Carrying Out of Researches for Determining the Term of Effective Exploitation of Thermal Insulation Materials for 100 Years (Part 2)

Gennadiy Farenyuk and Olena Oleksiienko

Abstract The study aims at finding indicators of longevity of the mineral wool products while being used as an thermal insulation layer of building envelope of construction projects with operational life up to 100 years. Subject of the study is valuation of changes in air permeability, compression strength at 10% linear deformation, operational characteristics of material—thermal conductivity, specimen appearance and geometry under cyclic climate effects that simulate environmental factors which affect the state of thermal insulating materials of building envelopes while being used in construction projects. It was conducted a study of life characteristics of Rockwool mineral wool products by Batts Lights (Rockmin) and Ruth Batts (Dachrock max) as the thermal insulating layer of building envelopes with the life time up to 100 years. During the study simulation of climatic impacts on the thermal insulating products was conducted in conditions of normal use of products in building envelopes and in conditions of probable failures of building envelopes. The results of the study show that the stability criteria of physical parameters of the Rockwool mineral wool product by Batts Lights (Rockmin) and Ruth Batts (Dachrock max) do not exceed acceptable limits after massive cyclic climatic impact. This makes possible to estimate the conditional life time of the mentioned Rockwool mineral wool products being not less than 100 years.

Keywords Thermal insulation · Durability · Climate effects · Thermal conductivity · Air permeability · Compression strength

1 Introduction

Modern building envelopes are constructed from materials of different thermophysical properties and terms of durability. The widespread use of new thermal insolating materials without proper verification in the practice of domestic house building causes

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V. Onyshchenko et al. (eds.), *Proceedings of the 3rd International Conference on Building Innovations*, Lecture Notes in Civil Engineering 181,
https://doi.org/10.1007/978-3-030-85043-2_9

thermal failures of building envelopes in the operation of buildings. The concept of the period of efficient operation of products was introduced to characterize the insulating materials and to determine the possibility of their use in the modern structural schemes of insulating cover of building in the national regulatory framework—DBN V.2.6–31 [1].

The period of efficient operation (estimated durability) of thermal insulating products is the estimated operational period during which the products retain their thermal insulating properties at the level of project performance, as evidenced by the results of laboratory tests and specified in the provisional warranty (lifetime).

The characteristics of an efficient operation period are based on the concept of material resource i.e. the parameter that characterizes the change of thermophysical properties of the material under service conditions that are simulated in the course of the tests.

The basis of the method of determination of the operational resources is the hypothesis of existence of material structure damage linear accumulation area under single or total climate effects. The accepted concept affords ground to determine the resource parameters by fixation and analysis of the nature of changes of general physical parameters that determine the thermal performance of building envelope within the field of linear accumulation of damages in both temperature and humidity effects. This is the approach that is also adopted in the standards for methods of testing roofing materials in accordance with the DSTU B EN 1296 [2] and insulating materials in accordance with the ISO 11,561 [3] and [4–11].

2 Methodology and Research

The tests are carried out for the products that perform insulation functions in constructions i.e. thermal insolating and air insolating functions. Accordingly, the change of the following thermophysical properties of materials such as thermal conductivity, air permeability are recorded during the test.

The research methodology is based on that fact that the tested material is subjected to cyclic climate effects that simulate operating conditions of the material in building envelopes after which the changes of the thermophysical properties of the materials are determined.

There is an operation imitation of climatic factors under normal use of the thermal insolating materials in building envelopes in the methodological basis when duration of effective operation of the material is estimated in accordance with the results of the thermophysical characteristics measurement depending on the constructive solution of thermal insulation of external building envelopes and in terms of possible structure damages and appropriate action of climatic factors directly to the insulation product.

As for the thermal insulating materials the period of efficient operation is measured by change of thermal conductivity in standard tests, as well as changes in an air permeability coefficient of material and change of the linear dimensions and strength characteristics.

