DETERMINATION OF U AND g COEFFICIENT FOR EXTERNAL PARTITIONS WITH TRANSPARENT INSULATION USING “LORD” SOFTWARE

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ABSTRACT

The purpose of this work was to determine U and g coefficients of the external wall with transparent insulation under real external climatic conditions. As the mainly methodology used for obtainment of the intended results was adoption of the methodology based on Paslink test cells system. To obtain from the collected data the searched coefficients various method of analysis was used. As the last one has been used the software “Lord”, which author has obtained from the Paslink Organisation. In the paper are presented the models constructed using software “Lord” and final results of tests as coefficients U and g. This results are compared with results obtained previously.

Keywords: Transparent Insulation, Test Cells, Dynamic Analysis

1. STUDIES OF WALL WITH TRANSPARENT INSULATION

1.1. Review of measurement methods for transparent walls

1.1.1. Steady-state tests

One of basic kinds of tests are tests performed in conditions of steady-state of heat exchange, not taking into account the variability of heat loads in time. Two measurement methods can be distinguished:
- determining thermal resistance of uniform material for small-size sample using heat-meter or using the method of insulated heating plate,
- determining final value of U coefficient for large sizes of samples, not necessarily uniform using the method of heating box.

Both these methods - described in professional literature and standardized – do not enable determination of g coefficient and due to that they have been rejected in case of these studies.

1.1.2. Dynamic tests

For partitions discussed in this article dynamic tests have been applied for over 10 years. Basic advantage of these tests is the possibility of determining thermal features under the influence of real climate conditions. Thus, there exists the possibility of determining g coefficient for examined elements.

Such test may be run in situ (on real buildings) or using measurement chambers undergoing the influence of real external climate.

Tests in situ

Tests of thermal resistance and U coefficient, run for over 30 years, were standardized in 1980s (ISO 9869).

Within a framework of standardizing the following basic assessments were made:
- Only thermal resistance of partition is determined by measurement. U coefficient is determined by adding standard values Ri and Re.
- It is allowed to use the method of averaging the data while analyzing the results. Yet it is recommended to use the method of dynamic identification of partition parameters.

Tests in chambers

As examples show [1], in resident buildings it is very difficult to obtain credible values of quantities necessary for assessing passive sun elements by means of experiment. The main obstacle in this case is lack of repetitiveness and too big number of uncontrolled variable parameters.
For such complex systems measurement chambers are the perfect solution, in which thermal parameters of the system are identified by exposing it to thermal loads caused by external and internal climate of controlled parameters. Desired parameters of the system are obtained basing on the energy balance of the chamber or the measurement of heat stream density.

Basing on this idea measurement stand was created, used in the research described in the article.

2. THE PURPOSE OF THE RESEARCH

The research described in the article was performed to determine coefficients U and g for external wall with transparent insulation under the influence of real climatic conditions.

Taking into consideration the results of dynamic tests and the leading position of test chambers among them the author of this elaboration applied the above mentioned measurement method using external test chamber. To identify thermal parameters heat-meter and thermometric resistors were used. The tests were carried out between 1998 and 2003 during the months of September – April.

3. RESEARCH POSITION

The research described in the article was carried out in measurement chamber, created on the initiative of Professor J. Mikoś.

![Diagram of the measurement chamber](attachment:diagram.png)

**Figure 1.** Functioning scheme for the stand built in Department of Building Processes.

Fig. 1 presents functioning scheme of the built stand.

The chamber has the form of steel skeleton filled with walls made of pressed concrete brick, heat insulated with foamed polystyrene plates. Inside the chamber is separated into three rooms insulated thermally one from another. Each room has the possibility of building over given wall element of size about 2,4 x 1,4 m. In each room electrical heating – cooling device is installed. Due to that the air temperature inside the rooms is fully controlled. The whole of the construction is sealed so as to eliminate uncontrolled air flow.

