, acidic and alkaline solutions under elevated temperature and pressure.

The samples were prepared as follows: the ground slag was mixed thoroughly with the calculated amount of lime and water, the prepared mixture was placed in the cylindrical metal molds and then it was subjected to autoclave treatment.

The treatment was carried out according to the given temperature schedule. The temperature raising and lowering was controlled with the usage of the rheostat. The pressure was monitored using the pressure gauge installed in the autoclave.

The study of the filtration properties: In the tests, the cylinder concrete samples with a diameter of 150 mm and a height of 150 mm were used. The deviations for all the samples did not exceed ±0.5 mm.

For the manufacture of samples, the ground slag from Kemerovo CHP waste piles and the lime of two standard fractions "-0.16" and "-0.08" were used.

Each experimental series, with regard to the possible rejection, consisted of 10 samples. If the surface of the samples had a 0.1 mm width crack, shells >5 mm or other defects due to bad mixture seal, these samples were not subjected to the tests. If the number of samples, declared unfit was >2, the whole series was rejected (Anonymous, 1994).

Water resistance was determined by the filtration coefficient in accordance with the State Standard 12730.5-84 "Concrete. Methods for water resistance determination" (Anonymous, 1996). For this purpose, we used the special unit, in the rotary sockets of which the cages with the samples were attached. Before testing, the samples were kept in the laboratory room until the moment when the sample weight change was <0.1% for one day. The gap between the samples prepared for testing and the metal cages was filled with the molten bitumen. Prior to testing the samples were tested for sealing reliability and defectiveness by assessing the nature of air filtration.

Water was supplied to the end surface of the fixed cages through the unit mains. Water used for the tests according to the State Standard 23732-79 was previously desaerated by boiling for >1 h and did not contain any aggressive and bridging particles.

The pressure was increased in steps of 0.1 megapascals with the curing time of 1 h at each step. The pressure rise was stopped when the filtrate appeared and the filtration coefficient was determined at the pressure achieved.

For each sample, the amount of water filtered was measured 6 times. The first measurement was performed 1 h after the start of filtration and the increase in the amount of filtered water at the three successive measurements at the intervals of 30 min should not exceed 20%. Further measurements were made every 30 min.

If the filtration was not observed during 96 h at the maximum pressure of 1.3 megapascals, the test was stopped. The measurements of the filtrate amount were carried out using a Volumetric Method, collecting water that has passed through the sample.

The value of the filtration coefficient was calculated by the formula:

$$K_f = \eta \frac{Q\delta}{S\tau\Delta P} k$$

Where:

K_f	=	The filtration coefficient см/с
δ	=	The sample thickness, cm (δ = 15 см)
S	=	The sample area, cm^2 (S = 177 cm^2)
τ	=	Time of the filtrate amount measuring, s
$\Delta P = P_1 - P_2$	=	The the input P_1 and ouput P_2 pressure difference (P_1 is adopted as equal to the excessive pressure in the unit and P_2 = 0 in case of free filtrate discharge from the sample surface)
η	=	Coefficient, accounting for water viscosity at various temperatures (as water temperature was 20°C, η = 1.0 was adopted)
k	=	Coefficient, accounting for the sample diameter effect (as the diameter of the sample was D = 15cm, k = 1 was adopted)

If the filtration coefficient of the samples did not exceed $K_f \leq 1.2\times10^{-10}$cm sec^{-1} (0.001 m/24 h), i.e. the material was water-resistant, the analyzed mixture parameters was changed, so that the filtration coefficient increased. The tests were carried out until the water-absorbent material with $K_f \leq 0.001$ m/24 h was obtained. If filtration coefficient of the obtained samples exceeded $K_f > 0.001$ m/24 h, i.e., the material was not water-resistant, the analyzed mixture parameters was changed, so that the filtration coefficient decreased. The tests were carried out until the impervious material was obtained (Uglyanica *et al*., 2014a).

When studying the influence of the mixture parameters, the following autoclaving parameters were adopted: the cure of the samples before autoclaving 4 h; the duration of water vapor pressure raise 0.75 h; the cure of the sample under the maximum pressure 6 h; the duration of pressure release to atmospheric pressure 5 h. The maximum water vapor pressure during the autoclave treatment was adopted to be 0.9 megapascals.