Determination of stability of thermal insulating products to cyclic climate effects (effective operation period). Stability factors of external appearance of the test samples were determined visually and recorded for each test sample. After 180 cycles of climate effects of freezing—thawing—heating it was determined on the base of visual inspection of the test samples that the appearance of the samples of Light Batts (Rockmin) and Ruth Batts (Dachrock max) brands does not change. Change of the material color and its continuity was not fixed visually in the course of peeling and tearing of the material fibers. Visual appearance of one of the test samples is shown in Fig. 1.

Change of geometrical dimensions of the samples is within 5% for Light Batts (Rockmin) brand and 2% for Ruth Batts (Dachrock max) brand that allows evaluating positively the stability of geometric dimensions and exterior view to the action of cyclic climatic factors.

The thermal conductivity of ROCKWOOL mineral wool products of Light Batts (Rockmin) brand—number of cycles diagram is shown in Fig. 2, Ruth Batts (Dachrock max) brand in Fig. 3 respectively.

Fig. 1 Exterior view of the samples before (sample at the left of the Figure) and after (sample at the right of the Figure) 180 cycles of climate impacts

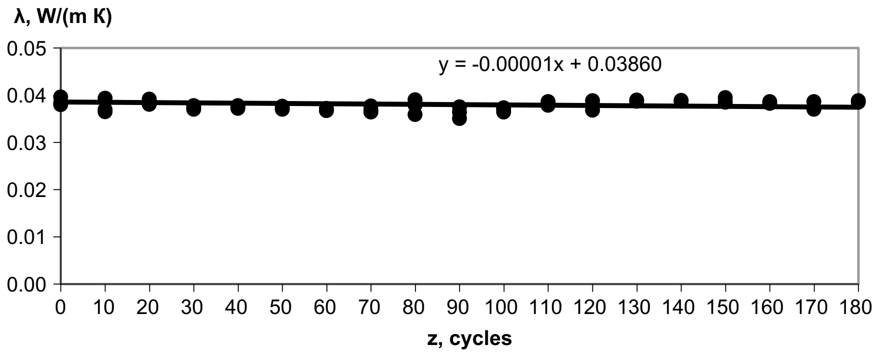

Fig. 2 The dependence of thermal conductivity of ROCKWOOL mineral wool products of Light Batts (Rockmin) brand from cyclic effects

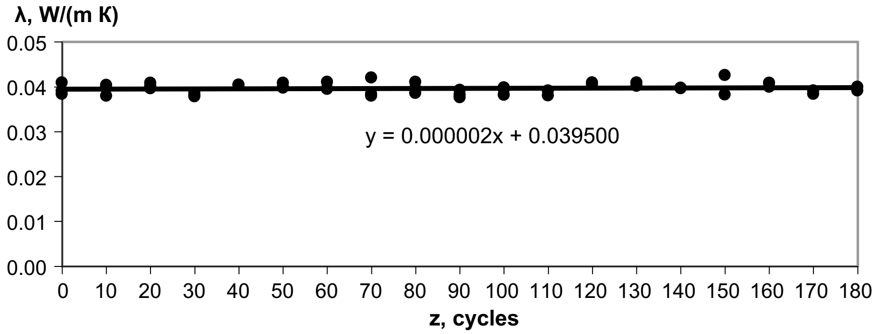

Fig. 3 The dependence of thermal conductivity of ROCKWOOL mineral wool products of Ruth Batts (Dachrock max) brand from cyclic effects

The dependence of thermal conductivity of ROCKWOOL mineral wool on the number of cycles of freezing—thawing—heating is approximated by the formulas:

– for Light Batts (Rockmin) brand:

$$\lambda(z) = 0,0386 - 0,00001 \cdot z \pm 0,0009 \tag{1}$$

– for Ruth Batts (Dachrock max) brand:

$$\lambda(z) = 0,0395 + 0,000002 \cdot z \pm 0,0004. \tag{2}$$

Resource rate determined by the “Eg. (17)” [10] is:

for Light Batts (Rockmin) brand—$r = -0{,}0018$;
for Ruth Batts (Dachrock max) brand—$r = 0{,}0004$.
Fulfillment of condition is checked by the formula “Eg. (23)” [10]:
for Light Batts (Rockmin) brand:

$$\frac{r}{\lambda_0} k_z = \frac{-0,0018}{0,0386} \cdot 5 = -0,23 \leq 0,2 \tag{3}$$

for Ruth Batts (Dachrock max) brand:

$$\frac{r}{\lambda_0} k_z = \frac{0,0004}{0,0395} \cdot 5 = 0,05 \leq 0,2 \tag{4}$$

