Heat-Technical Comparison of Wall Construction Systems Belonging to MMC

Alena Tažiková [1], Juraj Talian [1]

[1] *Technical University of Košice, Faculty of Civil Engineering, Kosice, Slovakia*

Abstract **– The article deals with comparison of three wall systems. One of the structural systems is conventional and the two others systems are among the Modern Methods of Construction (MMC). For comparison the endpoints were: thermal balance and condensation of water vapor. The thickness of the wall structures and the individual layers are modelled to meet the recommended amount of heat transfer coefficient U_{r1}. When this requirement is met, the condensation of water vapor in the wall structures is further analyzed. The aim is to determine whether, during the cycle of a year the balance of water vapor is negative and where is the location of condensation in the wall of the MMC wall construction used in Slovakia. The result of the investigation will be a comparison of selected structures and evaluating the most advantageous wall structure of selected construction systems.**

Keywords **– Wall construction systems, MMC technology, the thickness of the wall, heat transfer coefficient U, condensation of water vapor.**

1. Introduction

Currently present modern methods of construction MMC, as a suitable alternative to conventional construction system. The Modern construction methods are designed to save costs, to shorten construction times, and save the environment. The MMC systems include different types of wall structures. [1], [2]. When designing the structure of a wall structure, it is necessary to model the thicknesses of individual layers so that the desired thermal physical properties are preserved. The wall system consists of the wall support, the added thermal insulation and the surface finish on the exterior and the interior sides. It is possible to insulate the wall constructions by thermal insulation from both sides, the exterior side and the interior side, in order to achieve the desired standard heat transfer values. In the case of a thermal insulation design located from the interior, it is necessary to ensure that the amount of condensed water and evaporation is negative. In both cases, the proposed insulation thickness with regard to the required value of heat transfer coefficient U≤Ur1 and to prevent precipitation of water vapor on the inside of the wall structure. Various sources indicate various materials used to achieve the required heat transfer values. For example, the team of Johansson, Par; Adl-Zarrabi, Bijan; Kalagasidis, Angela Sasic, examined the wall structure with thermal insulation based on vacuum insulation panels (VIP). They have measured the temperature and the relative humidity in the wall and watched if the thermal insulation showed no signs of damage. [3] MMC wall constructions can also be used during renovations. A problem may occur during reconstructions and the project involves thermal insulation of walls from the inside of the wall structure (e.g. for reasons of preservation of the facade). Incorrect design may result in condensation of water vapor [4]. Condensation occurs in the inner layers of building materials at any point when the partial pressure of the water vapor diffuses and reaches its saturation pressure. Condensation, also called sweating, damages materials, reduces heat resistance and increases the overall heat transfer coefficient, leads to adverse events such as increased heat losses. It is therefore necessary to reduce the thickness of condensation zone and thoroughly review the course of temperature [5] [6].

Hydrothermal evaluation is a combined analysis of the transfer of heat, air and moisture through a construction structure [7]. When designing wall constructions, it is necessary to design the structure so as to prevent condensation of water vapor inside

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Corresponding author: Alena Tažiková,
Technical University of Košice, Faculty of Civil Engineering, Kosice, Slovakia
Email: alena.tazikova@tuke.sk

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the structure as this causes degradation of the structure. This was the reason for the analysis of selected MMC wall structures.

2. Materials and methods

For the comparison of the construction from the thermal-physical properties the following materials were used:

- Quadlock
- Velox WS
- Ytong Lambda

The compositions of the individual layers are shown in the tables. Constructional compositions are numbered, the composition is described from the interior.

The first material to be compared is **Quadlock**. The description of the material composition is given in Table 1.

Table 1. Quadlock

No.	Layer	thickness
1	Baumit FeinPutz	0,005 m
2	Baumit BauKleber	0,020 m
3	Expanded polystyrene Quadlock	0,079 m
4	Dense concrete -filled Quadlock	0,203 m
5	Expanded polystyrene Quadlock	0,108 m
6	Baumit BauKleber	0,020 m
7	Baumit FeinPutz ausen	0,006 m
	Hrúbka steny celkom	**0,441 m**

The second material to be compared is **Velox WS** and the description of the material composition is given in Table 2.

Table 2. Velox WS

No.	Layer	thickness
1	Baumit FeinPutz	0,015 m
2	Baumit BauKleber	0,020 m
3	Wooden Velox WS	0,035 m
4	Dense concrete - filled	0,185 m
5	Expanded polystyrene F70	0,180 m
6	Wooden Velox WS	0,038 m
7	Baumit BauKleber	0,006 m
8	Baumit FeinPutz ausen	0,020 m
	Hrúbka steny celkom	**0,499 m**

Last comparison material is **Ytong Lambda** and the description of the material composition is given in Table 3.

