

## EMPIRICAL DEPENDENCE OF SORPTION HUMIDITY OF KERAMZEBETON CONCRETE ON RELATIVE HUMIDITY OF AIR

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Article history:	Abstract:
<p><b>Received:</b> April 26<sup>th</sup> 2021  <b>Accepted:</b> May 11<sup>th</sup> 2021  <b>Published:</b> June 9<sup>th</sup> 2021</p>	<p>In the calculations of the humidity regime of building envelopes to predict their performance, sorption isotherms of materials of structural layers are used. The article presents analytical expressions of sorption isotherms of expanded clay concrete of various densities for a range of relative humidity from 30 to 100%.</p>
<p><b>Keywords:</b> Expanded clay concrete, humidity conditions, sorption isotherm, specific steam capacity, relative steam capacity, regression coefficient, Fisher criterion, variance of sorption moisture values, residual dispersion.</p>	

### INTRODUCTION:

To assess the performance of the external building envelope in unsteady conditions of exposure to external and internal environment, it is necessary to have information about changes in humidity in the materials of individual layers of the structure. A lot of research has been devoted to the forecasting of the humidity regime of building envelopes under operational conditions. Mathematical methods have been developed for calculating the humidity of structures operating under non-stationary conditions [1] and, therefore, at present it is possible to take into account changes in humidity depending on the state of the environment, the influence of initial humidity on the humidity regime of the structure.

The differential equation for the diffusion of water vapor under non-stationary conditions through a flat wall, both single-layer and multi-layer, is proposed to be solved using the finite difference method [1].

In calculating the humidity regime of building envelopes for each material that makes up the building envelope, it is necessary to know such an indicator, called specific steam capacity  $\xi$  (mg / (kg · Pa)), which is highly dependent on temperature. To take into account a significant change in the specific steam capacity  $\xi$  (mg / (kg · Pa)) depending on the temperature, when solving the differential equation of moisture conductivity, the concept of "Relative steam capacity ( $\xi_0$ , g / kg)" was introduced, which means the amount of moisture required to increase the relative humidity of 1 kg of material from 0 to 100%. In the calculations of the humidity regime of external walling made of various materials, the relative steam capacity  $\xi_0$  is determined from the graph of the sorption isotherm of each material.

$$\xi = \xi_0 / E, \quad (1)$$

Between the values of specific steam  $\xi$  and relative steam  $\xi_0$  of the material, there is the following dependence where E is the maximum value of the partial pressure of water vapor (Pa), corresponding to the temperature t under consideration.

Due to the fact that the sorption isotherms of almost the majority of building materials are curved lines, the value of  $\xi_0$  for individual sections of the isotherm is a variable value. For a small portion of the sorption isotherm, the following formula was proposed in [1] to determine the average value of the relative steam capacity  $\xi_{0,med}$  [1]

$$\xi_{0,cp} = \frac{\omega_2 - \omega_1}{\varphi_2 - \varphi_1} \cdot 10^6, \quad (2)$$

where  $\omega_1$  and  $\omega_2$  are the corresponding minimum and maximum moisture content of the material (in%) in a given section of the isotherm;  $\varphi_1$  and  $\varphi_2$  are the corresponding values of relative humidity;  $10^6$  is a constant introduced to convert % of the values of material moisture and relative air humidity to mg / kg. Based on the formula (2), it is possible to calculate the relative steam capacity  $\xi_0$  corresponding to a specific value of the relative air humidity  $\varphi$

$$\xi_0 = \frac{d\omega}{d\varphi} \cdot 10^6. \quad (3)$$

This means that when the mathematical expression of the sorption isotherm is known, then when calculating the moisture regime of the structure (especially using computer programs), the regularity of the dependence of the relative steam capacity  $\xi_0$  on the relative humidity  $\varphi$  can be determined analytically.

**Empirical equation of the sorption isotherm of keramzybeton concrete:** Experimental studies of many scientists found that under the conditions of operation of building structures, the relative humidity  $\varphi$  in their thickness usually does not fall below 40%. Therefore, we can consider it sufficient to use the equation for the dependence of the sorption humidity of materials  $\omega$  in the range of relative humidity  $\varphi$  in the range from 30% to 100% in the calculations of the humidity regime of building envelopes.