The test results of breathability coefficient *i*, kg/m^2 h Pa, with $\Delta p = 10\,Pa$ depending on the number of cycles of freezing—thawing—heating the ROCKWOOL mineral wool of Light Batts (Rockmin) and Ruth Batts (Dachrock max) brands shown in Figs. 4 and 5 respectively.

The ROCKWOOL mineral wool breathability coefficient dependence on the number of cycles of freezing—thawing—heating is approximated in the formulas:

for Light Batts (Rockmin) brand:

$$i(z) = 0,4511 - 0,00005 \cdot z \tag{5}$$

for Ruth Batts (Dachrock max) brand:

$$i(z) = 0,0617 + 0,00002 \cdot z \tag{6}$$

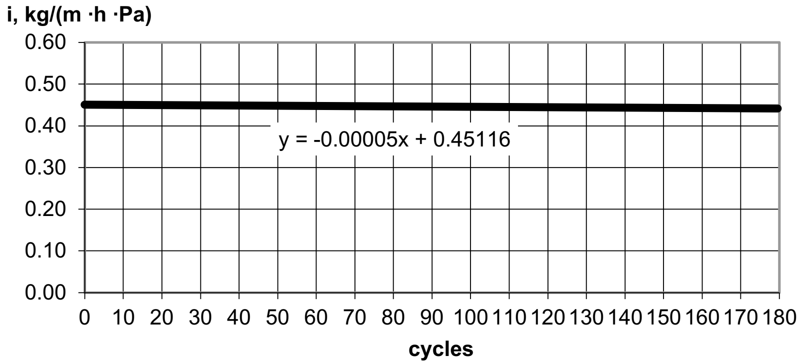

Fig. 4 Cyclic impact dependence of breathability coefficient of the ROCKWOOL mineral wool products of Light Batts (Rockmin) brand

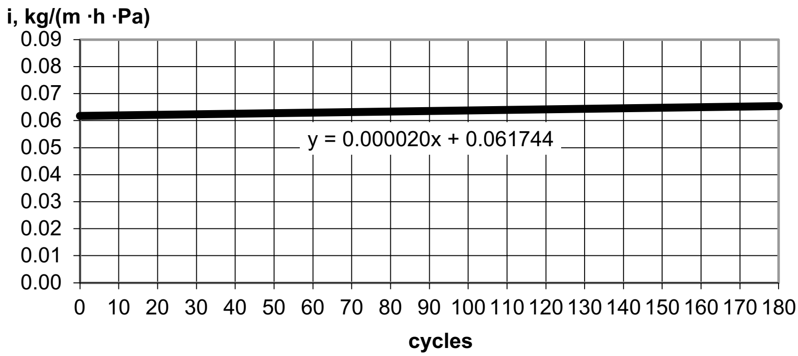

Fig. 5 Cyclic impact dependence on breathability coefficient of the ROCKWOOL mineral wool products of Ruth Batts (Dachrock max) brand

Resource rate determined by the “Eg. (17)” [10] is:

for Light Batts (Rockmin) brand—$r = -0{,}009$.
for Ruth Batts (Dachrock max) brand—$r = 0{,}0036$.
Fulfillment of condition is checked by the formula “Eg. (24)”[10]:
for Light Batts (Rockmin) brand:

$$\frac{r}{i_0}k_z = \frac{-0,009}{0,4511} \cdot 5 = -0,1 \leq 0,35 \tag{7}$$

for Ruth Batts (Dachrock max) brand:

$$\frac{r}{i_0}k_z = \frac{0,0036}{0,0617} \cdot 5 = 0,29 \leq 0,35 \tag{8}$$

The results of compressive strength test with 10% deformation depending on the number of cycles of freezing—thawing—heating of the ROCKWOOL mineral wool of Light Batts (Rockmin) and Ruth Batts (Dachrock max) brands are shown in Figs. 6 and 7 respectively.