Table 3. Ytong Lambda

No.	Layer	thickness
1	Baumit FeinPutz	0,006 m
2	Baumit BauKleber	0,008 m
3	Ytong Lambda+	0,450 m
4	Baumit BauKleber	0,008 m
5	Baumit FeinPutz ausen	0,006 m
	Hrúbka steny celkom	**0,478 m**

In the framework of the heat engineering assessment were in software Teplo 2014 modeled cross-sectional characteristics of individual wall systems to meet the requirement U = 0.22 W / (m^{2}K). Other boundary conditions were set as follows: design outside temperature Te = -13.0 °C, design inside air temperature Tai = 21.0 °C, design relative humidity of outside air RHe = 84.0% and design relative humidity of inlet air RHi = 55.0%. Based on the need to comply with STN 73 0540 - 2 regarding the value of the heat transfer coefficient Ur1 = 0.22 W / (m2.K), which is required from January 1, 2016. The thicknesses of individual layers of wall structures were designed to meet the U_{r1} requirement. All proposed structures were also considered in software AREA 2014 for 2D heat dissipation. By evaluating the 2D heat dissipation, the temperature field was calculated in all the model structures. The secondary result is the calculation of the surface temperature of the exterior and the interior constructions. The requirement of the standard for internal surface temperature is Tsi,N = 13.13 °C and must meet the requirement for the internal surface temperature Tsi> Tsi,N.

3. Results and discussion

After modulation of individual constructions in both applications, the individual constructions were considered. The individual temperatures and the distribution of the water vapor pressures are shown in the figures. The first figure shows the pressure distribution with marked pressure condensation zone. The saturated pressure, the theoretical pressure and the condensing zone are colored-resolved. The description is in the Table 4.

Table 4. The legend of steam distribution

Saturated pressure	red line
Theoretical pressure	dark red line
Condensing zone	blue line

The second image shows the temperature field with a graphical view of solubilized temperature and surface temperature.

Quadlock

In Quadlock construction in the boundary conditions are formed two condensation zones. The first condensation zone is between 3 and 4 layers and the second condensation zone is between 5 and 6 layers. The annual balance is negative, which means that the amount of evaporated water vapor "Mev" is higher than the condensed water vapor "Mc" at an operating requirement Mc<0.5 kg/m2. The disadvantage of this constructional structure is the formation of a first condensation zone and thereby the formation of a moist environment within the structure at the site of the thermal insulator of expanded polystyrene. The temperature and condensation zones are shown in Figure 1.

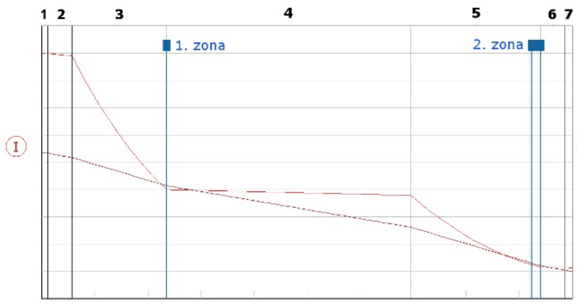

Figure 1. Distribution of water vapor pressures Quadlock

The temperature field of the Quadlock wall structure is shown in Figure 2. The internal surface temperature Tsi = 18.50 ° C complies with the standard requirement and is higher than Tsi, N = 13.13 ° C.

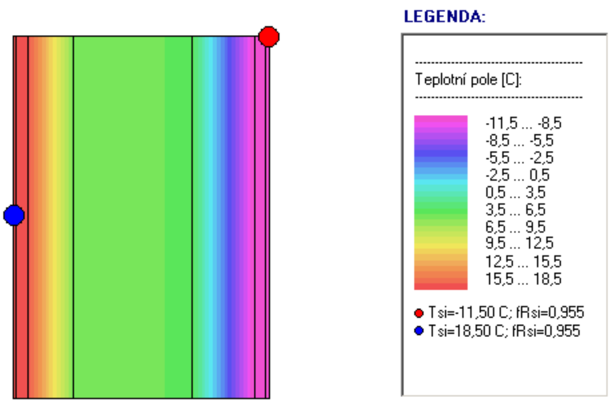

Figure 2. Temperature field Quadlock

Velox WS

In the Velox WS material under the given boundary conditions, only one condensation zone is formed on the outer side between the 6th and the 7th layers. Compared to the previous structure this construction is better because only one condensation zone is formed at the outer surface. The resulting annual balance is also negative, with the positive requirement Mc< 0.5 kg/m^2.

The temperature and condensation zones are shown in Figure 3.

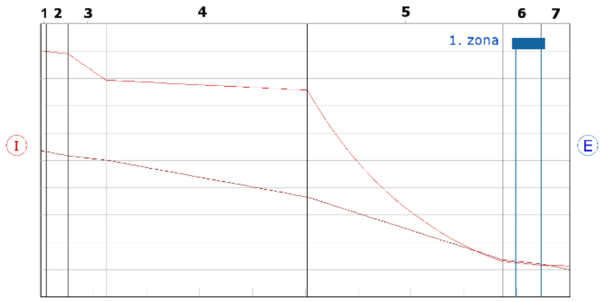

Figure 3. Distribution of water vapor pressures Velox WS

The temperature field of the Velox WS wall structure is shown in Figure 4. The internal surface temperature Tsi = 18.59 °C complies with the standard requirement and is higher than in the previous construction (Quadlock).