In this paper, for the analytical expression of the dependence of the sorption humidity  $\omega$  of expanded clay concrete of various densities on the relative air humidity  $\varphi$ , the author proposes an empirical formula of the following form

$$\omega = \frac{a + b \cdot \varphi}{1 - c \cdot \varphi} \quad (4)$$

Here, the values of the parameter C in the transforming function  $(1 - c \cdot \varphi)$  vary between 0 and 1, and for different densities of  $\gamma_0$  expanded clay concrete is determined by the iterative method using multistep regression analysis. The coefficients a and b of equation (4) are determined by the least squares method. When choosing a value with the main criterion, the minimum residual dispersion  $s_o^2$  between the experimental values of sorption humidity and the calculated values determined using the empirical formula (4) was adopted. When analyzing such non-linear regression equations, the forces of the correlation between the output parameter  $\omega$  and the factor  $\varphi$  are usually estimated by the value of the correlation ratio  $\eta$ , determined by the formula

$$\eta = \sqrt{1 - \frac{s_o^2}{s_\omega^2}} \quad (5)$$

where  $s_o^2$  - is the variance of the experimental values of sorption moisture relative to its average; it was determined by the formula

$$s_o^2 = \frac{1}{n-1} \left[ \sum_{i=1}^n \omega_i^2 - \left( \sum_{i=1}^n \omega_i \right)^2 / n \right]; \quad (6)$$

$s_o^2$  -residual dispersion between the experimental values of sorption humidity and calculated values; it is determined by the formula

$$s_o^2 = \frac{1}{n-k} \sum_{i=1}^n (\omega_i - \tilde{\omega}_i)^2 \quad (7)$$

In this case,  $n = 8$  is the total number of determined values of sorption moisture;  $\omega_i$  - sorption humidity at experimental points (for individual values of  $\varphi$ ), %;

$\tilde{\omega}_i$  - determined by the formula (4) the sorption moisture value of expanded clay concrete (in% by weight);  $k = 2$  is the number of unknown coefficients in equation (4).

Moreover, the relative approximation error at each experimental point  $\varepsilon_i$  is often also determined by the formula [2]

$$\varepsilon_i = \frac{\omega_p - \omega_o}{\omega_p} \cdot 100\% \quad (8)$$

The average value of the relative approximation error was determined by the formula

$$\varepsilon_{cp} = \frac{\sum |\varepsilon_i|}{n}, \quad \% \quad (9)$$

To test the adequacy of the empirical equation for the sorption isotherm, the Fisher F-test was used. The calculated value of the Fisher F-test was determined by the formula

$$F_p = \frac{S_\omega^2}{S_o^2} \quad (10)$$

The table value of the Fisher F-test was determined in accordance with the degrees of freedom of the variances  $s_\omega^2$  ( $n-1 = 7$ ) and  $s_o^2$  ( $n-k = 6$ ). If the condition  $Fr > Ft$  is fulfilled, the recommended equation for describing the sorption isotherm is considered adequate.

The unknown coefficients of sorption equation (4) for expanded clay concrete with a density of 1400, 1200, 1000 and 800 kg / m<sup>3</sup> were determined on the basis of empirical data given in [3].

Table 1 shows the results of calculations of the residual dispersions  $s_o^2$  and the corresponding values of the specified parameter C and the unknown coefficients of equations a and b, obtained as a result of regression analysis performed for the above expanded clay concrete.

