Plasters on Facades, and the Possibility of Inter-layer Condensation

Artur Miszczuk 1, Agnieszka Kaliszuk-Wietecka 1, Kazimierz Truchan 1

1 Warsaw University of Technology, Faculty of Civil Engineering, Institute of Civil Engineering, Team Building and Sustainable Development Armii Ludowej 16, 00-637 Warsaw, Poland

a.miszczuk@il.pw.edu.pl

Abstract. The publication focuses on what happened outside, on the possibilities and condensation of water vapor. The first part presents the advantages and disadvantages of plasters and the hazards resulting from the condensation of water vapor. To formulate conclusions, analyzes of various thermal insulation materials and external plasters were carried out. The obtained results indicate that the types and thickness of individual materials used in the wall affect the possibility of condensation of water vapor inside the building envelope.

1. Introduction

Currently, the most-used thermal insulation system is the ETICS (External Thermal Insulation Composite System). The system is quick in execution, cheap and aesthetic. However, attention should be paid to other aspects affecting the correctness of the work of the insulated elements. A serious problem may be the inter-layer condensation of the water vapor. Steam condensation may occur in special cases due to the diffusion of water vapor through building partitions. Diffusion is the movement of water vapor particles in the pores of the materials forming the baffle, due to the difference of partial pressures of steam, on both sides of this barrier. The water vapor moves from the environment of higher pressure to the environment of lower pressure.

2. Hazards resulting from the condensation of water vapor.

Depending on the place of condensate condensation and the drying time of the septum, various effects of this phenomenon are observed. It affects the reduction of thermal insulation of partitions, which results in increased heat losses [1] and the risk of freezing. It also affects the durability, aesthetic and functional values of the materials from which the barrier is made [2]. Excessive humidity of building materials leads to their chemical and biological corrosion [3-5], mechanical destruction as a result of crystallization in the material's pores, formation of efflorescence, as well as bursting of the material structure - in case of freeze.

When analysing issues related to water vapor diffusion, it should be remembered that all living processes taking place in the building cause the formation of a certain amount of water vapor [6], e.g.:

- evaporation from pot plants 7-15 g/h,
- sleeping individual 50 g/h,
• working dishwasher 200 g/wash,
• cooking meals 1000-2000 g/h.

The article presents the analysis of the possibility of inter-layer condensation forming, where the following data should be considered:

• geographical location of the building (average outdoor temperature and relative humidity of the air),
• internal conditions and purpose of the building (internal temperature and relative humidity of the air and the way of using rooms) [7],
• type and construction of the partition,
• the direction of heat flow,
• careful execution of the building partition.

3. The advantages and disadvantages of individual external plasters.
Investors, very often unknowingly, usually for financial reasons, or trying to get savings, leading to many irregularities during the building construction. The problem is, for example, the use of substitutes for materials and/or systems described in the design of the facility as well as the recommendations of the manufacturers, forgetting that the lack of compatibility of materials can lead to later problems [8, 9].

Another issue is the fact of incorrectly selected stages of the construction and finishes e.g.: exposing an unfinished object, or to the influence of atmospheric conditions or not observing the rules regarding the necessary technological breaks. An example of this is the arrangement of insulation on a damp, dirty barrier, which was exposed to adverse weather conditions throughout the winter. Another mistake of designers is the adoption of the thickness of insulation, only in terms of the minimum thickness that meet the applicable Technical Guidelines (U ≤ 0.23 W/(m²K) at tᵢ > 16°C for external walls) [10]. In addition, investors for financial reasons often reduce the thickness of insulation in relation to the design and current requirements for external barriers [10].

In the next stage of conducting insulation works also irregularities related to the choice of plaster may occur, so it is necessary to pay attention to the differences between their types, their advantages and disadvantages (remembering not only about the price, but also about vapor permeability) and recommendations as to their use on given type of insulation. Basic plaster parameters are presented in table 1. Among the external plasters described in table 1 for further simulation and analysis, acrylic plaster was selected. The choice is supported by the frequent use of acrylic plaster outside buildings and the fact that it has a high material diffusion resistance factor.