The compressive strength with 10% deformation of the ROCKWOOL mineral wool dependence on the number of cycles of freezing—thawing—heating is approximated in the formulas:

for Light Batts (Rockmin) brand:

$$\sigma^{10}(z) = 0,0004878 - 0,0000001 \cdot z \tag{9}$$

for Ruth Batts (Dachrock max) brand:

$$\sigma^{10}(z) = 0,034 - 0,000011 \cdot z \tag{10}$$

Resource rate determined by the “Eg. (17)” [10] is:

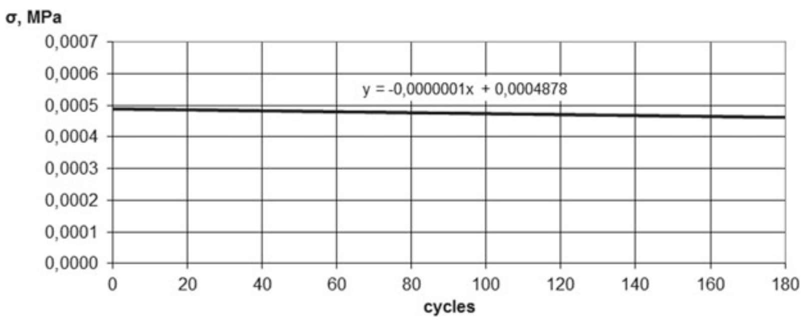

Fig. 6 Cyclic impact dependence on compressive strength with 10% deformation of the ROCKWOOL mineral wool products of Light Batts (Rockmin) brand

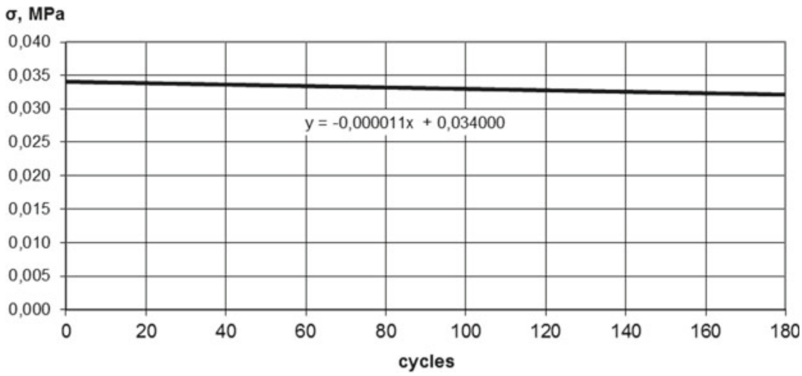

Fig. 7 Cyclic impact dependence on compressive strength with 10% deformation of the ROCKWOOL mineral wool products of and Ruth Batts (Dachrock max) brand

for Light Batts (Rockmin) brand—$r = -0{,}0018$.
for Ruth Batts (Dachrock max) brand—$r = -0{,}00{,}198$.
Fulfillment of condition is checked by the "Eg. (25)" [10]:
for Light Batts (Rockmin) brand:

$$\left|\frac{r}{\sigma_0^{10}}k_z\right| = \left|\frac{-0,000018}{0,0004878}\cdot 5\right| = |-0,18| = 0,18 \leq 0,35 \tag{11}$$

for Ruth Batts (Dachrock max) brand:

$$\left|\frac{r}{\sigma_0^{10}}k_z\right| = \left|\frac{-0,00198}{0,034}\cdot 5\right| = |-0,29| = 0,29 \leq 0,35 \tag{12}$$

Thus, the conditions by the "Eg. (23), (24) and (25)" [10] are fulfilled.

