Assessing thermal comfort of dwellings in summer using EnergyPlus

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SUMMARY

The simulation of a building as a whole offers an image of its behaviour, reflecting the complex relation established between the outdoor environment factors, the building characteristics, the use by its occupants, and the parameters which intervene in satisfying the comfort criteria. This paper gives an overview of the use of building simulation in Romania. It focuses on summer comfort.

INTRODUCTION

In specific climatic conditions (cold winters and hot summers), the housing fund of Romania, characterised, to a great extent, by a low level of insulation and high occupancy, is a great consumer of energy. Mention should be made that in the social mass housing units the energy is consumed exclusively to heat the space during winter time, the use of air conditioning plant not being the preferred choice. As the thermal climate rehabilitation measures are focused on saving the energy consumed for heating, the preoccupation for achieving comfort during summer time by passive measures appears as markedly topical.

Knowledge concerning the thermal climate parameters, their influence on the occupants and the influence of buildings and systems is today relatively known and established in international standards. Energy consumption of buildings depends significantly on the demands for the indoor environment, which also affects health, productivity and comfort of the occupants. The indoor environment is mentioned in prEN 15251 :2005 Criteria for the indoor environment including thermal, indoor air quality, light and noise. This standard presents IEQ (Indoor Environmental Quality) performance demands that can be used as input or default value for energy calculations, energy evaluations and building quality labeling.

One of the issues that is addressed in prEN 15251:2005 is the maximum allowable upper temperature in summer. For naturally ventilated buildings with a high degree of occupant control (e.g. access to operable windows and no strict clothing policy) the standard allows for the use of an adaptive criterion.

THERMAL COMFORT : MODELS AND CRITERIA

The environmental parameters that constitute the thermal environment are: temperature (air, radiant, surface), humidity, air velocity and personal parameters (clothing together with activity level). Criteria for an acceptable thermal comfort (PMV-PPD index) are evaluated by Fanger model. In the Fanger model the optimum internal condition for a building (i.e. one in which occupants will report comfort) is correlated exclusively to parameters referring to conditions which are internal to the building (mentioned above). Standard ISO 7730 is based on the steady state Fanger model of human physiology. The Predicted Mean Vote is strongly dependent on metabolic rate and clothing insulation. In the technical report 1752 (CEN 1998), are proposed 3 categories of thermal environment.

Table 1. Three categories of thermal environment. Percentage of dissatisfaction due to general comfort and local discomfort (ISO EN 7730, 2005, CR 1752, 1998.),[1]

Cate-gory	Thermal state of the body as a whole		Operative temperature °C		Max. mean air velocity m/s	
	PPD %	PMV	Summer (0,5 clo) Cooling	Winter(1 clo) Heating	Summer(0,5 clo) Cooling	Winter(1 clo) Heating
A	< 6	-0.2 < PMV < + 0.2	23,5 – 25,5	21,0 – 23,0	0,18	0,15
B	< 10	-0.5 < PMV < + 0.5	23,0 – 26,0	20,0 – 24,0	0,22	0,18
C	< 15	0.7 < PMV < + 0.7	22,0 – 27,0	19,0 – 25,0	0,25	0,21

For the last years several new CEN standards have been developed (e.g. USA – ASHRAE 55 2004 and the European draft pr EN 15251 which proposed Adaptive Comfort model based on comfort survey in the field.

The Adaptive Comfort model was proposed by Nicol and Humphreys. It states that people in real, naturally ventilated buildings, tend to adapt their comfort requirements to the prevailing outside temperatures. This model takes into account that people in real life situations are not functioning at constant conditions; instead they vary their activities, posture, metabolic rate and clothing according to the climate and its variations. Thus, the optimum indoor temperature (i.e. one at which occupants will report comfort) varies with the history of outside temperatures; in particular, it has a strong correlation with the average external temperature in the last few days. The adaptive principle is: if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort. They do this by making adjustments to their clothing, activity and posture, as well as to their thermal environment. The set of conceivable adaptive actions in response to warmth or coolness may be classified into five categories:

1. regulating the rate of internal heat generation
2. regulating the rate of body heat loss
3. regulating the thermal environment
4. selecting a different thermal environment
5. modifying the body's physiological comfort conditions

Design values for the indoor operative temperature as a function of mean monthly outdoor air temperature for buildings without mechanical cooling systems are shown in figure 1:

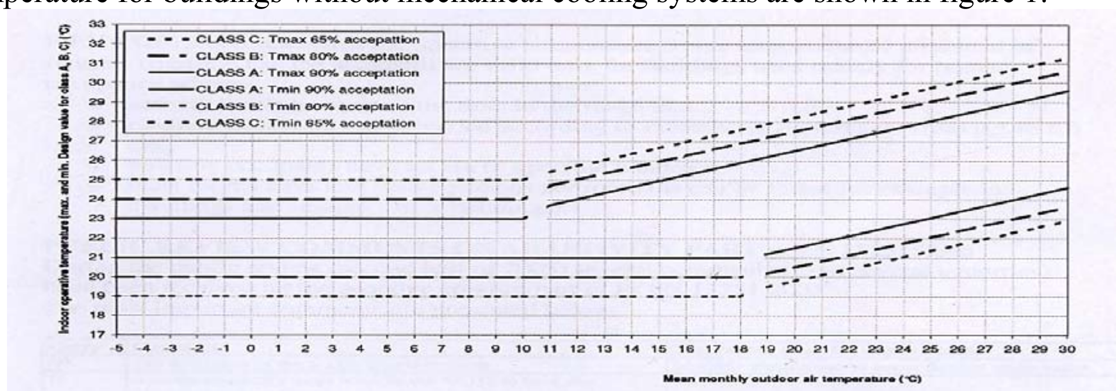

Figure 1. Design values for the indoor operative temperature, [2]

Four categories of adaptive thermal comfort are identified in prEN 15251:2005:

- Categories A: Thermal environment of the building meets the criteria of category A when the room temperature in the rooms representing 95% of the occupied space is not more than 3% of occupied hours a year outside the category A temperature limits.
- Category B: Thermal environment of the building meets the criteria of the category B when the room temperature in the rooms representing 95% of the occupied space is not more than 3% of occupied hours a year outside the category B temperature limits.
- Category C: Thermal environment of the building meets the criteria of category C when room temperature in the rooms representing 95% of the occupied space is not more than 3% of occupied hours a year outside the category C temperature limits.
- Category D: A building belongs to the category D if it does not meet the criteria of category C.

CASE STUDY

The building was modeled in EnergyPlus simulation environment. The main purpose is describing the thermal performance of the building from the viewpoint of external gains and losses (climate) and internal casual gains and losses. The building was modeled with 3 geometry thermal zones (fig. 2). All zones are virtually mutually ventilated by circulating air to keep uniform indoor environment in the entire building. Natural ventilation takes places through operable exterior windows and interior doors in all zones. In addition to natural ventilation, there are cracks in all exterior and interior walls. Cracks in the exterior walls allow infiltration of outside air into the zones. The location of the building is the city of Galati, in July. There was used a Weather File, with Rain Indicators. The occupation set up is the numeric representation of the way, the house is occupied and used by their residents. The important data are: number of occupants (3 in zone A, 2 in zone B), schedule of occupancy, the internal maximum ventilation ratio, and the schedule of weather, the openings (windows and doors, the ventilation set point 21^{o}C). The working hours are from 9.00 to 17.00. The wind pressure coefficient data are taken from literature,[3] for a simple rectangular building shape, surrounded by buildings of equal height. Hourly schedules with 24 schedule events are used for building parameters like window opening. These schedules are reused for all days of the simulation period.

EnergyPlus is an energy analysis and thermal load simulation program,[4]. It calculates the energy required to maintain each zone at a specific temperature for each hour of the day. A zone is an air volume at a uniform temperature plus all the heat transfer and heat storage surfaces bounding or inside of that air volume.

The building model must:

1. Determine heat transfer and heat storage surfaces ;
2. Define equivalent surfaces ;
3. Specify surfaces and subsurface (windows, doors, etc) construction and materials ;
4. Compile surface and subsurface information.