The chamber is so placed towards cardinal points of the compass that all tested wall elements are exposed towards south. In photography 1 chamber view from the side of tested elements, in fig. 2 – 4 details concerning the construction of the chamber are presented.
Photo 1. Chamber view from the side of tested elements.

Figure 2. View of the chamber.

Figure 3. Section of the chamber.
3.1. Tested wall elements

In test chamber the author of the article built a partition composed of the following material layer:
- wall made of pressed concrete brick – 0.38 m thick,
- absorbing layer – glue layer with refining additions, correcting absorptive properties of heat radiation,
- transparent insulation – 0.10 m thick,
- transparent plaster.

The partition has the surface of dimensions 1.35 x 2.40 m and fills entirely the hole in test chamber. In fig. 5 presented is the section of the tested wall elements and the distribution of measurement points. In „C” chamber (fig. 2) traditional three-layer wall was made, so as to compare energetic efficiency of the tested solution with typical external partition.

3.2. Applied equipment

Testing thermal properties

The following measuring equipment was used for the tests:
- heat-meters of MG–3 type, glued in central part of the wall,
- thermometric resistors of Pt 100 type, glued to external and internal surface and fused into absorbing layer,
- additional thermometric resistors registering temperature of external air and temperature inside the chamber,
- measuring bridge of FMN–TGL 10395 type,
stabilized feeder,
digital multimeter with output of IEC 625 standard,
commutators controlled from IEC625 bus,
electricity meters,
PC computer.

Tests of solar properties
- set of sensors and devices as for thermal tests, with solarimeter for registering total solar radiation.

3.3. Scope of measurements

As a result of performed measurement the following information was recorded:
- chosen parameters describing external climate:
  - values of temperatures of external air,
  - values of total intensity of solar radiation,
- parameters describing response of the partition:
  - values of temperatures in chosen points of the partition,
  - values of density of heat stream on internal surface of the partition,
  - values of temperatures inside measurement chambers,
- consumption of electrical energy necessary for keeping the assumed temperature of inside the chambers 20°C.

4. MEASUREMENT RESULTS

In the diagram (fig. 6) presented is the variability of temperatures and intensity of solar radiation for the tested partition in January as typical. Full image of obtained results is owned by the author.

5. ELABORATION OF TEST RESULTS

First, all the obtained results were presented in graphic form, as in the diagram (fig. 6). It allowed for visual assessment of the quality of collected data and quick elimination of false readouts.

From the analysis of gathered results one may read that in the period of conventionally assumed heating season, that is between September and April the value of total intensity of solar radiation attains maximum value equalling 841 [W/m²]. Average value for this period is 92 [W/m²]. Considerable decrease in these values is important, after rejecting extreme months: September, October, March, April. It signifies considerable decrease of climate parameter influencing directly the efficiency of the wall with transparent insulation during winter period.

In table 1 presented is maximum and minimum value of temperature difference between absorbing layer and internal surface of the partition for particular months of heating season.
Table 1. Dynamic changes of temperature distribution recorded in the tested partition.

<table>
<thead>
<tr>
<th>Month</th>
<th>te [°C]</th>
<th>Qsol [W/m²]</th>
<th>tpa – tpi [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
<td>max</td>
<td>max</td>
</tr>
<tr>
<td>September</td>
<td>4,9</td>
<td>25,6</td>
<td>643</td>
</tr>
<tr>
<td>October</td>
<td>-5,2</td>
<td>21,8</td>
<td>664</td>
</tr>
<tr>
<td>November</td>
<td>-5,0</td>
<td>12,0</td>
<td>507</td>
</tr>
<tr>
<td>December</td>
<td>-12,5</td>
<td>13,0</td>
<td>597</td>
</tr>
<tr>
<td>January</td>
<td>-16,0</td>
<td>8,4</td>
<td>754</td>
</tr>
<tr>
<td>February</td>
<td>-19,6</td>
<td>13,0</td>
<td>841</td>
</tr>
<tr>
<td>March</td>
<td>-5,7</td>
<td>15,0</td>
<td>821</td>
</tr>
<tr>
<td>April</td>
<td>-2,6</td>
<td>24,7</td>
<td>740</td>
</tr>
</tbody>
</table>