When studying the influence of the basicity coefficient on the filtration properties the samples prepared from ground slag and unslaked lime with the the basicity coefficient of K_{ocH} = 0.80 were tested first. Since, the basicity coefficient rate equal to 0.8 was the lowest limit when studying the compression properties. Obtaining the impermeable material, we decreased the basicity coefficient by 0.1.

It is known that the use of the hydrated lime significantly reduces the filtration properties of autoclave materials. When testing the samples made from the ground slag and the hydrated lime, the basicity coefficient of the mixture was changed in the range of K_{ocH} = 0.6÷1.6 in increments of 0.1. In this case, all the samples tested were not water-resistant. In further experiments, we used only the first grade calcium quicklime.

When studying the influence of the water cementitious ratio of the mixture on the filtration properties of autoclave materials, the water cementitious ratio of the mixture was adopted as equal to 0.4-0.8 in increments of 0.1, since the plastic dough can't be obtained under the lower values and the very liquid suspension is obtained under the higher values.

When determining the dependence of the filtration properties of the autoclaved material on the freeness of quicklime and slag in the autoclave mixture, the samples with quicklime/slag ratios of W = 0.16: 0.16; 0.08: 0.16 and 0.08: 0.08 were produced; the water cementitious ratio being changed in the range of water cementitious ratio = 0.5÷0.8 (with such ratio the dough is easily manufactured and the excess water does not affect the mechanical properties of the material) and the basicity coefficient in the range of K_{main} = 0.8÷0.2. When obtaining the impermeable material the parameters of the mixture were changed to produce the water-proof material and vice versa.

When studying the influence of the autoclaving parameters on the на filtration properties of the autoclaved material first, we manufactured the samples with the pre-autoclaving cure duration 2 h and then we were increasing it up to 10 h in increments of 2 h.

To determine the influence of water vapor pressure rise on the filtration properties of the samples were autoclaved material we produced the samples with duration of the water vapor raising 0.75 h and then this parameter was increased to 1.5 h and then in increments of 1.5-4.5 h. The minimum duration of pressure rise 0.75 h. The maximum duration 4.5 h.

The degree of influence of the mixture cure in the autoclave under the maximum pressure on the filtration properties of the autoclave material was initially determined on the samples kept under the maximum vapor pressure for 8 h. Thereafter, the autoclave treatment duration was reduced under the maximum water vapor pressure up to 2 h in increments of 2 h.

The duration of the water vapor pressure decrease in the study of the degree of the influence of the water vapor pressure decrease on the filtration properties of the autoclaved material was 5 h and then the value of this parameter was reduced to 2 h in increments of 1 h. This is due to the fact that under the sudden drop in the water vapor pressure the conditions for the chemical reactions are less favorable than under the slow decrease, moreover, at this step the product has the higher temperature than the environment, so there is a rapid evaporation in the pores filled with the condensate which can lead to a significant reduction of the filtration properties (Bozhenov, 1978).

The study of the compression properties: For the tests we used the Kemerovo CHP ground slag with the particle size up to 0.16 mm. To prepare the samples the slag was milled to the desired dispersion. The diameter of the samples was 71 mm and the height 20 mm.

The chemical composition of the first grade quicklime used for the slacking: CaO-94.00%, MgO-1.99%, SiO_2-1.00%, Al_2O_3-1.05%, Fe_2O_3-1.07%, SO_3-0.5%. All the components of the mixture were weighed on the electronic balance with the 0.01 g. measuring accuracy.

The amount of the lime was determined on the basis of the required basicity ratio (K_{main}), calculated using the formula (Bozhenov, 1978).

For the sample preparation, the ground slag and the lime were mixed to get the homogeneous state and were slaked with water. The guide ring of the odometer was filled with the obtained mixture, then it was placed in the autoclave and the autoclave treatment was performed. Then, the compression tests of the resulting autoclaved material were carried.

