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THE ANALYSIS OF THE THERMAL-HUMIDITY CONDITIONS OF THE CHOSEN PARTS OF THE BUILDING WITH REGARD TO THE MOULD HAZARD

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Abstract: In European norm [PN EN ISO 13788: 2002] computational procedures concerning the hazard of the appearance and condensation of mould and were suggested at the given temperature and humidity of the inner air. Using the norm procedures, in the paper the analysis of the chosen exterior partitions, used in the farm buildings, was carried out. The analysis was based on testing the hazard of the appearance of steam condensation and development of mould on the surface of partitions at inner temperatures, commonly considered to be optimum, for the particular categories of the farm animals. The carried out analyses show the relationships which are interesting from the point of view of the other, binding so far, analytical and computational procedures in this field. The results seem to be useful in the farming practice with regard to both designing and maintaining the farm buildings.

Key words: building partitions, mould, humidity, thermal bridges, farm buildings

INTRODUCTION

One of the requirements for the building partitions (except for construction safety, use, fire hazard and the others) is the use of material-structural solutions for the exterior building partitions and the creation of the thermal-humidity conditions, preventing the appearance of mould [Technical conditions…].

Simultaneously, the regulations include the thermal-humidity requirements for the building partitions only in a form of the temperature guidelines on their inner surfaces. On the wall surface from the inside it is necessary to keep the temperature that is at least 1° higher from the dew point of the indoor air. Whereas the practice, supported by the appropriate diagnostic and computational methods, indicates the existence of

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the places, in buildings, characterized by the temperatures lower than on the other parts of the wall – thermal bridges. At the same time, these are the places with a higher risk of the steam condensation, causing humid and mouldy places on the building partition. The potential places characterized by the hazard are e.g. corners with built-in reinforced concrete column.

The authors of research aimed to test the probability of the mould appearance in the chosen places of the building characterized by various constructions, working in different thermal-humidity conditions, according to the computational procedure included in the norm PN-EN ISO 13788.

Among the analyze, the examples of the buildings working in the conditions adjusted to the requirements for the chosen farm buildings were taken into consideration.

METHODOLOGY

The computational procedure embraces checking the probability of mould appearance by calculating "the temperature of the inner surface of the building component or the building element" and specifying "the thermal quality of the building casing" according to the norm [PN EN ISO 13788]. The thermal quality may be characterized for any part of the building, for the partitions with the thermal bridges as well as without them, which means that for a given facility and assigned localization one can calculate the values of the temperature indicator f_{Rsi} for the least beneficial thermal-humidity conditions, for the places with a high mould hazard. The designer should consider it as a critical value, which needs to be exceeded in a properly designed partition. The temperature indicator [according to PN-EN ISO 13788] is specified in a formula:

$$f_{Rsi,\min} = \frac{\theta_{si,\min} - \theta_e}{\theta_i - \theta_e} \tag{1}$$

where: $\theta_{si\ \min}$ – minimum acceptable surface temperature [°C],
θ_e – average monthly outer air temperature [°C],
θ_i – inner air temperature [°C].

The method presumes the fixed state of the heat and mass flow; it does not take into consideration the number of physical phenomena which in reality may influence the humidity conditions. This inaccuracy may easily be leveled by an assumed safety coefficient, accepted on the level of 5–10% depending on the designer. The calculations are made at the given edge conditions such as:

– average monthly outer air temperature,
– average monthly outer air and relative humidity values, for a given localization,
– inner air temperature and relative humidity, depending on the purpose of the building.

There is a common continuation of calculations accepted for each and every kind of partition, no matter what their character is, the choice of the place for defining the critical temperature is up to the designer.

COMPUTATIONAL EXAMPLES

The presented examples concern the analyses of the example farm buildings, built in accordance with the technology used in the 60's and the analogous system with the use of contemporary materials. The calculations were made for the facilities meant for the farm animals, taking the conditions of the inner microclimate, considered to be optimum for the particular animal categories. The accepted structural solutions (Table 1):

– wall constructed in a reinforced concrete frame with the fillings of gas concrete blocks 24 cm wide; the coated surfaces of the columns are retracted in relation to the back of the wall by circa 7 cm; the thermal insulation of the columns is made of fibre boards (node 1),

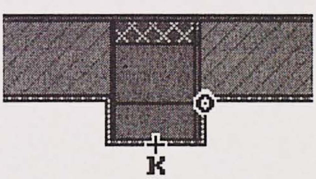
– cellular concrete walls 36,5 cm thick with the reinforced concrete column, insulated with the polystyrene boards 11,5 cm thick (node 2),

– corner of the wall made of gas concrete blocks with the reinforced concrete column coated with gas concrete; taking into consideration the fixing technology of the wall elements, the column is moved inside the room by circa 11 cm (node 3),

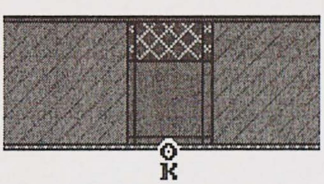
– corner of the cellular concrete wall 36,5 cm thick with the polystyrene insulation 11,5 cm thick; the column and the wall are on the same surface (node 4).