This difference shows that in Polish climatic conditions the distribution of temperature in the partition with transparent insulation does not always correspond with the distribution usually presented in professional literature. There often occur periods when the temperature of the absorber is lower from the temperature of internal surface. It is illustrated in detail in diagrams of temperature distribution in tested partition (fig. 7) presented below. In these diagrams presented are distributions of characteristic gradients occurring in the partition during the tests.

5.1. Determining coefficients U and g

5.1.1 Method of averaging the data

In this method the heat penetration coefficient is determined from the following equations:

\[ U = \frac{q_n}{\Delta T_n}; \quad q_n = \frac{(n-1)q_{n-1} + q_n}{n}; \quad \Delta T_n = \frac{(1-n)\Delta T_{n-1} + \Delta T_n}{n} \]

Accuracy of coefficients determination depends on dynamics of thermal impacts on tested element and duration of measurements.

Using this method for elaboration of results the following values have been obtained: \( U = 0,33 \quad [\text{W/m}^2\text{K}] \) and \( g = 0,11 \).

5.1.2 Application of LORD 3.2 software

Second method applied for determining coefficients U and g was the method of dynamic analysis basing on LORD 3.2 software elaborated by PASLINK EEIG organization. The software is a specialist tool used
for analyzing the results of measurements obtained in PASSYS chambers, assisting the process of identification of thermal and solar parameters of tested elements. The basis of its operation is the analysis of introduced RC model, reflecting the tested thermal system. Theoretical bases are given in professional literature [2].

Model

During the first approach the partition tested by the author (fig. 5) was modelled in form of RC network presented in fig. 8, further marked as “A”.

The following result was obtained for data from the period of January 2001, presented in Fig. 6:

\[ U = 0.853 \text{ [W/m²K]} \pm 0.4\%, \quad g = 0.239 \text{ [-]} \pm 0.4\%, \quad \text{value of residuum 1,028}. \]

Graphic representation of the result is shown in Figs. 9 and 10.

Subsequently, the model was simplified, reducing it to the form presented in Fig. 11.
This brought the following result:
\[ U = 0,167 \, [\text{W/m}^2\text{K}] \pm 42,5\%, \, g = 0,227 \, [-] \pm 1,8\%, \text{value of residuum 1,936.} \]

6. CONCLUSIONS

In table 2 presented are results of calculations for the tested partition.

Table 2. Results of calculations.

<table>
<thead>
<tr>
<th>Method of averaging the results</th>
<th>LORD software, „A” model</th>
<th>LORD software, „B” model</th>
</tr>
</thead>
<tbody>
<tr>
<td>U [W/m²K] , g [-]</td>
<td>U [W/m²K] , g [-]</td>
<td>U [W/m²K] , g [-]</td>
</tr>
<tr>
<td>0,33 , 0,11</td>
<td>0,85 , 0,24</td>
<td>0,17 , 0,23</td>
</tr>
</tbody>
</table>
Differences between obtained results arise from the chosen calculation method. While identifying the parameters of the partition using the method of averaging the results one should pay extra attention to choosing appropriate time interval from which the data will be analyzed. It should be a period of stable thermal parameters. In case of partition with transparent insulation it is difficult to obtain such conditions. Dynamic analysis using LORD software seems to be less sensitive to such disturbance. Thus, it is more appropriate for partitions of high dynamics of thermal processes. However, it requires some experience from the person running the analysis, especially in the domain of employing appropriate calculation model. As one can see, employing different models for the same partition has considerable influence on final result of calculations.

REFERENCES

[1] Henryk Krause, Podstawy temperaturowej diagnostyki przegrod budowlanych