The preliminary tests have shown that the average density of the autoclave materials on the basis of the ground slag does not exceed 1250 kg m^{-3}. With the shaft depth of up to 1000 m the maximum pressure for the determination of the compression properties of the autoclave materials is 12.5 MPa such a negative scenario is possible in the absence of adhesion between the filling mass and the shaft lining.

In accordance with the State Standard 12248-96 (Uglyanica *et al.*, 2014b), the loading was done in steps. The step value was 0.2 MPa. Each loading step was applied until the conditional stabilization of the sample deformation, the criterion of which was the sample deformation rate not exceeding 0.01 mm over the last 10 min of observation. The deformation of the sample was measured by the dial gauge.

When studying the influence of the mixture parameters, the following autoclaving parameters were adopted: the cure of the samples before autoclaving 4 h;

the duration of water vapor pressure raise 0.75 h; the cure of the sample under the maximum pressure 6 h; the duration of pressure release to the atmospheric pressure 5 h. The maximum water vapor pressure during the autoclave treatment was 0.9 MPa.

According to the recommendations (Bozhenov, 1978), the basicity ratio for the durable autoclave materials should be equal to 0.8-1.2. Proceeding from this, first the 0.8 basicity ratio mixture was applied. If the samples were compressed we increased the lime content in the mixture in basicity ratio increments of 0.1 until the shrink-proof material was obtained if they were not compressed, we reduced it until the samples were shrunk under any load. As is known, the use of the hydrated lime instead of the quicklime, the physical and mechanical properties of the autoclaved cements are significantly reduced. Proceeding from this, first the 1.2 basicity ratio mixture was applied. If the samples were compressed, we increased the lime content in the mixture in basicity ratio increments of 0.1 until the shrink-proof material was obtained if they were not compressed, we reduced it until the samples were shrunk under any load.

According to the recommendations (Bozhenov, 1978) the water cementitious ratio for the autoclave materials should be taken equal to 0.4-0.8. Since when carrying out the tests to determine the effect of the basicity ratio on the compression properties of the autoclaved materials from the ground slag and the lime, we tested the samples with the minimum water cementitious ratio for further testing, we initially produced the samples with the 0.4 water cementitious ratio and the minimum basicity ratio, with which the samples tested to determine the basicity ratio effect on the compression properties of the autoclaved material were not compressed. If the samples were not compressed, the value of the basicity coefficient largely was reduced in increments of 0.1 until the sample began to shrink if they were compressed the basicity coefficient was increased in increments of 0.1 to obtain the shrink-proof material. Further, we increased the water cementitious ratio in increments of 0.1-0.8 and by changing the basicity ratio in increments of 0.1, we determined the degree of the influence of the water cementitious ratio on the compression properties of the autoclaved material.

For the preparation of the above samples the Kemerovo CHP dump ground slag of "-0.16" fraction, the first grade quicklime (slaked) calcium lime of "-0.16" fraction and water were used.

As is well known, the finer cement grinding can significantly improve the physical and mechanical properties of the material. According to Bozhenov (1978), the grains <0.16 mm should be considered as the cement components but being too fine the cement particles stuck together and the opposite effect is observed. To determine the cement dispersion degree a sieve with a mesh size of 0.08 mm is typically used. In the experiments, the "-0.08" grade quicklime was used. Initially, we produced the samples with the "-0.08" grade lime and the water cementitious ratio of 0.5 (since with such water cementitious ratio the dough is easily prepared and the excess water has no influence on the mechanical properties of the material) and the minimum basicity ratio with which the samples tested to determine the basicity ratio effect on the compression properties of the autoclaved material were not compressed. If the samples were compressed the basicity ratio was decreased in increments of 0.1 until the compressed material was obtained if compressed the basicity ratio was increased in increments of 0.1 until the shrink-proof material was obtained. To prepare the samples the "-0.16" grade Kemerovo CHP dump ground slag was used.

When conducting the experiments to determine the influence of the fineness of the cement components on its compression properties we used the "-0.08" grade quicklime and ground slag. First we produced the samples from the "-0.08" grade slaked lime and the ground slag, the water cementitious ratio of 0.5 and the minimum basicity ratio with which the samples tested to determine the quicklime fineness effect on the compression properties of the autoclaved material were not compressed. If the samples were not compressed the basicity ratio was decreased in increments of 0.1 until the compressed material was obtained if compressed the basicity ratio was increased in increments of 0.1 until the shrink-proof material was obtained.