| Plaster type | Advantages | Disadvantages |
|--------------|------------|---------------|
| mineral      | the binding element is cement (white or gray), consists mostly of natural ingredients with enriching additives, it is highly vapor-permeable, resistant to fouling by algae and fungi, there are plasters dyed in mass, however, the color palette is very limited, plaster in gray or white is the cheapest among plasters generally available. | not very resistant to mechanical damage, most often produced in white and gray, to obtain a different color, it needs to be painted over, after damage to the paint coat you can see the plaster in a natural color, and it looks very unsightly, stained plaster is significantly more expensive than white (there is a risk of color differences in individual plaster sacks and therefore manufacturers recommend one-time painting), and the additional cost of paint and labor makes this solution more expensive than acrylic plaster. |
| acrylic      | very good quality, resistant to mechanical damage, affordable prices, stained in bulk, retains permanent colors for a long time without the need to paint. | lack of resistance to biological corrosion (there may be unsightly coatings and discoloration on the surface of the plaster). Manufacturers use additives that render plaster resistant to algae and fungi. However, not all companies normally use these additives and not all of them in enough quantity. |
should not be used in wet places (near the sea, lakes, large clusters of trees) and in the villages due to exposure to algae, or fungi invasion,
- due to low vapor permeability, is not suitable for mineral wool.

- resistant to fouling (perfect for places where acrylic plaster would be exposed to intense biological corrosion),
- as flexible as acrylic plaster,
- lower coefficient of diffusion resistance against water vapor (compared to acrylic plaster) - suitable for use on mineral wool,
- it gets dirty slower than acrylic plaster and has more durable colors (provided that only the mineral pigments are used for coloring).

- slightly more expensive than acrylic plaster,
- when used for coloring pigments other than mineral, the colors are quickly burned by UV radiation and the plaster fades,
- the choice of mineral colors is small (the palette of finished plasters is not as rich as acrylic),
- there are no strong, intense or dark colors,
- applying plaster requires practice when applied.

- high flexibility, hydrophobicity and low diffusion resistance,
- high resistance to biological corrosion,
- can be used in any place and in various conditions,
- resistant to mechanical damage,
- increased resistance to dirt - the plaster becomes dirty quite slowly and cleans faster (thanks to the water spilling on the surface of the plaster).

- the most expensive among plasters.

4. The method used to conduct condensation analysis of water vapor.
The article presents analysis of the possibility of condensation of water vapor for an external wall covered with various plasters. The necessary calculations were made using the GLASTA computer program. It made it possible to calculate the value of thermal resistance in the external partition, to determine the occurrence of possible condensation zones, to calculate the amount of condensate in individual periods (months) and to simulate the removal of moisture accumulated in the partition. The Glaser method is used in the algorithms of the program: normal and extended. Both methods estimate the risk of condensation formation, its duration and the possibility of drying out for a given climate zone. The normal Glaser method allows to determine only the amount of condensation in the interlayer space. In this method, no account is taken of what happens with condensation (in practice condensation moistens the material). The extended Glaser method is based on the definition of the critical water content in a given material according to which the critical water content of a material is the water content above which the water goes into the liquid phase. Below the critical content, water moves through diffusion. The normal Glaser method was used for the analyzes presented in the article.

As a basic principle of the possibility of using a partition, in practice, it is assumed that if there is condensation in the partition in autumn and winter, this condensate must evaporate in the remaining calculation cycle (12 months). However, in the case of plaster coatings, the appearance of condensation at the interface of thermal insulation/plaster and/or at the joint of plaster/paint - in temperatures below zero - there is a risk of degradation (bursting) of plastering and its detachment from thermal insulation and/or the occurrence of spanning paint surface. This may lead to exposure of thermal insulation, and hence to mechanical, biological or chemical damage. In addition, the condensation of water vapor in the thermal insulation layer causes that the penetration of heat through the partition increases.

5. Simulations and analyzes.
In order to analyze the problems presented in the article, a single-family building was adopted for analyzes. It was assumed that the building is in central Poland (Warsaw) (table 2), an indoor temperature of 20°C was assumed. The calculations were made for the external wall separating the heated room - the kitchen (since there is an elevated moisture content in the room) from the external environment.
Table 2. Meteorological data for Warsaw.

