

# The quality estimation of exterior wall's and window filling's construction design

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**Abstract.** The article reveals the term of "artificial envelope" in dwelling building. Authors offer a complex multifactorial approach to the design quality estimation of external fencing structures, which is based on various parameters impact. These referred parameters are: functional, exploitation, cost, and also, the environmental index is among them. The quality design index  $Q_k$  is inputting for the complex characteristic of observed above parameters. The mathematical relation of this index from these parameters is the target function for the quality design estimation. For instance, the article shows the search of optimal variant for wall and window designs in small, middle and large square dwelling premises of economic class buildings. The graphs of target function single parameters are expressed for the three types of residual chamber's dimensions. As a result of the showing example, there is a choice of window opening's dimensions, which make the wall's and window's constructions properly correspondent to the producible complex requirements. The authors reveal the comparison of recommended window filling's square in accordance with the building standards, and the square, due to the finding of the optimal variant of the design quality index. The multifactorial approach for optimal design searching, which is mentioned in this article, can be used in consideration of various construction elements of dwelling buildings in accounting of suitable climate, social and economic construction area features.

## 1. Introduction

Currently, the building science and technique frequently use the term "building envelope". This term implies the space, separated from the nature environment by the artificial containment. The volume of artificial containment provides defined climatic, ecological, sanitary hygienic and other parameters, which are required for comfortable accommodation, safety equipment placement and optimal technological processes passing [1].

And viewed in that light, external filler structures are customary to consider in complex with an artificial envelope, which, most important, "passively" forms favorable thermal heating, acoustic and lighting regimes of the indoor environment [2]. Properly designed parameters of "envelope building" enable to reduce exploitation expenditures and to increase the comfort accommodation level. This subject is particularly significant in case of the dwelling building design.

The artificial building containment primarily includes the filler structure like walls, windows and roofs. Window fillings, both with the wall constructions of dwelling houses, play the predominant role in dwelling comfort maintenance and from a perspective of heat losses. What is the most efficient project for the artificial envelope of the residential building? This question implies it's decision in a complex



and multivariate approach to the envelope's construction elements design, first of all, to the design of window fillings.

## 2. Materials and Methods

Construction parameters of window fillings play an important role in providing of comfortable indoor microclimate and in heating losses value in residential houses [3]. Moreover, windows are to be considered as a linking element between indoor and outdoor environment, which have an impact on psychological state of health of the inhabitant's. In this connection and in the frame of the efficient design searching for artificial building envelope, the issue of permissible choice for window dimensions raises urgently.

According to the authors and to the several research issues [4, 5, 6, 7], the three groups of the most of the covering construction's parameters can be applied. Among them, there are functional indicators,  $D_1$ ; exploitation indicators,  $D_2$ ; indicators of cost,  $D_3$ ; ecological indicators,  $D_4$  (which is need depending on the special customer requirements). In this connection and in order to the complex consideration of these parameters, it seems logical to introduce the integral design quality index  $Q_k$ :

$$Q_k = F_1 D_1 + F_2 D_2 + F_3 D_3 + F_4 D_4; \quad (1)$$

where:

$D_1$  - the functional parameters, for instance, which influence on the comfort;

$D_2$  - the exploitation parameters;

$D_3$  - the indicators of cost;

$D_4$  - the ecological indicators;

$F_1, F_2, F_3, F_4$  - the values of the weighting factors.

For taking into consideration the each parameter's impact on the index  $Q_k$ , the relative estimation through the using of the regulatory framework or prototype and analogical projects (when there are no the standard data) should be used. According to this issue subject, the described above indexes are applied for the window's blocks, fixed in the external walls of dwelling buildings.

The functional parameters,  $D_1 = \Sigma D^f$ , should include the following factors:

$D_1^f$  - the equivalent indoor noise level,  $L_{eq}$ ;

$D_2^f$  - natural light coefficient, NLC;

$D_3^f$  - the medium radiation surface temperature index,  $t_R$ ;

$D_4^f$  - the air exchange value through the window fillings;

$D_5^f$  - the index of durability and reliability of the window blocks.

In the author's opinion, only the first three above parameters have the main importance, and thus, should be taken into consideration for the construction design estimation of external wall in a combination with the window fillings.

The exploitation parameters,  $D_2 = \Sigma D^e$ , involve heat loss through the building coverage and the value of natural light flow in the premises:

$D_1^e$  - overall heat loss through the external wall and the window,  $Q$ ;

$D_2^e$  - natural light flow duration in dwelling premises,  $t_L$ .