The parameters of the outer climate were accepted in accordance with climatic data for Warsaw, with average and minimum temperatures in January (–1,1°C i –16°C) [World Climate Design Data 2001] and average monthly relative humidity value (85%).

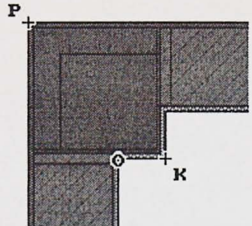
Table 1. Nodes selected for the calculations
Tabela 1. Węzły wybrane do analizy



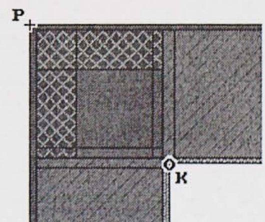
NODE No 1
Węzeł 1



NODE No 2
Węzeł 2



NODE No 3
Węzeł 3



NODE No 4
Węzeł 4

The inner climate conditions were accepted for three categories of animals, with regard to the demands [Myczko 2002], taking into consideration minimum and optimum temperatures, and optimum relative humidity of the room (Table 2).

Table 2. Assumed edge conditions
Tabela 2. Przyjęte warunki brzegowe

TEMPERATURE		RELATIVE HUMIDITY
Θ_i[°C]	Θ_i[°C]	Φ[%]
+12	+15	75
+24	+28	60
+14	+17	70

On the basis of the formula (1) the temperature indicator, for January, was calculated, taking into consideration the inner temperature referring to the minimum acceptable pressure of the saturated steam, and then the obtained value was compared to the indicators obtained for the temperatures appearing on the inner surface of the selected nodes in the table. Temperatures on the surface, in the place of bridges were calculated with help of the computer programme EUROCOBRA. The results are presented in Tables 3–6.

Table 3. Temperature values in a chosen point of the partition at the given inner and outer air temperatures and relative humidity in a room, nodes 1–4
Tabela 3. Wartości temperatury w wybranych miejscach ścian przy zadanych wartościach temperatury i wilgotności względnej w pomieszczeniu, węzły 1–4

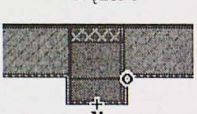
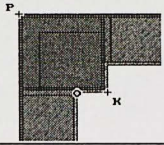
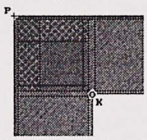
Number of mode Numer węzła	Θ_e[°C]	[°C]	75%		70%		60%	
			+12	+15	+14	+17	+24	+28
1	2	3	4	5	6	7	8	9
NODE No 1 Węzeł 1 	1.1	Θ_i[K]	10,1	12,6	11,8	14,3	20,3	23,7
		Θ_i[O]	9,03	11,7	10,9	13,3	18,9	22,1
	–16	Θ_i[K]	9,03	10,4	9,6	10,4	18,1	21,5
		Θ_i[O]	6,3	8,7	7,9	8,7	15,9	19,1
NODE No 2 Węzeł 2 	1.1	Θ_i[K]	11,4	14,3	13,3	16,2	22,9	26,7
		Θ_i[O]	10,4	13,0	12,2	14,8	21,0	24,5
	–16	Θ_i[K]	10,8	13,6	12,6	15,6	22,2	26,1
		Θ_i[O]	8,6	11,2	10,4	13,0	19,2	22,7

Table 3 cont.
Tabela 3 cd.

1	2	3	4	5	6	7	8	9
NODE No 3 Węzeł 3	1.1	Θ_i[K]	7,6	9,6	9,0	11,0	15,6	18,3
	–16	Θ_i[K]	2,7	4,7	4,0	6,0	10,7	13,3
NODE No 4 Węzeł 4	1.1	Θ_i[K]	8,8	11,0	10,3	12,6	17,8	20,9
	–16	Θ_i[K]	5,1	7,4	6,6	8,9	14,2	17,2

The minimum temperature indicators were calculated for the given parameters of the inner and outer climate (Table 4).