| Month indication | Month   | Number of days in a month | The average air temperature outside the building [°C] | Average air humidity outside the building [%] | Water vapor pressure outside the building [Pa] | The average air temperature inside the building [°C] | Average indoor air humidity [%] | The water vapor pressure inside the building [Pa] |
|------------------|---------|---------------------------|-----------------------------------------------------|---------------------------------------------|-----------------------------------------------|-----------------------------------------------------|--------------------------------|---------------------------------|
| 1                | September | 30                        | 13.3                                                | 91                                          | 1389                                          | 20                                                  | 55                            | 1286                            |
| 2                | October   | 31                        | 8.3                                                 | 32                                          | 1007                                          | 20                                                  | 55                            | 1286                            |
| 3                | November  | 30                        | 2.8                                                 | 37                                          | 680                                           | 20                                                  | 55                            | 1286                            |
| 4                | December  | 31                        | 0                                                   | 90                                          | 550                                           | 20                                                  | 55                            | 1286                            |
| 5                | January   | 31                        | -1.7                                                | 88                                          | 467                                           | 20                                                  | 55                            | 1286                            |
| 6                | February  | 28.2                      | -1.7                                                | 89                                          | 472                                           | 20                                                  | 55                            | 1286                            |
| 7                | March     | 31                        | 2.8                                                 | 88                                          | 657                                           | 20                                                  | 55                            | 1286                            |
| 8                | April     | 30                        | 7.8                                                 | 83                                          | 878                                           | 20                                                  | 55                            | 1286                            |
| 9                | May       | 31                        | 13.3                                                | 79                                          | 1206                                          | 20                                                  | 55                            | 1286                            |
| 10               | June      | 30                        | 16.1                                                | 80                                          | 1464                                          | 20                                                  | 55                            | 1286                            |
| 11               | July      | 31                        | 17.8                                                | 83                                          | 1691                                          | 20                                                  | 55                            | 1286                            |
| 12               | August    | 31                        | 17.8                                                | 86                                          | 1752                                          | 20                                                  | 55                            | 1286                            |

For the first analysis it was assumed that the wall has a masonry structure, made of ceramic hollow blocks with holes (e.g. Porotherm) (table 3). For the partition to meet the current requirements [10] from the outside, 7 cm thick polystyrene was adopted for insulation (Styrofoam was accepted because the cost of mineral wool per m² is approximately 2 times higher). From the outside, acrylic plaster was made on the insulation. The barrier thus designed and constructed is not free from inter-layer condensation of water vapor (figure 1). However, it is anticipated that the condensate will evaporate completely in the summer months (table 4, figure 2).

Table 3. Data characterizing individual materials used in the building envelope no. 1.

| No. | Material            | d [m] | λ [W/m·K] | R [m²·K/W] | μ [-] | Sd [m] |
|-----|---------------------|-------|-----------|------------|-------|--------|
| 1   | OUTSIDE             | -     | -         | 0,04       | -     | -      |
| 2   | acrylic plaster     | 0,003 | 0,70      | 0,004      | 140   | 0,42   |
| 3   | styrofoam           | 0,07  | 0,043     | 1,628      | 60    | 4,20   |
| 4   | perforated brick    | 0,38  | 0,143     | 2,657      | 5     | 1,90   |
| 5   | cement-lime plaster | 0,02  | 1,0       | 0,020      | 10    | 0,20   |
| 6   | INSIDE              | -     | -         | 0,13       | -     | -      |

∑R = 4,480 [m²·K/W]
U = 0,223 [W/m²·K]

where:
d - material thickness, λ - thermal conductivity coefficient, R - heat transfer resistance, μ - material diffusion resistance factor, Sd - diffusion-equivalent air layer thickness [12, 13] and U - heat transfer coefficient through the building envelope.

Table 4. The amount of condensate in the building envelope No. 1.

| Month    | Condensation of water vapor | The amount of condensate in a month (minus sign means drying out) g, [kg/m²] | Total amount of condensate M, [kg/m²] |
|----------|----------------------------|--------------------------------------------------------------------------------|-------------------------------------|
| September| NO                         | 0                                                                               | 0                                   |
| October  | NO                         | 0                                                                               | 0                                   |
| November | NO                         | 0                                                                               | 0                                   |
| December | YES                        | 0.0073                                                                          | 0                                   |
| January  | YES                        | 0.0234                                                                          | 0.0073                              |
| February | YES                        | 0.0218                                                                          | 0.0306                              |
| March    | NO                         | -0.0260                                                                         | 0.0524                              |
| April    | NO                         | -0.0264                                                                         | 0.0264                              |
| May      | NO                         | 0                                                                               | 0                                   |
| June     | NO                         | 0                                                                               | 0                                   |
| July     | NO                         | 0                                                                               | 0                                   |
| August   | NO                         | 0                                                                               | 0                                   |
In order to eliminate the occurrence of condensation in the above case, one should choose one of the following options:

- increase the thickness of insulation (up to 16 cm thickness) leaving acrylic plaster,
- increase the thickness of thermal insulation made of expanded polystyrene (up to 14 cm thick) along with the change of plaster for steam permeable, e.g.: silicate plaster,
- change the type of insulation from foamed polystyrene to a material with lower diffusion resistance (e.g. mineral wool) and the use of plaster with a lower diffusion resistance (e.g. silicate plaster).