Table 1

Material	Show-bodies	Values			Regression coefficients corresponding to the minimum value $S_o^2$	
					a	b
Expanded clay, $\gamma_0=1400$ кг/м <sup>3</sup>	C	0,86	<b>0,87</b>	0,88	1,578198	-0,01163
	$S_o^2$	0,047921	<b>0,03872</b>	0,056708		
Expanded clay, $\gamma_0=1200$ кг/м <sup>3</sup>	C	0,84	<b>0,85</b>	0,86	1,012107	0,638393
	$S_o^2$	0,019970	<b>0,012055</b>	0,019795		
Expanded clay, $\gamma_0=1000$ кг/м <sup>3</sup>	C	0,83	<b>0,835</b>	0,84	0,577244	1,079923
	$S_o^2$	0,029327	<b>0,029271</b>	0,031902		
Expanded clay, $\gamma_0=800$ кг/м <sup>3</sup>	C	0,85	<b>0,855</b>	0,86	0,219062	1,091288
	$S_o^2$	0,033001	<b>0,032246</b>	0,034807		

As can be seen from table 1, for expanded clay concrete with a density of  $\gamma_0 = 1400$  kg / m<sup>3</sup> with a minimum value of residual dispersion  $s_o^2 = 0,03872$  the specified parameter is  $c = 0.87$ , and the corresponding regression coefficients are  $a = 1.578198$  and  $b = -0.01163$ . Thus, for expanded clay with a density of  $\gamma_0 = 1400$  kg / m<sup>3</sup>, the sorption isotherm can be expressed by the following empirical equation

$$\omega_p = \frac{1,578198 - 0,01163 \cdot \varphi}{1 - 0,87 \cdot \varphi} \quad (11)$$

The results of checking the adequacy of this equation are shown in table 2.

Table 2.

**Results of statistical processing of data on sorption moisture for expanded clay concrete with a density of  $\gamma_0 = 1400$  kg / m<sup>3</sup> at  $c = 0.87$**

№	$\varphi$	$\omega_{\varphi}$ , % by [3]	$\omega_{pr}$ % according to the formula (11)	$\omega_p - \omega_{\varphi}$	$\epsilon_{ir}$ %	$\epsilon_{cpr}$	$\frac{S_{\omega}^2}{S_o^2}$	Condition $F_p > F_T$
1	0,3	1,9	2,130864	0,230864	10,8343	4,46	$\frac{10,85125}{0,03872}$	280,25 > 4,21
2	0,4	2,5	2,413413	-0,08659	-3,588			
3	0,5	3	2,782977	-0,21702	-7,798			
4	0,6	3,5	3,287069	-0,21293	-6,478			
5	0,7	4	4,015488	0,015488	0,3857			
6	0,8	5	5,160832	0,160832	3,1164			
7	0,9	7	7,224561	0,224561	3,1083			
8	1	12	12,05051	0,050513	0,4192			

As can be seen from table 2, for expanded clay concrete with a density of  $\gamma_0 = 1400$  kg / m<sup>3</sup>, the variance of the experimental values of sorption humidity relative to its average, determined by formula (6), is  $S_{\omega}^2 = 10,85125$ . And the value of the residual dispersion, determined by the formula (7), is equal to  $S_o^2 = 0,03872$ . The calculated value of the Fisher F-criterion according to the formula (10) is  $F_p = 280.25$ . With the degree of freedom  $f_1 = 8-1 = 7$  and  $f_2 = 8-2 = 6$ , the tabular value of the Fisher F-test is  $F_t = 4.21$  [2]. Since the condition  $F_p > F_T$  is satisfied, the empirical equation (11) can be considered adequate for the analytical expression of the sorption isotherm of expanded clay concrete with a density of  $\gamma_0 = 1400$  kg / m<sup>3</sup>. In this case, the value of the correlation ratio, which estimates the tightness of the correlation between the output parameter  $\omega$  and the factor  $\varphi$  determined by formula (5), is

$$\eta = \sqrt{1 - \frac{0,03872}{10,85125}} = 0,998,$$

which indicates the presence of a very strong correlation between sorption humidity and relative air humidity. This means that in calculations of the humidity regime of building envelopes made using expanded clay with a density of  $\gamma_0 = 1400 \text{ kg / m}^3$ , within the range of relative air humidity  $\varphi$  from 30 to 100%, a confidence probability of 95%, one can use the empirical equation (11). In this case, the average relative error determined by the formula [9]  $\epsilon_{med} = 4.46\%$ .