Table 4. Values $f_{rs,\ min}$ at the given inner and outer air temperatures and relative humidity in a room
Tabela 4. Wartości $f_{rs,\ min}$ przy zadanych wartościach temperatury i wilgotności względnej w pomieszczeniu

Θ_e[°C]	$f_{rs,\ min}$	75%		70%		60%	
		+12	+15	+14	+17	+24	+28
–1,1	$f_{rs,\ min\ 1A}$	0,671	0,727	0,672	0,707	0,673	0,708
–16	$f_{rs,\ min\ 1B}$	0,846	0,858	0,820	0,839	0,795	0,807

Temperature indicators calculated in the given points of the partition (for the temperatures in Table 3) are presented in Table 5.

Table 5. Values f_{rs} in the chosen places of the partition at the given inner and outer air temperatures and the relative humidity in a room, nodes 1–4
Tabela 5. Wartości f_{rs} w wybranych miejscach ścian przy zadanych wartościach temperatury i wilgotności względnej w pomieszczeniu, węzły 1–4

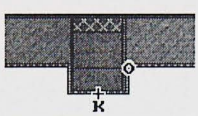
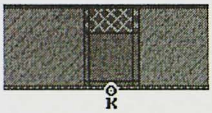
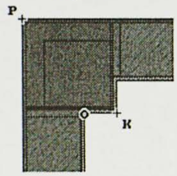
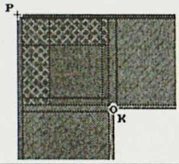
Number of mode Numer węzła	Θ_e[°C]	f_{rs}	75%		70%		60%	
			+12	+15	+14	+17	+24	+28
1	2	3	4	5	6	7	8	9
NODE No 1 Węzeł 1	1.1	$f_{rs\ 1a}$	0,664	0,790	0,795	0,796	0,796	0,797
	–16	$f_{rs\ 1b}$	0,796	0,797	0,779	0,748	0,764	0,798

Table 5 cont.
Tabela 5 cd.

1	2	3	4	5	6	7	8	9
NODE No 2 Węzeł 2	1.1	f_{rs}	0,878	0,876	0,881	0,978	0,880	0,879
	–16	f_{rs}	0,878	0,877	0,880	0,879	0,880	0.879
NODE No 3 Węzeł 3	1.1	f_{rs3a}	0,664	0,665	0669	0.668	0,661	0,574
	–16	f_{rs3b}	0,668	0,669	0,667	0,666	0,667	0,665
NODE No 4 Węzeł 4	1.1	f_{rs4a}	0,756	0,751	0,755	0,757	0,753	0,756
	-16	f_{rs4b}	0,753	0,755	0,753	0,754	0,755	0,754

THE ASSESSMENT OF THE OBTAINED RESULTS

The calculations, which were carried out, resulted in varied values of the indicators in the given nodes of the partition. In node 3, for the outer temperatures, both in average (–1,1°C) and minimum (–16°C), in all the assumed ranges of the inner microclimate, the values of the indicator calculated for the temperatures referring to the saturated steam pressure were not exceeded. As follows:

$$f_{rs,\,\min} = 0{,}671 > f_{rs} = 0{,}664,\ f_{rs,\,\min} = 0{,}727 > f_{rs} = 0{,}665,\ f_{rs,\,\min} = 672 > f_{rs} = 0{,}669$$

$$f_{rs,\,\min} = 0{,}707 > f_{rs} = 0{,}668,\ f_{rs,\,\min} = 0{,}673 > f_{rs} = 0{,}661,\ f_{rs,\,\min} = 0{,}708 > f_{rs} = 0{,}574$$

It means that in accordance with [PN EN ISO 13788] occurrence of mould hazard. In node 1 and 4 the hazard appears only at the minimum outer temperature (–16°C), except for the only case in node 1 (for the inner temperature +12°C and relative humidity in a room 75%).

Solely in the case of the node 3 mutual relations between $f_{rs,\,\min}$ and f_{rs} show the lack of probability of the development of corrosion.

Table 6. Mould hazard refering to the nodes: – no, + yes
Tabela 6. Zagrożenie pleśnią węzła

NODE	TEMPERATURE Ø$_e$[°C]	75%		70%		60%	
		+12	+15	+14	+17	+24	+28
1	–1,1	+	–	–	–	–	–
	–16	+	+	+	+	+	+
2	–1,1	–	–	–	–	–	–
	–16	–	–	–	–	–	–
3	–1,1	+	+	+	+	+	+
	–16	+	+	+	+	+	+
4	–1,1	–	–	–	–	–	–
	–16	+	+	+	+	+	+

SUMMARY

Designing in accordance with the requirements so far, ie. maintaining the temperature 1°C higher than temperature of the dew point with reference to the surface of the inner partition, which is not efficacious in practice. It is observed most often that these are the places of high condensation risk that become mouldy. The phenomenon of mould, commonly known as one of the building shortcomings, threatening health [Hancock 1996], in case of the farm buildings, is of high significance.