The proposed solutions cause a complete absence of interdependence of water vapor during the whole period (12 months).

Table 5. Data characterizing individual materials used in the building envelope no. 2.

| No. | Material          | d  [m] | λ  [W/m·K] | R  [m²·K/W] | μ  [-] | S  [m] |
|-----|------------------|--------|------------|-------------|-------|-------|
| 1   | OUTSIDE          | -      | -          | 0,04        | -     | -     |
| 2   | acrylic plaster  | 0,003  | 0,70       | 0,004       | 140   | 0,42  |
| 3   | mineral wool     | 0,07   | 0,043      | 1,628       | 1     | 0,07  |
| 4   | perforated brick | 0,38   | 0,143      | 2,657       | 5     | 1,90  |
| 5   | cement-lime plaster | 0,02 | 1,00       | 0,020       | 10    | 0,20  |
| 6   | INSIDE           | -      | -          | 0,13        | -     | -     |

\[\Sigma R = 4,480 \text{ m}^2\cdot\text{K/W}\]
\[U = 0,223 \text{ W/m}^2\cdot\text{K}\]
However, it often happens that investors are trying to cut costs on both material and labour in order to "seem" (as it turns out later). One of the problems that occur is the failure to comply with the recommendations of manufacturers of insulating materials and plasters (table 1). An example of this is the use as thermal insulation - mineral wool and the improper plastering on it, such as acrylic plaster (table 5). If high-vapor permeable insulation is used, high-vapor permeability plasters should also be used. In the event of non-compliance with this principle, condensation of water vapor occurs (table 6, figure 3, figure 4) where the mineral wool connects with acrylic plaster.

| Month    | Condensation of water vapor | The amount of condensate in a month (minus sign means drying out) | Total amount of condensate M, [kg/m²] |
|----------|-----------------------------|-----------------------------------------------------------------|--------------------------------------|
| September| NO                          | 0                                                               | 0                                    |
| October  | NO                          | 0                                                               | 0                                    |
| November| YES                         | 0.0298                                                          | 0                                    |
| December| YES                         | 0.0693                                                          | 0.0298                               |
| January  | YES                         | 0.0835                                                          | 0.0991                               |
| February| YES                         | 0.0818                                                          | 0.1827                               |
| March    | YES                         | 0.0044                                                          | 0.2645                               |
| April    | NO                          | -0.1665                                                         | 0.2689                               |
| May      | NO                          | -0.1024                                                         | 0.1024                               |
| June     | NO                          | 0                                                               | 0                                    |
| July     | NO                          | 0                                                               | 0                                    |
| August   | NO                          | 0                                                               | 0                                    |

Figure 3. Chart showing condensation spots in building envelope no. 2 in one calculation cycle.

Figure 4. Chart showing amount of condensate in building envelope no. 2 in one calculation cycle.

An equally important problem that arises on the construction site is the employment of non-specialized teams that cannot properly perform plastering. It may result in:
the plaster breaks off the surface or the appearance of white, lime efflorescence/discoleration,
appearance of differences in colour (this happens in case of plasters dyed in bulk, with improper
performance of plaster coating),
formation of shrinkage cracks, which results in lowering the durability of the facade,
inhomogeneous surface appearance of the facade due to the mashing of the plaster, applied on
a poorly levelled surface,
appearance of white or light grey efflorescence and lime deposits (in the case of plastering during
hot weather) or leaching of the binder and pigment from the volume of the plaster (if it gets wet
by rain).

As a result of the above-mentioned problems, the investor is forced to spend additional funds
(previously unforeseen) on the facade paint in order to hide the shortcomings made by the plaster
contractor. It often happens that materials incompatible with each other or products from different
manufacturers were used [14]. However, sometimes it comes to a situation where attempts to improve
the faulty facade that does not meet the aesthetic requirements may give the opposite effect.
In this example, as a result of the application of an inadequate paint coat (e.g. acrylic paint coating)
on the previously analyzed layers of the barrier (table 3.) there is an increase in inter-layer condensation
(Table 7., Figure 6.). In this case, there is a risk of water vapor condensation at the joint of the ceramic
block with openings and expanded polystyrene (Figure 5.).