The initial duration of each autoclaving stage was the following: the cure of the samples before autoclaving 4 h; the duration of water vapor pressure raise 0.75 h; the cure of the sample under the maximum pressure 6 h; the duration of pressure release to the atmospheric pressure 5 h. To determine the degree of the influence of each parameter on the compression properties of the autoclave materials the values of this parameter were changed in accordance with the following algorithms.

If the samples were not compressed the basicity ratio was decreased in increments of 0.1 if compressed the basicity ratio was increased in increments of 0.1 (the basicity ratio being increased to 1.1, since it is not reasonable to use the mixtures with the large lime content). The shrink-proof material having been obtained, or the minimum basicity ratio when the samples were not compressed having been determined, the studied parameter of autoclaving was changed.

First we measured the degree of the effect of the pre-autoclaving cure on the compression properties and for this purpose, we produced the samples with the pre-autoclaving cure duration of 2 h and increased it to 10 h in increments of 2 h.

To determine the influence of the water vapor pressure rise on the compression properties of the autoclaved material we prepared the samples with the duration of the water vapor pressure increase 0.75 h, then increased to 1.5 h and then to 4.5 h in increments of 1.5 h.

The degree of the influence of the mixture cure in the autoclave under the maximum pressure on the compression properties of the autoclave material was initially determined on samples kept under the maximum water vapor pressure for 8 h. Thereafter, the autoclaving duration under the maximum water vapor pressure was reduced up to 2 h in increments of 2 h.

The duration of the water vapor pressure decrease in the study of the degree of influence of the in water vapor pressure decrease on the compression properties of autoclaved material was 5 h, then the value of this parameter was reduced in steps of 1 h.

RESULTS AND DISCUSSION

The research conducted in the compression properties of autoclaved materials on the basis of fuel and power industry wastes resulted in the following conclusions.

To obtain the shrink-proof autoclaved material it is necessary to use a mixture of the fine 0.08 and 0.16 mm grade ground slag and the lime.

The amount of lime in the autoclave cement has a significant impact on their properties. When the lime of the standard grinding is used; the water cementitious ratio being of 0.5, autoclaving parameters being of 4-0.75-6-5, the samples are compressed at the basicity ratio equal to 1.2. If the quicklime is replaced by the slaked lime the basicity ratio increases to 1.3.

The fragment of the research results is presented in Table 1. The graphic illustration of the research results is presented in Fig. 1.

The water cementitious ratio in the range of 0.4-0.6 doesn't affect the compression of the autoclaved material, when the water cementitious ratio is >0.6 the material compression increases.

The fine grinding reaching 0.08 mm; the basicity ratio decreases from 0.7-0.5. The fragment of the research results is presented in Table 2.

The graphic illustration of the research results is presented in Fig. 2. In the case of the fine grinding of the slag and the lime up to 0.08 mm for obtaining the shrink-proof material, the basicity ratio decreases from 0.5-0.3.

Table 1: The compression of the samples, tested under the pressure of 12.5 MPa

The basicity ratio	Compression (%)
1.2	2.76
1.3	0.00

Table 2: The compression of the samples, tested under the pressure of 12.5 MPa

K_{ocH}	Compression (%)
0.7	0.00
0.6	0.00
0.5	0.00
0.4	8.42

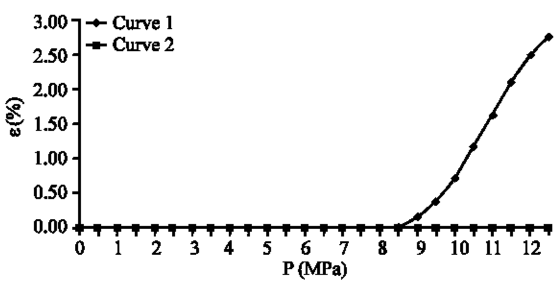

Fig. 1: The dependence of the compression ε on the loading P and the basicity ratio K_{main} (using the slaked lime): curve 1: the basicity ratio K_{main} = 1.2; curve 2: the basicity ratio K_{main} = 1.3

