Correlations in hydrothermal properties of building insulation

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Abstract. The contribution comprises analysis that is based on scientific work as a part of participation on the international research project carried out at the University of Prešov in Prešov and Vienna University of Technology entitled “Detection and Management of Risk Processes in Building Insulation” and numbered SRDA SK-AT-0008-10. Statistical approach with correlations among humidity, time and temperature values in the space between the wall and building insulation uses the set of data obtained during the measurement series as testing using a new technology with equipment that does not influence the environment properties in the space. Therefore such real mapping can bring a real picture of possible condensation as a risk process in the building envelope.

1. Introduction
Problem of indoor building environment is closely connected with the life quality of its inhabitants. Health of human being is directly influenced by the air components in his surrounding and is a subject matter in some of the research works with their specific points of view. The authors present for instance mass transfer model and its improvement analyzing environment interaction with both outdoor emissions and emissions from building materials, such as volatile organic compound emissions [8]. The main problem stresses indoor air quality and its influence on the health trying to use the mutual correlations of certain chemical elements for prediction. Specification of pollutants concentration, for instance inorganic gasses and bio aerosol [5], maps especially indoor quality under the outdoor influence.

All those issues are connected with the research on material quality [2], its thermal properties [6], stability under the external conditions for instance by setting the coefficient of moisture expansion at room temperature with comparison the materials according to the different thickness [7], based on laboratory experiments, using mostly numerical methods. Moisture problem also appears in connection with the building materials durability under the outer conditions [4]. Special attention is paid to the rising damp in historical buildings [3].

Another very serious problem is connected with microorganisms whose appearance is influenced with the high humidity level and the following condensation that is counted as a risk process for both building materials and health of the house inhabitants. Cavity in the space between the wall and building insulation is the place where air humidity can be concentrated in the high level. As building envelope is covered with different insulating materials also probability of condensation process appearance can reach different levels. Therefore detection of the humidity level in real situation
without insulation destruction is of high importance. One of the signs that can influence the condensation process is the temperature leading together with the humidity level to dew point calculation. The paper deals with the correlation of humidity with the time and temperature in degrees of Celsius. The relationship is based on statistical analysis using the data obtained during the real measurement series using a new strategy with the equipment [1] constructed during the work on the international research project carried out at the University of Prešov in Prešov and Vienna University of Technology entitled “Detection and Management of Risk Processes in Building Insulation” and numbered SRDA SK-AT-0008-10.

2. Statistical analysis with setting the correlation dependency
The measurement series that was realized on building insulation made of polystyrene with the thickness of 8 centimeters comprises more than 1680 points tested from January 17, 2012 to February 21, 2012 in the period of every 30 minutes. The obtained results are expressed using the graphical representation in figure 1 with the values of both temperature and humidity in the space between the wall and polystyrene and temperature in ambient surrounding of the building.

![Graphical representation of both temperature and humidity values in the cavity between the wall and polystyrene and the temperature in ambient surrounding of the building.](image)

Figure 1. Graphical representation of both temperature and humidity values in the cavity between the wall and polystyrene and the temperature in ambient surrounding of the building.

2.1. Setting the correlation dependency
The values obtained during the measurement series were the basement for setting the correlation in statistical analysis. The correlation using the least square method expressed the dependency of humidity values on the time and temperature in the space between the wall and polystyrene. The decision was set for the linear dependency with the following testing of its statistical significance. The obtained least square regression line

\[ z = a_0 + a_1 x + a_2 y, \]  

(1)
where

$x_i$ — values in the time of testing points,
$y_i$ — the values of temperature in the space between the wall and insulation [$^\circ$C],
$z_i$ — the values of humidity level in the space between the wall and insulation [%].

Using the calculation, coefficient values were obtained as follows:

\[ \begin{align*}
a_0 &= 30.98793132, \\
a_1 &= 0.042121379, \\
a_2 &= 2.479693774.
\end{align*} \]

2.2. Testing the statistical significance of obtained linear correlation dependency

To prove the reliability of the linear dependency among the values

\[\sum_{i=1}^{n} z_i^2 - a_0 \sum_{i=1}^{n} z_i - a_1 \sum_{i=1}^{n} x_i z_i - a_2 \sum_{i=1}^{n} y_i z_i\]

the obtained values of residual sum of squares lead to the setting the characteristic $t$ (4) for testing the statistical significance of the coefficients.

\[ t = \frac{a_j}{s_{a_j}}, \quad (4) \]

Hypotheses:

$H_0$: Variable $Z$ is linearly dependent on variable $X$,
$H_1$: Variable $Z$ is linearly dependent on variable $Y$.