This group of factors reveals the heat loss through the building coverage as a predominant comfort parameter.

The cost indexes,  $D_3 = \Sigma D^c$ , could include the value of the wall and window building and their exploitation and repair expenditures:

$D_1^c$  - the cost of construction's building,  $C_{cb}$ ;

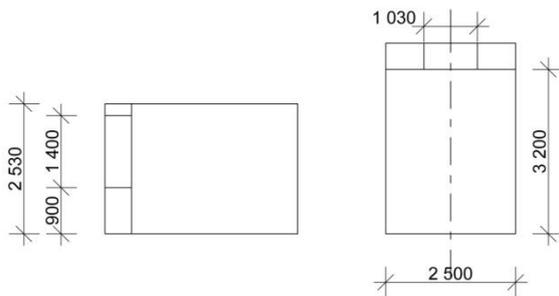
$D_2^c$  - the cost of exploitation and repair expenditures,  $C_{er}$ .

The cost of construction's building,  $C_{cb}$ , has a first priority during the stage of designing and implementation of the project.

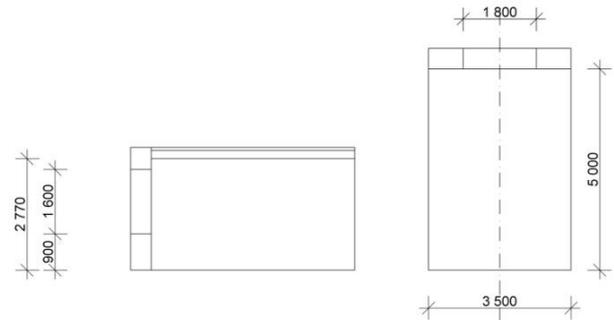
Finally, after the factors analyzing and selection the most important through them, there was obtained the functional connection for the index of design option estimation for windows fillings,  $Q_w$ :

$$Q_w = F_1 D_1^k + F_2 D_2^k + F_3 D_3^k + F_4 D_1^3 + F_5 D_1^3; \quad (2)$$

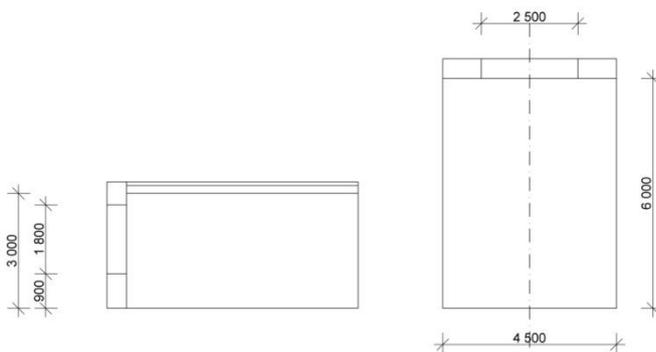
It's seems to be interesting to research this connection and to find the range of variability for  $Q_w$  coefficient, in case of windows scale dimensions depending on floor square in dwelling buildings of Russian "economy class" [8-11]. The example bellow shows the window filling construction with the triple-pane window (4M1-12-4M1-12-4M1), for the purposes of three types of room dimensions in residential buildings. These dimensions, which were chosen by the authors, are: 2.5x3.2; 3.5x5; 6x4.5 m; Figures 1-3.



**Figure 1.** Residential premise, variant 1.



**Figure 2.** Residential premise, variant 2.



**Figure 3.** Residential premise, variant 3.



**Figure 4.** Construction of triple-pane window, Model type 4M1-12-4M1-12-4M1.

The method of minimal target function result searching is used to find out the value of the index of design option estimation,  $Q_w$ , (3). This method is based on the deviation evaluating of the five indexes for each type of the windows from the best possibly existing parameters, for instance the table 1.

$$\delta_i = \frac{|F_i - F_i^n|}{F_i^n}; \quad (3)$$

The table 1 reveals relative points of design option estimation index,  $Q_w$ , for five positions of window's dimensions in the first variant of living premise (the small premise). Here, the relative deviations of certain parameters in connection (2) from the reference values,  $\delta_i$ , in accordance with the function (3) are multiplied with the weight coefficients, fined due to the expert evaluation method ( $F_1=0.30$ ;  $F_2=0.27$ ;  $F_3=0.15$ ;  $F_4=0.18$ ;  $F_5=0.11$ ). The standard values of the using parameters were determined upon the normative literature and author's own researches.