People, lights, equipment, outside air infiltration and ventilation all constitute internal gains for the thermal zone that are described as a peak level with a schedule for each hour.

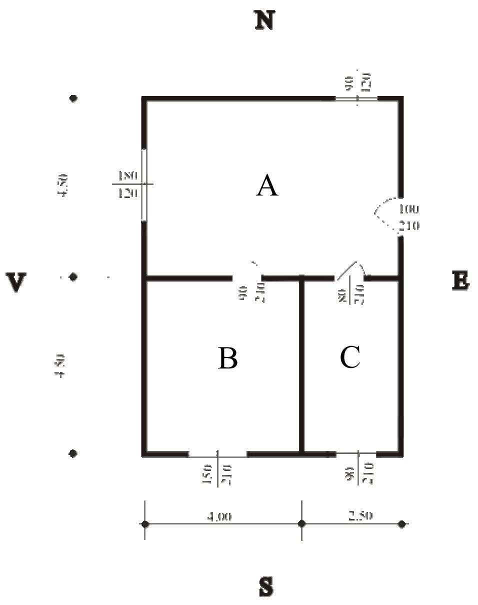

Figure 2. Test house

RESULTS, COMMENTS

By running the Energy Plus program there have been obtained data referring to the parameters which influence the comfort level. There have been considered such factors as indoor air temperature (fig.3), relative humidity (fig.4). The variation in time of the PMV index is shown in fig.5. and infiltrations (fig.6). On the bases of this information, it was possible to analyse the extent to which the comfort exigencies are met as against the Fanger and Adaptive model.

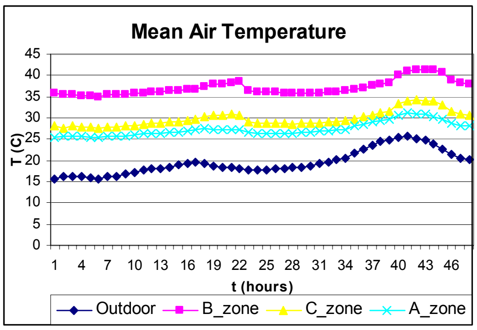

Figure 3. Mean Air Temperature

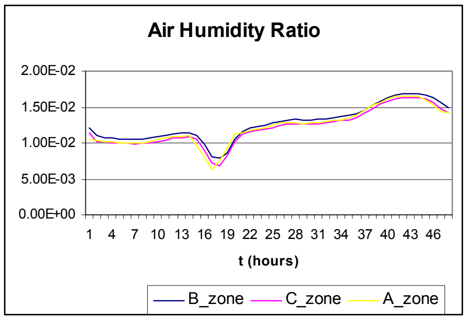

Figure 4. Air Humidity Ratio

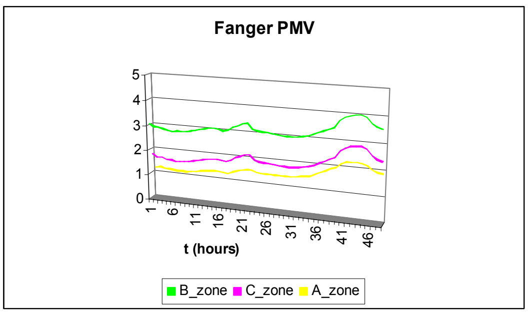

Figure 5. Fanger PMV , Simulation I

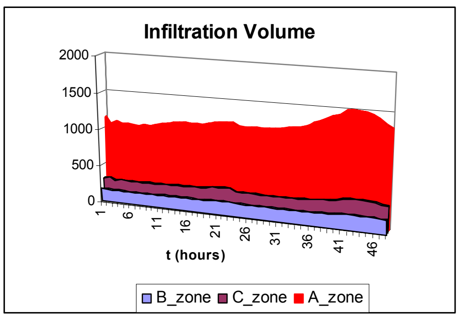

Figure 6. Infiltration Volume

It can be seen from fig.5 that the PMV index for the 3 zones varies between 1, 2, and 4, which means that not even the minimum conditions, for class C of comfort, are met. The least favourable situation is found in zone B, with double exposure.