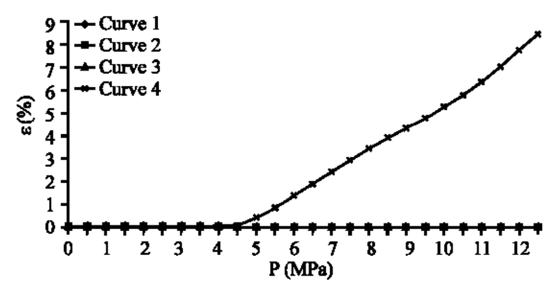

Fig. 2: The dependence of the compression ε on the loading P and the basicity ratio K_{main}: curve 1: the basicity ratio K_{main} = 0.7; curve 2: the basicity ratio K_{main} = 0.6; curve 3: the basicity ratio K_{main} = 0.5; curve 4: the basicity ratio K_{main} = 0.4

The fragment of the research results is presented in Table 3. The graphic illustration of the research results is presented in Fig. 3.

The duration of the pre-autoclave cure within the range of 2-10 h doesn't affect significantly the compression of the autoclaved cement. The duration of the water vapor pressure being increased from 0.75-4.5 h, the compression of the autoclaved material increases thrice.

The fragment of the research results is presented in Table 4. The graphic illustration of the research results is presented in Fig. 4.

The autoclaving duration under the maximum water vapor pressure within the range of 6-8 h doesn't affect significantly the compression of the material. The autoclaving duration decrease to 4 h increases the lime consumption for obtaining the shrink-proof autoclaved material.

Table 3: The compression of the samples, tested under the pressure of 12.5 MPa

K_{ocH}	Compression (%)
0.5	0.00
0.4	0.00
0.3	0.00
0.2	6.26

Table 4: The compression of the samples, tested under the pressure of 12.5 MPa

The duration of the pressure increase (h)	K_{main}	Compression (%)
0.75	0.6	6.78
1.50	0.6	12.91
3.00	0.6	14.41
4.50	0.6	18.80

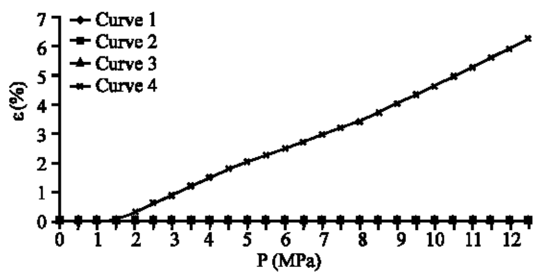

Fig. 3: The dependence of the compression ε on the loading P and the basicity ratio K_{main}: curve 1: the basicity ratio K_{main} = 0.5; curve 2: the basicity ratio K_{main} = 0.4; curve 3: the basicity ratio K_{main} = 0.3; curve 4: the basicity ratio K_{main} = 0.2

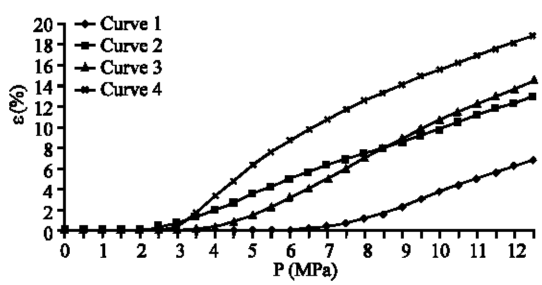

Fig. 4: The dependence of the compression ε on the loading P and the duration of pressure increase (when K_{main} = 0.6): curve 1: the duration of pressure increase 0.75 h; curve 2: the duration of pressure increase 1.50 h; curve 3: the duration of pressure increase 3.00 h; curve 4: the duration of pressure increase 4.50 h

The duration of the slag-lime cement autoclaving being <4 h, when the basicity ratio is = 1.1 and the cement particles are = 0.16 mm, it is impossible to obtain the shrink-proof autoclaved material.