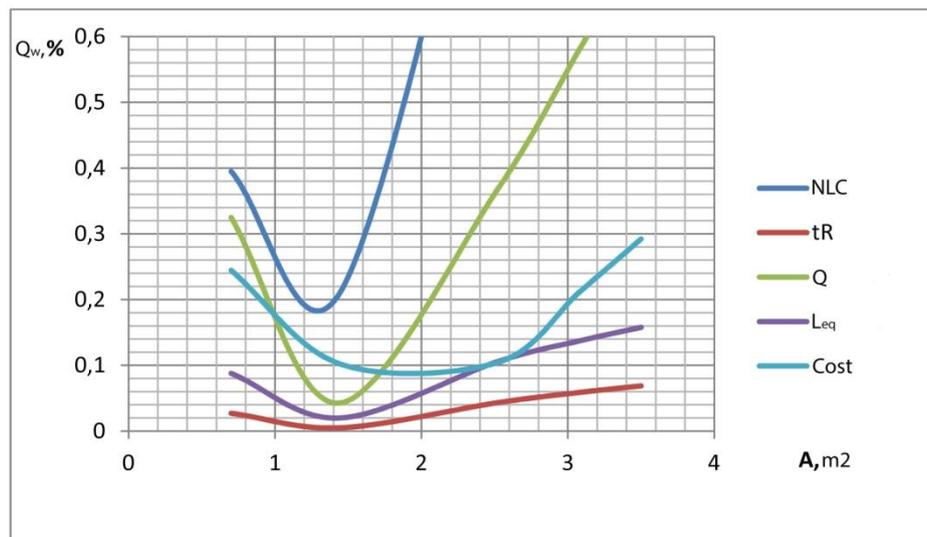
The width of window openings, alongside with their constant height, is varying with the certain step. The external walls of the building in represented instance are designed from polystyrene concrete blocks ( $\delta=380$  mm, heat transmission U-value =0,1 W/m<sup>2</sup>C) and lining bricks ( $\delta=120$  mm, heat transmission U-value=0.365 W/m<sup>2</sup>C).

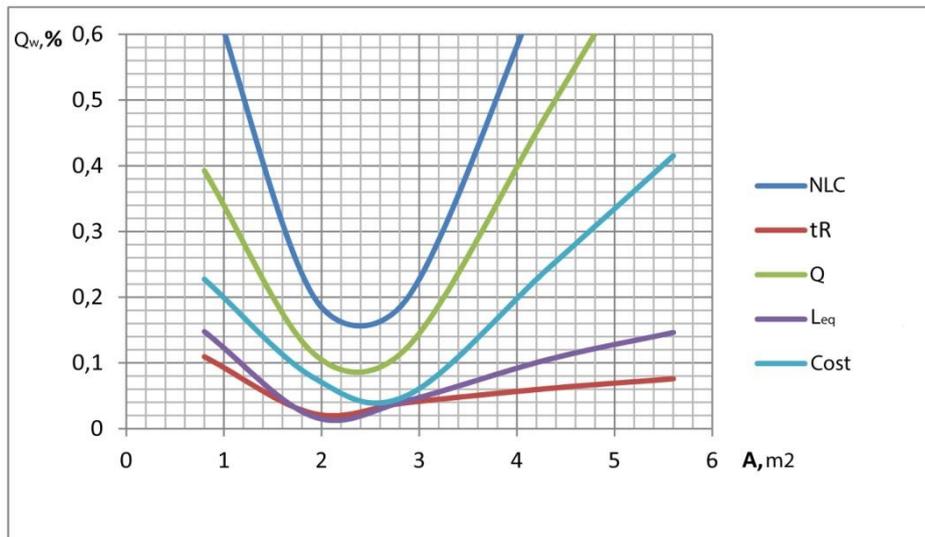
**Table 1.** The selection of target function value for the residential premise in the variant 1.