Expanded clay with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$  has a higher porosity than expanded clay with a density of  $\gamma_0 = 1400 \text{ kg / m}^3$ . In this regard, the values of equilibrium sorption humidity for these expanded clay concrete at certain values of relative humidity differ from each other, while maintaining the nature of the isothermal curves.  $s_o^2 = 0,012055$

As the results of the regression analysis show (Table 1), for expanded clay concrete with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$  with a minimum value of residual dispersion, the specified parameter is  $c = 0.85$ , and the corresponding regression coefficients are  $a = 1.012107$  and  $b = 0.683933$ . Thus, for expanded clay concrete with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$ , the sorption isotherm can be expressed by the following empirical equation

$$\omega_p = \frac{1,012107 + 0,683933 \cdot \varphi}{1 - 0,85 \cdot \varphi} \tag{12}$$

The results of checking the adequacy of this equation are shown in table 3.

Table 3.

**Results of statistical processing of data on sorption moisture for expanded clay concrete with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$  at  $c = 0.85$**

Nº	$\varphi$	$\omega_{\varphi}$ , % by [3]	$\omega_p$ , % according to the formula (12)	$\omega_p - \omega_{\varphi}$	$\epsilon_{ir}$ %	$\epsilon_{cpr}$ %	$\frac{S_{\omega}^2}{S_o^2}$	Condition $F_p > F_T$
1	0,3	1,5	1,615604	0,115604	7,1555	3,22	$\frac{10,077}{0,012055}$	835,93 > 4,21
2	0,4	2	1,920400	-0,07960	-4,145			
3	0,5	2,5	2,315311	-0,18469	-7,977			
4	0,6	2,8	2,84723	0,04723	1,6588			
5	0,7	3,5	3,602425	0,102425	2,8432			
6	0,8	4,7	4,758817	0,058817	1,236			
7	0,9	6,8	6,751748	-0,04825	-0,715			
8	1	11	11,00333	0,003333	0,0303			

From the data of table 3 it can be seen that for expanded clay concrete with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$ , the variance of the experimental values of sorption humidity relative to its average, determined by formula (6), is  $S_{\omega}^2 = 10,077$ . And the value of the residual dispersion, determined by the formula (7), is equal to  $S_o^2 = 0,012055$ . The calculated value of the Fisher F-criterion according to the formula (10) is  $F_r = 835.93$ . Since the degrees of freedom remain unchanged, the tabular value of the Fisher F-test also remains unchanged, and is equal to  $F_t = 4.21$  [2]. And in this case, the condition  $F_r > F_t$  is fulfilled; therefore, the empirical equation (12) can be considered adequate for the analytical expression of the sorption isotherm of expanded clay concrete with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$ . In this case, the value of the correlation ratio, which estimates the tightness of the correlation between the output parameter  $\omega$  and the factor  $\varphi$ , determined by formula (5), is

$$\eta = \sqrt{1 - \frac{0,012055}{10,077}} = 0,999,$$

which also indicates the presence of a very strong correlation between sorption humidity and relative air humidity. Therefore, in the calculations of the humidity regime of building envelopes made using expanded clay with a density of  $\gamma_0 = 1200 \text{ kg / m}^3$ , in the range of relative air humidity  $\varphi$  from 30 to 100%, a confidence probability of 95%, one can use the empirical equation (12). In this case, the average relative error determined by the formula [9] is  $\epsilon_{med} = 3.22\%$ .

Table 1 shows the data on the value of the set parameter C, corresponding to the minimum value of the residual dispersion for even more porous expanded clay concrete with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ . For this expanded clay concrete with a minimum value of residual dispersion  $s_o^2 = 0,029271$  the specified parameter is  $c = 0.835$ , and the corresponding regression coefficients are  $a = 0.577244$  and  $b = 1.079923$ . Thus, for expanded clay concrete with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ , the sorption isotherm can be expressed by the following empirical equation

$$\omega_p = \frac{0,577244 + 1,079923 \cdot \varphi}{1 - 0,835 \cdot \varphi} \tag{13}$$

The results of checking the adequacy of this equation for the sorption isotherm are given in table 4.

Table 4.