The fragment of the research results is presented in Table 5. The graphic illustration of the research results is presented in Fig. 5 and 6.

Table 5: The compression of the samples, tested under the pressure of 12.5 MPa

The duration of the cure under the maximum pressure (h)	K_{ocH}	Compression (%)
4	0.7	12.06
4	0.8	10.80
4	0.9	4.28
4	1.0	0.00
2	0.9	16.61
2	1.0	12.61
2	1.1	11.65

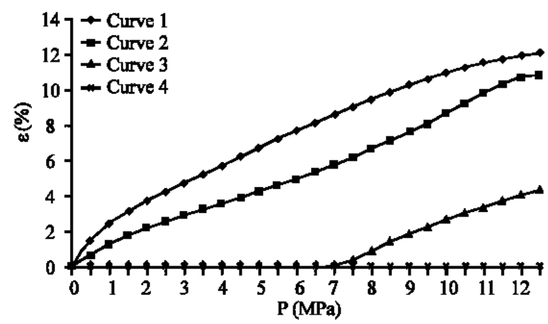

Fig. 5: The dependence of the compression ε on the loading P and the basicity ratio K_{main} (the cure duration under the maximum pressure being 4 h): curve 1: the basicity ratio K_{main} = 0.7; curve 2: the basicity ratio K_{main} = 0.9; curve 3: the basicity ratio K_{main} = 0.9; curve 4: the basicity ratio K_{main} = 1.0

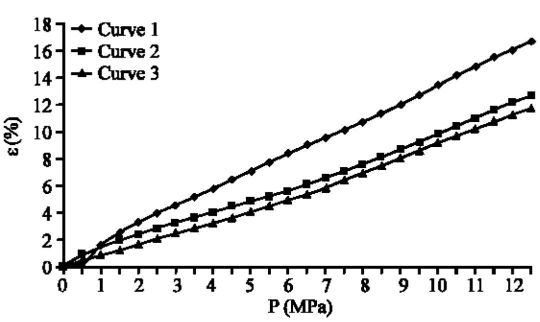

Fig. 6: The dependence of the compression ε on the loading P and the basicity ratio K_{main} (the cure duration under the maximum pressure being 2 h): curve 1: the basicity ratio K_{main} = 0.9; curve 2: the basicity ratio K_{main} = 1.0; curve 3: the basicity ratio K_{main} = 1.1

The decrease of the water vapor pressure release duration from 5-4 h, determines the basicity ratio increase for obtaining the shrink-proof autoclaved material from 0.7-0.9.

The duration of the water vapor pressure release being <4 h, when the basicity ratio is ≤1.1 and the cement particles are ≤0.16 mm, it is impossible to obtain the shrink-proof autoclaved material.

The research conducted in the filtration properties of autoclaved materials on the basis of ground slag and lime resulted in the following conclusions.

The use of the slaked lime instead of the unslaked one in the slag-lime mixture doesn't allow for obtaining the water-proof autoclaved material.

The fragment of the research results is presented in Table 6. The graphic illustration of the research results is presented in Fig. 7.

Increasing the water cementitious ratio of the slag-lime mixture for obtaining the water-proof material it is necessary to increase the basicity ratio of the autoclaved cement.

The decrease in the fineness of the lime and slag grinding in the mixture from 0.16-0.08 mm allows for decreasing the basicity ratio K_{main} from 0.5-0.3, the waterproofing qualities being constant.

The duration of the pre-autoclaving cure in the range of 4-10 h doesn't affect significantly on the filtration coefficient of the autoclaved material, when the duration is <4 h it is necessary to increase the basicity ratio.