Table 7. The amount of condensate in the building envelope No. 3.

| Month  | Condensation of water vapor | The amount of condensate in a month (minus sign means drying out) | Total amount of condensate M_\text{c} [\text{kg/m}^2] |
|--------|----------------------------|---------------------------------------------------------------|--------------------------------------------------|
| September | NO | 0 | 0 |
| October | NO | 0 | 0 |
| November | NO | 0 | 0 |
| December | YES | 0.0099 | 0 |
| January | YES | 0.0260 | 0.0099 |
| February | YES | 0.0242 | 0.0359 |
| March | NO | -0.0233 | 0.0601 |
| April | NO | -0.0368 | 0.0368 |
| May | NO | 0 | 0 |
| June | NO | 0 | 0 |
| July | NO | 0 | 0 |
| August | NO | 0 | 0 |

Figure 5. Chart showing condensation spots in building envelope no. 3 in one calculation cycle.
Another example of incorrect behaviour at the construction stage is the closing of technological moisture inside buildings - e.g. by inserting external carpentry before the end of wet works inside the building or failure to achieve the air-tightness of the building assumed at the design stage [15, 16]. As a result, moisture instead of evaporation stays in the building. Noteworthy is also the problem of obtaining the intensity assumed by the investor and the "depth" of the facade colour. This problem occurs while painting a larger area of the building, in which case you should not make breaks. Performing it results in a clear visible and unsightly appearance of the border between the individual stages of painting the plaster. In order to mask the manufacturing errors or attempt to achieve the assumed intensity of the colour, an additional paint coating is applied. This translates into the risk of inter-layer condensation [17], as shown in the example of the analyzed building. In addition, the amount of condensate is increased due to the presence of an additional layer of paint, which has low vapor permeability (table 8.).

**Table 8.** The amount of condensate in the building envelope no. 3 with an additional layer of paint.

| Month    | Condensation of water vapor | The amount of condensate in a month (minus sign means drying out) | Total amount of condensate M, [kg/m²] |
|----------|-----------------------------|------------------------------------------------------------------|--------------------------------------|
| September| NO                          | 0.0003                                                           | 0                                    |
| October  | NO                          | 0.0213                                                           | 0.0003                               |
| November | YES                         | 0.0366                                                           | 0.0216                               |
| December | YES                         | 0.0360                                                           | 0.0582                               |
| January  | YES                         | -0.0250                                                          | 0.0942                               |
| February | YES                         | -0.0724                                                          | 0.0724                               |
| March    | NO                          | 0.082                                                             | 0                                    |
| April    | NO                          | 0.15                                                              | 0                                    |
| May      | NO                          | 0.095                                                             | 0                                    |
| June     | NO                          | 0.15                                                              | 0                                    |
| July     | NO                          | 0.095                                                             | 0                                    |
| August   | NO                          | 0.15                                                              | 0                                    |

The recent analysis consisted in checking the impact of changing the building's function on the possibility of condensation of water vapor. For this purpose, the residential function was changed to a place with increased temperature and air humidity (e.g. swimming pool hall). Change in the average internal temperature from 20°C to 25°C and the average indoor humidity from 55% to 75% (which translated into a change in water vapor pressure from 1286 Pa to 2376 Pa), significantly affects...
the condensation distribution and vapor recovery in 12-month computational cycle (table 9.). The condensation of water vapor occurs in two places: on the combination of styrofoam/acrylic plaster and perforated brick/styrofoam (figure 7.). In the case of the first place, the condensate appearing in the autumn and winter months completely dry in the summer months. In the case of the second place, the amount of condensate is so large that it is not able to completely dry out (figure 8.). This means that in subsequent cycles (12-month) there will be an increase in moisture content used in the partition. The occurrence of such a situation leads to a reduction in the insulation of the external barrier, biological and chemical corrosion. The negative consequence of the increasing amount of condensate is also the bursting of the material structure as a result of frost.