**Results of statistical processing of data on sorption moisture for expanded clay concrete with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$  at  $c = 0.835$**

Nº	$\varphi$	$\omega_{\text{э}}, \%$ , by [3]	$\omega_{pr}, \%$ , according to the formula (13)	$\omega_p - \omega_{\text{э}}$	$\epsilon_{ir}, \%$	$\epsilon_{cpr}, \%$	$\frac{S_{\omega}^2}{S_o^2}$	Condition $F_p > F_T$
1	0,3	1,3	1,202429	-0,09757	-8,114	3,9	$\frac{9,17357}{0,029271}$	313,4 > 4,21
2	0,4	1,5	1,515335	0,015335	1,012			
3	0,5	1,9	1,917949	0,017949	0,9358			
4	0,6	2,3	2,455306	0,155306	6,3253			
5	0,7	3,0	3,20864	0,20864	6,5024			
6	0,8	4,5	4,34091	-0,15909	-3,665			
7	0,9	6,5	6,234102	-0,2659	-4,265			
8	1	10,0	10,04343	0,043434	0,4325			

The data in table 4 indicate that, for expanded clay concrete with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ , the variance of the experimental values of sorption humidity relative to its average, determined by formula (6), is  $S_{\omega}^2 = 9,17357$ . And the value of the residual dispersion, determined by the formula (7), is equal to  $S_o^2 = 0,029271$ . The calculated value of the Fisher F-criterion according to the formula (10) is  $F_r = 313.4$ . The table value of the Fisher F-test is  $F_t = 4.21$  [2]. The condition  $F_r > F_t$  is fulfilled, which means that the empirical equation (13) can be considered adequate for the analytical expression of the sorption isotherm of expanded clay concrete with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ . In this case, the value of the correlation ratio, which estimates the tightness of the correlation between the output parameter  $\omega$  and the factor  $\varphi$  determined by formula (5), is

$$\eta = \sqrt{1 - \frac{0,029271}{9,17357}} = 0,998,$$

which also indicates the presence of a very strong correlation between sorption humidity and relative air humidity. We can conclude that in the calculations of the humidity regime of building envelopes made using expanded clay with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ , within the range of relative humidity  $\varphi$  from 30 to 100%, a confidence probability of 95%, we can use the empirical equation (13). In this case, the average relative error determined by the formula [9] is  $\epsilon_{med} = 3,9 \%$ .

Expanded clay with a density of  $\gamma_0 = 800 \text{ kg / m}^3$  has even greater porosity than expanded clay with a density of  $\gamma_0 = 1000 \text{ kg / m}^3$ . Therefore, the values of equilibrium sorption humidity for these expanded clay concrete at certain values of relative air humidity also differ from each other. As the results of the regression analysis show (Table 1), for expanded clay concrete with a density of  $\gamma_0 = 800 \text{ kg / m}^3$  with a minimum value of the residual dispersion  $s_o^2 = 0,032246$  the specified parameter is  $c = 0.855$ , and the corresponding regression coefficients are  $a = 0.219062$  and  $b = 1.091288$ . Thus, for expanded clay with a density of  $\gamma_0 = 800 \text{ kg / m}^3$ , the sorption isotherm can be expressed by the following empirical equation

$$\omega_p = \frac{0,219062 + 1,091288 \cdot \varphi}{1 - 0,855 \cdot \varphi} \tag{14}$$

The results of checking the adequacy of this equation are shown in table 5.

Table 5.

**Results of statistical processing of data on sorption moisture for expanded clay concrete with a density of  $\gamma_0 = 800 \text{ kg / m}^3$  at  $c = 0.855$**

Nº	$\varphi$	$\omega_{\text{э}}, \%$ , by [3]	$\omega_{pr}, \%$ , according to the formula (14)	$\omega_p - \omega_{\text{э}}$	$\epsilon_{ir}, \%$	$\epsilon_{cpr}, \%$	$\frac{S_{\omega}^2}{S_o^2}$	Condition $F_p > F_T$
1	0,3	0,8	0,734964	-0,06504	-8,849	3,93	$\frac{8,0684}{0,032246}$	250,21 > 4,21
2	0,4	1	0,996313	-0,00369	-0,37			
3	0,5	1,3	1,335724	0,035724	2,6745			
4	0,6	1,7	1,794312	0,094312	5,2561			
5	0,7	2,4	2,448214	0,048214	1,9693			
6	0,8	3,3	3,455967	0,155967	4,513			
7	0,9	5,6	5,211339	-0,38866	-7,458			
8	1	9	9,036839	0,036839	0,4077			