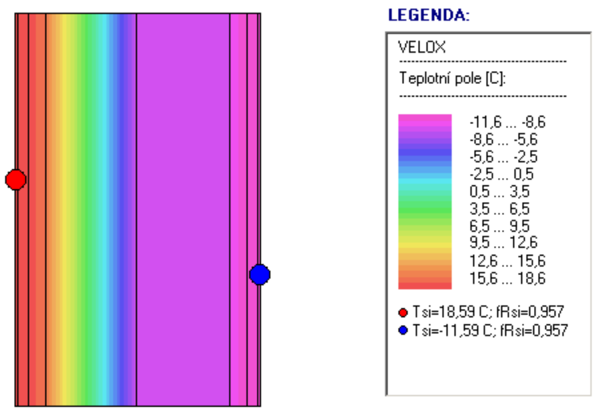

Figure 4. Temperature field Velox WS

Ytong Lambda

In the Ytong Lambda material, just as with the Velox WS material, under the given boundary conditions, only one condensation zone is formed on the outer layer between 3 and 4 layers. The resulting annual balance is also negative and the requirement applies Mc< 0.5 kg/m2. The temperature and condensation zones are shown in Figure 5.

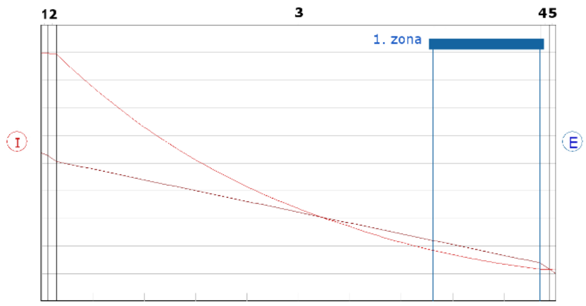

Figure 5. Distribution of water vapor pressures Ytong

The temperature field of the Ytong Lambda wall structure is shown in Figure 6. The internal surface temperature is the second highest Tsi = 18.53 ° C and also meets the standard requirement.

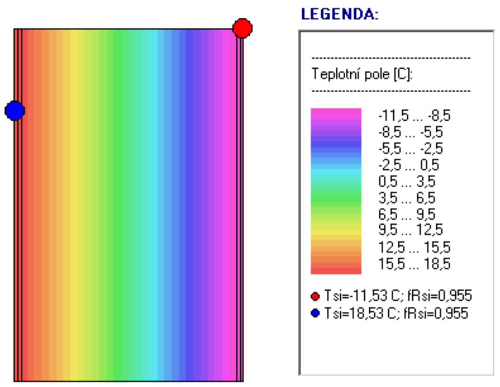

Figure 6. Temperature field Ytong

In general, we can say that from the point of view of humidity and temperature from the comparison of the structures belonging to modern methods of construction, the most suitable composition is Velox WS. In this construction, the smallest amount of condensate occurs Mc = 0,0024 kg/m^2. At the same time, this composition has the highest surface temperature Tsi = 18.59 °C under the given temperature conditions. In terms of quantity of condensation, Ytong Lambda has only one condensation zone closer to the exterior.

4. Conclusion

The article compared three wall constructions, Quadlock, Velox WS and Ytong Lambda in terms of thermal engineering. The comparison of these wall constructions was in the moisture characteristics and the temperature patterns of the structures in the selected temperature range. The most suitable construction in the selected criteria was the Velox WS construction, because it had the best result in water vapor balance and at the same time has the highest internal surface. The higher temperature of the inner surface of the structure from the interior side contributes to improving the temperature conditions in the interiors.

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References

[1]. Tazikova, A., & Kozlovska, M., & Strukova, Z. (2015). Cost analysis of wall structures based on permanent concrete forms. *International Multidisciplinary Scientific GeoConference, Ecology, Economics, Education and Legislation*, Vol. 3, 173-180.

[2]. Lesniak, A., & Zima, K. (2015). Comparison of traditional and ecological wall systems using the AHP method. *International Multidisciplinary Scientific GeoConference, Ecolog, Economics, Education and Legislation*, Vol. 3, 157-164.

[3]. Johansson, P., Adl-Zarrabi, B., & Kalagasidis, A. S. (2016). Evaluation of 5 years' performance of VIPs in a retrofitted building façade. *Energy and Buildings*, *130*, 488-494.

[4]. Pinigiene, J., & Susinskas, S. (2016). Hygrothermal performance of a masonry wall retrofitted with interior insulation, the analysis of temperature and moisture distribution in wall construction. *Intelligent Technologies in logistics and mechatronics systems*, 125-129.

[5]. Miao, J., et al. (2015). Research on self-thermal insulation wall construction technology of autoclaved aerated concrete block, *AER-Advances in engineering research*, Vol. 30, 1063-1068.

[6]. Yamankaradeniz, N. (2015). Minimalization of thermal insulation thickness taking into account condensation on external walls. *Advances in mechanical engineering*, *7*(9), 1-11.

[7]. O'Leary, T.P., et al. (2015), The design of modeling, monitoring and validation method for a solid wall structure. *Energy procedia*, Vol. 78, 243-248.