Table 9. The amount of condensate in the building envelope no. 3 in the event of a change in the utility function of the building.

| Month    | Condensation of water vapor | The amount of condensate in a month (minus sign means drying out) | Total amount of condensate $M_i$ [kg/m²] |
|----------|-----------------------------|------------------------------------------------------------------|-----------------------------------------|
| September| YES                         | 0.0186                                                           | 0                                       |
| October  | YES                         | 0.1037                                                           | 0.0186                                  |
| November | YES                         | 0.1837                                                           | 0.1223                                  |
| December | YES                         | 0.2292                                                           | 0.3060                                  |
| January  | YES                         | 0.2460                                                           | 0.5352                                  |
| February | YES                         | 0.2277                                                           | 0.7812                                  |
| March    | YES                         | 0.1733                                                           | 1.0089                                  |
| April    | YES                         | 0.0718                                                           | 1.1963                                  |
| May      | YES                         | 0.0005                                                           | 1.2539                                  |
| June     | NO                          | -0.0507                                                          | 1.2544                                  |
| July     | NO                          | -0.0811                                                          | 1.2037                                  |
| August   | NO                          | -0.0749                                                          | 1.1226                                  |

The amount of condensate that left in the building envelope after the first calculation cycle 1.0478

Figure 7. Graph of condensation places in the building envelope no. 3 in one calculation cycle in the event of a change in the utility function of the building.
Figure 8. The graph of the amount of condensate in the building envelope no. 1 in one calculation cycle in the event of a change in the utility function of the building.

6. Summary and conclusions

As it results from the calculations made during the design and execution of external partitions, several issues should be noted. The most important of them include meeting the current requirements regarding the heat transfer coefficient, correct and compatible selection of all materials in the partition, correct design of the partition system and employment of a qualified execution team, as well as meticulous supervision of the construction process.

Correct design of the partition in terms of both heat and humidity, as well as the failure to introduce ill-considered changes at the execution stage, allows not only to reduce the aesthetics of the facade, but also additional financial outlays.

References

[1] A. Kaliszuk-Wietecka and A. Miszczuk, Rozkład zapotrzebowania na energię pierwotną i końcową w budynku wielorodzinnym, Materiały Budowlane, no. 12, pp. 68–70, 2013.
[2] Moisture Control Guidance for Building Design, Construction and Maintenance, U.S. Environmental Protection Agency, 2013
[3] Daniel Aelenei and Fernando M.A. Henriques, Analysis of the condensation risk on exterior surface of building envelopes, Energy and Buildings, vol. 40, pp. 1866-1871, 2008
[4] P. Pogorzelec, Korozja mikrobiologiczna ocieplonych fasad budynków i jej aktywne zapobieganie, Izolacje, no. 4, pp. 36, 2019.
[5] J. Bochena and M. Labus, Study on physical and chemical properties of external lime–sand plasters of some historical buildings, Construction and Building Materials, no. 45, pp. 11-19, 2013.
[6] Condensation in Buildings Handbook, Australian Building Codes Board, 2014
[7] S. Firląg and A. Miszczuk, Efektywność działania wentylacji naturalnej i możliwości jej usprawnienia, Rynek Instalacyjny, no. 6, pp. 68–73, 2016.
[8] A. Miszczuk, The influence of construction and material solutions on the level of air tightness in single energy buildings, MATEC Web of Conferences, vol. 196, pp. 1–8, 2018.
[9] A. Miszczuk, Influence of air tightness of the building on its energy-efficiency in single-family
buildings in Poland, MATEC Web of Conferences, vol. 117, pp. 1–8, 2017.
[10] Obwieszczenie Ministra Infrastruktury i Rozwoju z dnia 17 lipca 2015 r. w sprawie ogłoszenia jednolitego tekstu rozporządzenia Ministra Infrastruktury w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie.
[11] S. Nenadalova et al., "Diffusion Parameters of Basic Diffusion Adhesive Mortars with Silicate or Acrylic Plaster", Advanced Materials Research, vol. 1124, pp. 16-22, 2015
[12] PN-EN 12524:2002: Building materials and products - Hygrothermal properties - Tabulated design values.
[13] Technical cards for material manufacturers.
[14] S. Chładzyński and S. Zalewski, Farby elewacyjne – rodzaje, właściwości i zastosowanie, Izolacje, no. 3, 2010.
[15] A. Miszczuk, The Level of Airtightness in Energy-efficient Single-family Houses in Polan, Procedia Engineering, vol. 153, pp. 461–466, 2016.
[16] A. Miszczuk and K. H. Żmijewski, Analiza budynków o niskim zapotrzebowaniu na energię, Materiały Budowlane, no. 1, pp. 24–27, 2015.
[17] Clara Pereiraa, Jorgede Britob, Jose D. Silvestreb, Contribution of humidity to the degradation of facade claddings in current buildings, Engineering Failure Analysis, Vol. 90, pp. 103-115, 2018