Window opening's square, m <sup>2</sup>	The value of target function in natural units					The target function deviations from it's extremes					The value of common target function (Q <sub>w</sub> )	Position of the variant
	NLC, %	tR, °C	Q, Wt	L <sub>eq</sub> , dBA	Cost, rubles.	δKEO	δtR	δQ	δL	δCost		
0.7	0.61	18.49	149	27.36	16153	0.395	0.027	0.325	0.09	0.24	0.22	2
1.442	1.21	17.91	211	30.60	19195	0.21	0.005	0.042	0.02	0.10	0.08	1
2.52	2.06	17.22	301	33.17	23615	1.06	0.043	0.367	0.11	0.10	0.40	3
3.08	2.54	16.94	348	34.12	25911	1.54	0.058	0.5809	0.14	0.21	0.59	4
3.5	2.72	16.76	383	34.73	27633	1.72	0.068	0.740	0.16	0.29	0.68	5
Reference values	1	18	220	40	21384							

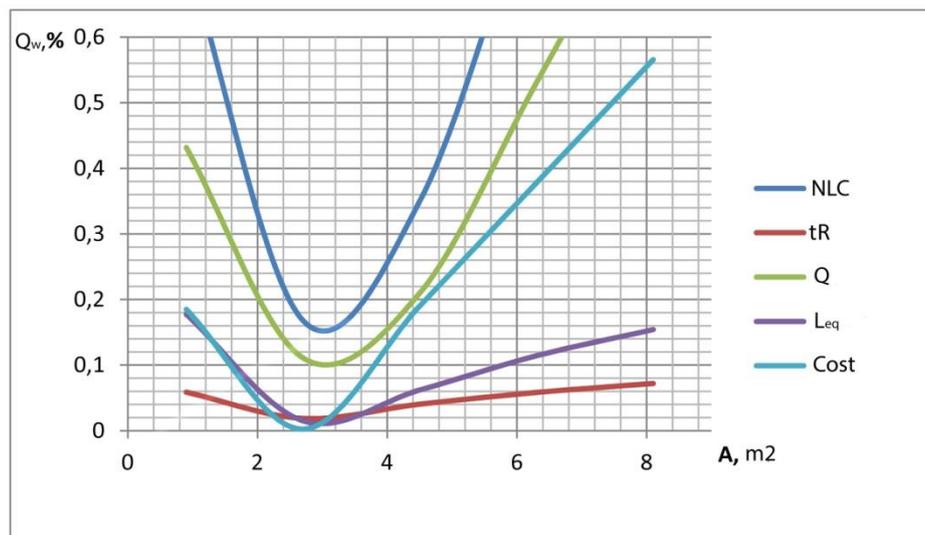
### 3. Results

After the calculations being accomplished, the graphs of deviation for each parameter from their standard quantities (connection (2)) for three types of the premises was obtained, figures 5-7. The graphs can reveal the spot of "optimum" for the square opening's dimensions of three types of the premises, shown above.

**Figure 5.** The graphs of certain target function parameters for room dimensions 2.5x3.2 m.



**Figure 6.** The graphs of certain target function parameters for room dimensions 3.5x5.0 m.



**Figure 7.** The graphs of certain target function parameters for room dimensions 4.5x6.0 m.

Optimal square values for the small square dwelling premises (2.5x3.2) are in the range of 1.3 to 1.6 sq. m. The middle and the large premises (3.5x5 m and 4.5x6 sq. m by this issue) have the optimal window's dimensions range of 2.1 to 2.5 sq. m. and of 2.7 to 3.2 sq. m., respectively.

As is known, the building normative documents [12, 13], in particular, the Russian SNiP 2.08.01-89\*, and the scientific literature [14] require the relationship between the window and the floor square to be from 1:5,5 to 1:8. The calculations and the graphs for the first two variants above generally confirm the feasibility of these requirements. The large premises window openings (the third variant), in accordance with the outcome of calculation experiment, can have less dimensions as in existing norms, but this is a matter to be resolved in future.

#### 4. Conclusions

The multifactoral approach to the quality estimation of building design makes it possible to choose an optimal physical and technical parameters number, firstly, dimensions of window openings. Importantly, the other construction elements can be considered in a similar way, in accordance with the suitable climatic, social and economical features of the construction site region.

And furthermore, the complex multifactor approach, revealed in this issue, allows to address possible contradictions in tasks and interests between designers, developers and customers on the beginning stages of design and residential building construction.

Thus wise, the concerned complex multifactoral approach to the design quality estimation of external fencing structures is based on introduction of main groups of parameters. These four groups include functional, exploitation, cost and environmental parameters. The offered quality design index  $Q_k$  is inputting for the complex characteristic of observed above parameters. So the mathematical relation of this index is the target function for the quality design estimation. The multifactoral approach for optimal design searching, which is mentioned in the article, will allow to consider various construction elements of dwelling buildings in accordance with suitable climate, social and economic construction area features.

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