Table 6: The filtration coefficient of the studied samples

The basicity ratio	K_f m/24 h	Note
1.2	0.00413	Water absorbent
1.3	0.00363	Water absorbent
1.4	0.00318	Water absorbent
1.5	0.00269	Water absorbent
1.6	0.01078	Water absorbent

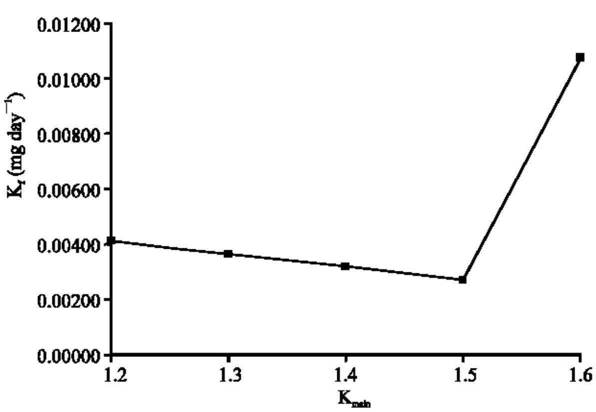

Fig. 7: The dependence of the filtration coefficient K_f on the basicity ratio K_{main} (using the slaked lime)

The duration of the water vapor pressure increase in the range from 0.75-3 h doesn't affect significantly on the filtration coefficient of the autoclaved material when the pressure increase duration is higher it is necessary to increase the basicity ratio.

The duration of the autoclaving under the maximum pressure in the range of 6-8 h doesn't affect significantly on the filtration coefficient of the material.

The decrease of the autoclaving to <4 h increases the lime consumption for obtaining the water-proof material. When the autoclaving is <4 h, when the basicity ratio is ≤1.1 and the cement particles are ≤0.16 mm, it is impossible to obtain the shrink-proof autoclaved material. The fragment of the research results is presented in Table 7. The graphic illustration of the research results is presented in Fig. 8.

Table 7: The filtration coefficient of the studied samples

The duration of the cure under the maximum pressure (h)	K_{main}	K_f m/24 h	Note
8	0.5	0.00050	Water-proof
8	0.4	0.03930	Water absorbent
6	0.5	0.00063	Water-proof
6	0.4	0.04092	Water absorbent
4	0.5	0.00297	Water absorbent
4	0.6	0.00197	Water absorbent
4	0.7	0.00151	Water absorbent
4	0.8	0.00081	Water-proof
2	0.8	0.02680	Water absorbent
2	0.9	0.02413	Water absorbent
2	1.0	0.01850	Water absorbent
2	1.1	0.01430	Water absorbent

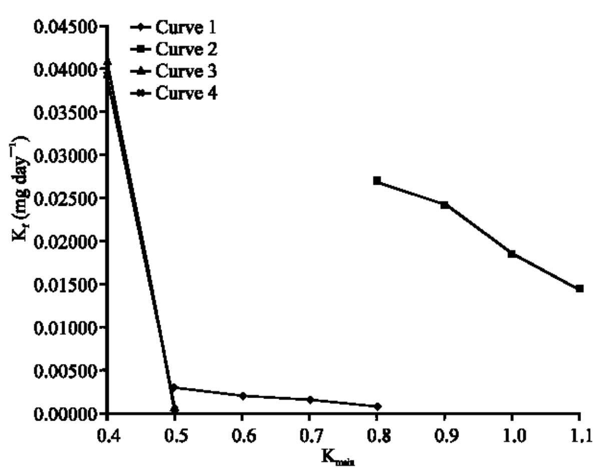

Fig. 8: The dependence of the filtration coefficient K_f on the basicity ratio K_{main} and the duration of the cure under the maximum pressure: curve 1: the duration of the cure under the maximum pressure 2 h; curve 2: the duration of the cure under the maximum pressure 4 h; curve 3: the duration of the cure under the maximum pressure 6 h; curve 4: the duration of the cure under the maximum pressure 8 h

The decrease of the water vapor pressure release duration from 5-3 h, determines the basicity ratio increase by 0.4 for obtaining the water-proof material.

The water vapor pressure release duration being decreased for <4 h, when the basicity ratio is ≤1.1 and the cement particles are ≤0.16 mm, it is impossible to obtain the shrink-proof autoclaved material.

CONCLUSION

The results of the studies conducted allow determining the rational parameters for the autoclaved slag-lime mixture for obtaining the water-proof and shrink-proof stowing slag concrete in the vertical mine workings under liquidation and utilize the man-made slag waste of fuel and power enterprises (Uglyanica *et al*., 2011).

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