Summary data on the results of testing the efficient operation period of the ROCKWOOL mineral wool of Light Batts (Rockmin) and Ruth Batts (Dachrock max) brands are listed in Table 1.

Table 1 Results of testing the material efficient operation period

Brand	Density, kg/m^3	$\frac{r}{\lambda_0}k_z$	$\frac{r}{i_0}k_z$	$\frac{r}{\sigma_0^{10}}k_z$	Efficient operation period
Light Batts (Rockmin)	37	−0,23	−0,1	0,18	Not less than 100 years
Ruth Batts (Dachrock max)	145	0,05	0,29	0,29	Not less than 100 years

Stability of the Rockwool mineral wool performance figure to the effects of climatic moisture. The test results of thermal conductivity and changes of geometrical parameters of the Rockwool mineral wool samples by simulating the impact of climatic factors are listed in Appendix A.

As a result of the tests a criterion of thermal conductivity change was calculated for each sample by the "Eg. (26)" [10] the greatest value of which for each mode is presented in Table 2.

According to the results of the tests it is specified that the requirements of criterion "Eg. (26)" [10] for stability of thermal conductivity under cyclic wetting–drying effects that simulate conditions of the thermal insulating products in the course of the probable failure of building envelope in the process of upkeep of buildings with the corresponding soaking of thermal protection by liquid water and its natural drying are performed.

Stability of the Rockwool mineral wool performance figures to the effects of solar radiation and fog. As a result of the tests carried out in order determined in point [10] a criterion of thermal conductivity change was calculated for each sample by the "Eg. (26)" [10] the greatest value of which for testing mode is presented in Table 3.

Table 2 Results of testing the Rockwool mineral wool for resistance to climatic moisture

Brand	Drying temperature, °C	The greatest criterion	Specified specification, no more than	Conformity
Light Batts (Rockmin)	+20	0,006	0,1	+
	0	0,002		+
	−10	0,012		+
Ruth Batts (Dachrock max)	+20	0,012		+
	0	0,032		+
	−10	0,017		+

Table 3 Results of tests on mineral wool Rockwool resistance to climatic moisture

Brand	Average thermal conductivity in initial conditions, W/(m K)	Average thermal conductivity after climate effects, W/(m K)	The greatest value of criterion	Normative characteristic not more than	Conformity
Light Batts (Rockmin)	0,0386 ± 0,0009	0,0393 ± 0,0006	0,058	0,1	+
Ruth Batts (Dachrock max)	0,0395 ± 0,0004	0,0409 ± 0,0003	0,054		+

The received experimental data show that the requirements of criterion "Eg. (26)" [10] for stability of thermal conductivity under cyclic effects of radiation and high air humidity simulating condition of thermal insulating products during the probable failure of building envelopes in the course of operation of construction projects with related direct effect of solar radiation and humid air on the thermal insulating layer are carried out.

Thus, the stability of thermophysical characteristics of the tested products under conditions not foreseen for the thermal insolating mineral wool products in building envelope but which may possibly occur in the course of building operation and are defined as failures that can be repaired, is high enough for the established evaluation criteria.

3 Conclusion

The researches of identification of life characteristics of the Rockwool mineral wool products of Batts Lights (Rockmin) and Ruth Batts (Dachrock max) brands for the use of products as the thermal insulating layer of building envelopes with the life time up to 100 years were conducted. The researches were conducted with simulation of climatic impacts on the thermal insulating products under conditions of normal use of products in building envelopes and under conditions of probable failures of building envelopes. The evaluation of life time was carried out by the nature of changes of the thermal insolating product performance criteria—air permeability, thermal conductivity, compressive strength at 10% linear deformation and changes of appearance and geometric parameters of the samples under cyclic climatic impacts and in terms of possible damages of building envelope during operation of buildings.

According to the results it is found that the stability criteria of physical parameters of the Rockwool mineral wool product of Batts Lights (Rockmin) and Ruth Batts (Dachrock max) brands after the complex of cyclic climatic impacts are within acceptable limits, which allows to assess the conditional life time of the mentioned Rockwool mineral wool products for not less than 100 years.

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