From the data of table 5 it can be seen that for expanded clay concrete with a density of  $\gamma_0 = 800 \text{ kg / m}^3$ , the variance of the experimental values of sorption humidity relative to its average, determined by formula (6), is  $S_\omega^2 = 8,0684$ . And the value of the residual dispersion, determined by the formula (7), is equal to  $S_o^2 = 0,032246$ . The calculated value of the Fisher F-criterion according to the formula (10) is equal to  $Fr = 250.21$ . Since the degrees of freedom remain unchanged, the tabular value of the Fisher F-test also remains unchanged, and is equal to  $Ft = 4.21$  [2]. And in this case, the condition  $Fr > Ft$  is satisfied, therefore, the empirical equation (14) can be considered adequate for the analytical expression of the sorption isotherm of expanded clay concrete with a density of  $\gamma_0 = 800 \text{ kg / m}^3$ . In this case, the value of the correlation ratio, which estimates the tightness of the correlation between the output parameter  $\omega$  and the factor  $\varphi$ , determined by formula (5), is

$$\eta = \sqrt{1 - \frac{0,032246}{8,0684}} = 0,9979,$$

which indicates the presence of a very strong correlation between sorption humidity and relative air humidity. Therefore, in the calculations of the humidity regime of building envelopes made using expanded clay concrete with a density of  $\gamma_0 = 800 \text{ kg / m}^3$ , in the range of relative air humidity  $\varphi$  from 30 to 100%, a confidence probability of 95%, one can use the empirical equation (14). In this case, the average relative error determined by the formula [9] is  $\epsilon_{med} = 3.22\%$ .

Figure 1 shows the calculated graphs of sorption isotherms and experimental data on the sorption moisture of expanded clay concrete with a density of  $\gamma_0 = 1400, 1200, 1000, \text{ and } 800 \text{ kg / m}^3$ .

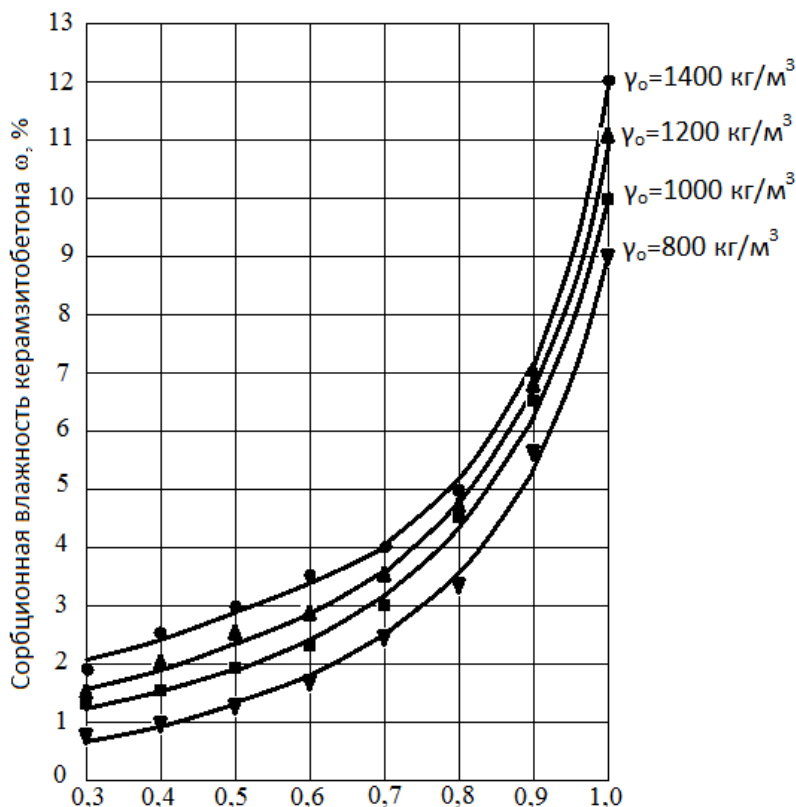


Fig. 1. Estimated graphs of sorption isotherms and experimental data on the sorption moisture of expanded clay concrete:

- - for  $\gamma_0 = 1400 \text{ kg / m}^3$ ;
- ▲ - for  $\gamma_0 = 1200 \text{ kg / m}^3$ ;
- - for  $\gamma_0 = 1000 \text{ kg / m}^3$ ;
- ▼ - for  $\gamma_0 = 800 \text{ kg / m}^3$ .

### 3. CONCLUSIONS

The results of the regression analysis show that for expanded clay concrete with a density of 1400, 1200, 1000 and 800  $\text{kg / m}^3$ , the dependences of sorption humidity  $\omega$  on relative air humidity  $\varphi$  ranging from 30 to 100% can be expressed using equations (11), (12), (13) and (14). At the same time, the values of the correlation ratio, which estimates the tightness of the correlation between the output parameter  $\omega$  and the factor  $\varphi$ , for the above expanded clay aggregates range from 0.997 ... 0.999. This means that when expressing the sorption isotherms in the proposed form of the equation, the dependence of the sorption humidity  $\omega$  of expanded clay concrete on the relative air humidity  $\varphi$  approaches almost functional. Therefore, it is possible to use them in the calculations of the humidity regime of building envelopes made using expanded clay concrete, operated in non-stationary temperature-humidity conditions.



**BIBLIOGRAPHY:**

1. Fokin K.F. Construction heat engineering of enclosing parts of buildings. - Moscow, ABOK PRESS, 2006 .-- 287 p.
2. Lvovsky E.N. Statistical methods for constructing empirical formulas: Textbook for technical colleges. 2nd ed., Revised. and add. - Moscow, Higher School, 1988. -239 p.
3. Guidance on the calculation of the humidity conditions of the external building envelope / NIISF Gosstroy USSR. - Moscow, Stroyizdat, 1984. -168 p.
4. B.F. Vasiliev. Field studies of the temperature and humidity regime of large-panel residential buildings. –M .: Stroyizdat, 1968. –120 p.
5. V.M. Ilyinsky. Design of building envelopes, taking into account the physical and climatic effects. –M .: Stroyizdat, 1955. -240 p.
6. V.M. Ilyinsky. Building thermal physics (enclosing structures and building microclimate). –M .: Higher school, 1974. -320s.
7. How low-rise residential buildings are built in the USA: [Electronic resource]. –Access mode: /www.bigpicture.ru/.
8. Catalog of modern building technologies for low-rise construction: an interregional meeting on the implementation of measures of state support in the field of housing for young people "ACCESSIBLE HOUSING - YOUTH", / Ministry of Sports, Tourism and Youth Policy of the Russian Federation Federal Agency for Youth Affairs All-Russian Public Organization Union of MZhK of Russia "; - M.: 2011 .-- 25 p.
9. MM Makhmudov et al. Methodological instructions for the heat engineering calculation of the external enclosing structures of buildings. - Samarkand, SamGASI. 1988.
10. MirzaiRiza. Residential buildings of medium storey, erected by industrial methods for a hot-dry climate zone: the example of large cities in Iran. Diss. Ph.D. Moscow, MARCHI. 2009.-p. 195.
11. Bearing walls "Taldom-Thermo" with a frame of thermoprofiles and thermal insulation of mineral wool boards. Designguidelines. Code M25.3 / 02. Moscow, 2003
12. Isambaev I, Berdiev M., Norkulov B.M., Tadjiyeva D., Axmadi M. "The dynamics of channel processes in the area of damsels water intake" International Scientific Conference Construction Mechanics, Hydraulics and Water Resources Engineering (CONMECHYDRO – 2020) 23-25 April 2020, Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan <https://doi:10.1088/1757-899X/883/1/012033>