The dependency is tested for the level $\alpha = 0.05$

\[ t_{0.95}(1680) = 1.645 \]

\[ s_{a_j} = \frac{s_{rec}}{\sqrt{\frac{\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2}{n}}} \quad (5) \]

Statistical significance of the obtained value for coefficient $a_1$:

\[ t = 1.773655086, \]

We can say that hypothesis $H_0$ is proved and variable $Z$ is linearly dependent on variable $X$ as for $a_1$:

\[ |t| > t_{0.95}(1680). \]
\[ s_{a_2} = \frac{s_{reg}}{\sqrt{\frac{1}{n} \sum_{i=1}^{n} y_i^2 - \left( \frac{\sum_{i=1}^{n} y_i}{n} \right)^2}} \]

Statistical significance of the obtained value for coefficient \(a_2\):
\[ t = 49.2885992. \]

We can say that hypothesis \(H_0\) is proved and variable \(Z\) is linearly dependent on variable \(Y\) as for \(a_2\):
\[ |t| > t_{0.05}(1680). \]

Confidence level in the form of intervals:
\[ a_j \pm t_{1-\alpha/(p-1)} \cdot s_{a_j}, \]

for coefficient \(a_1\):
\[ (0.0030553;0.0811874), \]

for coefficient \(a_2\):
\[ (2.3969348;2.5624528). \]

Using the statistical analysis, humidity values are linearly dependent on the time and temperature in the space between the wall and polystyrene with satisfactory significance.

3. Setting the correlation among the slope values with the following statistical significance testing

In this section the slope values of \(\Delta\) humidity and \(\Delta\) temperature are expressed in figure 2 and figure 3.

**Figure 2.** Graphical representation of both \(\Delta\) humidity and \(\Delta\) temperature values in the cavity between the wall and insulating material.
The linear dependency of $\Delta$ humidity on time and $\Delta$ temperature in the space between wall and polystyrene

$$z = c_0 + c_1 x + c_2 y$$

(6)

where

$x_i$ … values in the time of testing points,

$y_i$ … the values of $\Delta$ temperature in the space between the wall and insulation,

$z_i$ … the values of $\Delta$ humidity level in the space between the wall and insulation.

Values obtained by calculation:

$c_0 = 0.027752551$,

$c_1 = -0.004041503$,

$c_2 = 2.855895657$.

Figure 3. Graphical representation of both $\Delta$ humidity and $\Delta$ temperature values in the cavity between the wall and insulating material with two axes.

Hypotheses:

$H_0$: Variable $Z$ is linearly dependent on variable $X$,

$H_1$: Variable $Z$ is linearly dependent on variable $Y$.

The dependency is tested for the level $\alpha = 0.05$

$t_{0.05(1680)} = 1.645$

$s_{rc} = 0.369101861$

Statistical significance of the obtained value for coefficient $c_1$:

$t = -3.106614541$
We can say that hypothesis $H_0$ is proved and variable $Z$ is linearly dependent on variable $X$ as for $c_1$:

$$|t| > t_{0.95}(1680).$$

Statistical significance of the obtained value for coefficient $c_2$:

$$t = 17.66426465$$

We can say that hypothesis $H_0$ is proved and variable $Z$ is linearly dependent on variable $Y$ as for $c_2$:

$$|t| > t_{0.95}(1680)$$

Confidence level in the form of interval for coefficient $c_1$:

$$(-0.006182; 0.001901)$$

Confidence level in the form of interval for coefficient $c_2$:

$$(2.5899379; 3.1218534)$$

Using the statistical analysis, the values of $\Delta$ humidity are linearly dependent on both time and $\Delta$ temperature in the space between the wall and polystyrene with satisfactory significance.

4. Summary
The paper is based on statistical analysis the real data obtained during the measurement series mapping the values of humidity and temperature in the cavity between the wall and insulating material on building envelope. The insulation was used in the form of polystyrene with the thickness of 8 centimetres. More than 1680 measuring results for every variable during the testing period from January 17, 2012 to February 21, 2012 were the basement for setting correlation using least square as statistical method for linear dependency of humidity with both time and temperature values and also for $\Delta$ humidity and both time and $\Delta$ temperature.

Hypotheses testing proved statistical significance of obtained values. It means that those correlations are important for decision regarding the quality of insulating material on the building envelope.

5. References
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