The microclimate of the rooms for farm animals is the element of the zoo technical conditions, influencing the efficiency of production [Myczko 2002]. One of the requirements for the farm buildings nowadays is to assure the minimum of the animal well-being range, which is such a system of maintenance that will provide animals with the best possible health conditions. Above mentioned method, in fact consisting of simplified calculation methods, based on the experience and generally received knowledge, allows analyzing trouble spots of the partition within the phase of designing. The choice of the places to be analyzed and tested as to the condensation hazard is not imposed. So for the research, it is extremely important to select the appropriate nodes of the partition where it is expected for the temperature to be lower than in the other parts of the wall.

In accordance with the norm, in edge conditions the average monthly values of the outer air are taken into consideration. In the above mentioned example condensation hazard was also tested for the minimum temperatures. Then the mould hazard appeared in three tested nodes, in all the accepted thermal-humidity ranges for the particular categories of the animals.

CONCLUSIONS

1. The computational examples showed the influence of the accepted parameters of the outer climate (average and minimum temperature) on the occurrence of mould hazard in the designed partitions.

2. In the particular ranges of the inner temperature, at the given, specified conditions of the outer climate, there is a little change as to susceptibility of the partition to corrode in places particularly prone to become humid.

3. The condensation hazard is highly influenced by the shaping of the partition with regard to structural and architectural aspects.

4. The method of humidity estimation, included in [PN EN ISO 13788] may be useful in analyses testing the correctness of thermal-humidity building partitions within the phase of designing new facilities or modernized ones.

5. This method can be considered to be useful to define the mould hazard, provided that the places prone to have critical temperatures are appropriately specified.

6. In the buildings with exceptional thermal-humidity requirements, including the farm buildings, testing the partitions as to condensation seems to be particularly important.

7. While designing the outer partitions in the farm buildings it is advisable to analyse things, taking into consideration optimum temperature and humidity for each and every category of animals kept in the facility.

8. It seems to be crucial to test the influence of how long the critical temperatures last in the partition on the phenomenon of getting mouldy.

REFERENCES

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Myczko A., 2002. Stan, kierunki i perspektywy chowu trzody chlewnej w Polsce – wymagania formalno-prawne. Stan i kierunki chowu trzody chlewnej z podziałem na grupy technologiczne stosowane technologie utrzymania i struktury obszarowej gospodarstw. Analiza przepisów prawnych polskich i uni europejskiej dotyczących utrzymania świń z uwzględnieniem wymagań dotyczących ochrony środowiska oraz budowy i eksploatacji chlewni. IBMER Poznań, 16 (17).

PN EN ISO 13788: 2002. The thermal-humidity characteristics of the construction components and elements of the building. The temperature of the inner surface so as to avoid the critical surface humidity and intersurface condensation. Estimation methods.

Technical conditions, which should be fulfilled with reference to buildings and their location DzU No 109, poz. 1156, dated May 12th.

ANALIZA WARUNKÓW CIEPLNO-WILGOTNOŚCIOWYCH WYBRANYCH ELEMENTÓW BUDYNKU W ASPEKCIE ZAGROŻENIA PLEŚNIĄ

Streszczenie. W europejskiej normie [PN EN ISO 13788] określono procedury obliczeniowe dotyczące niebezpieczeństwa pojawienia się kondensacji pary wodnej i pleśni przy danej temperaturze i wilgotności względnej powietrza wewnętrznego. W pracy przeprowadzono analizę wybranych przegród zewnętrznych stosowanych w budynkach gospodarskich z uwzględnieniem wspomnianej normy. Analiza została oparta na badaniach dotyczących zagrożenia wystąpienia pary wodnej i rozwoju pleśni na powierzchni przegród, przy temperaturze wewnętrznej powszechnie uważanej za optymalną dla poszczególnych

kategorii zwierząt hodowlanych. Przeprowadzone analizy wykazują zależności, będące w tym zakresie interesującymi z punktu widzenia innych procedur analitycznych i obliczeniowych. Rezultaty wydają się być przydatne przy projektowaniu i utrzymaniu budynków gospodarskich.

Słowa kluczowe: przegrody budowlane, pleśnie, wilgoć, mostki termiczne, budynki inwentarskie

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