The Adaptive Model: The operative temperature values for the 3 zones have been calculated and compared to the optimum ones recommended by the Adaptive Comfort Model (table 2, Simulation I). In the given situation the comfort criteria for zone A are satisfied, while in zone C the operative temperature values are relatively near the design ones. The research was resumed for a situation where passive measures were used in view of improving the comfort, such as: replacing glazing (table 2, Simulation II) in zone B and using blinds. The results obtained by running EnergyPlus are shown below:

Table 2. The operative and recommended temperature's values

Outdoor Temp	Design Value	Simulation I Zone operative values			Simulation II Zone operative values		
		A	B	C	A	B	C
17.8	24.7	24.4	33.1	26.2	23.1	23.8	25.0
18.0	24.7	24.4	33.0	26.2	23.1	23.8	25.0
18.1	24.8	24.4	33.0	26.1	23.1	23.8	25.0
18.3	24.8	24.5	32.9	26.1	23.2	23.8	25.0
18.4	24.9	24.5	32.9	26.1	23.2	23.9	25.0
18.8	25.0	24.7	32.9	26.2	23.4	24.0	25.0
19.2	25.1	24.8	33.0	26.3	23.6	24.2	25.2
19.7	25.3	25.0	33.1	26.5	23.8	24.4	25.4
20.1	25.4	25.2	33.2	26.7	24.0	24.7	25.6
20.5	25.6	25.4	33.4	26.9	24.2	24.9	25.8
21.8	26.0	26.0	33.7	27.2	24.9	25.5	26.2
22.7	26.3	26.5	34.2	27.8	25.4	26.1	26.8
23.5	26.6	26.9	34.5	28.2	25.8	26.5	27.2
24.4	26.9	27.4	34.9	28.6	26.4	27.0	27.7
24.8	27.0	27.8	35.2	29.0	26.7	27.3	28.0
25.3	27.1	28.8	37.1	30.9	27.7	28.5	30.1
25.7	27.3	29.1	37.9	31.5	28.1	29.0	30.6

The values presented in table 2, Simulation II, show that the comfort criteria are satisfied, over the simulation time, according to the adaptive model in the three zones, as follows:

Zone A – 100%
Zone B – 83.3 %
Zone C – 66 %

If a difference of 0.2 ^{0}C against the designed value is accepted.

The Fanger Model,[5]: The values of PMV index (fig.7) which vary between 1 and 2.5 for zone A orientated in the most favourable position, show that not even in this situation the minimum comfort criteria (class C) are met.

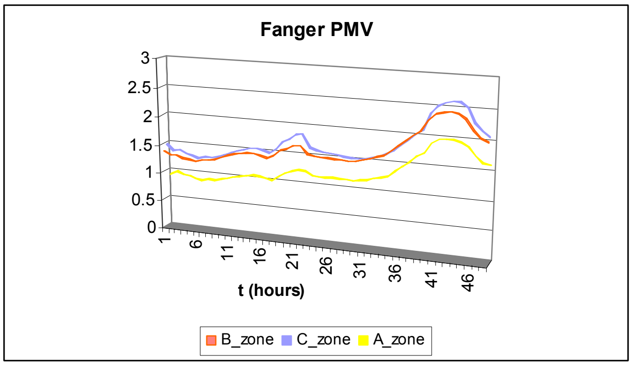

Figure 7. Fanger PMV, Simulation II

CONCLUSIONS

This paper gives an overview of the use of building simulation in Romania. It focuses on summer comfort. Summer comfort,[6] depends on the characteristics of the building envelope; in particular, the transparent components and the materials play a relevant role. In summer time, most of the cooling loads depend on the solar gains, coming from the transparent surfaces of the building. The analysis presented in this paper gives some useful information, concerning energy simulation of buildings. Transparent components deeply affect the energy balance of the building. The simulation of a building as a whole offers an image of its behaviour, reflecting the complex relation established between the outdoor environment factors, the building characteristics, the use by its occupants, and the parameters which intervene in satisfying the comfort criteria.

The Adaptive Comfort Model constitutes an instrument of realistic assessment of the quality of the indoor environment from the point of view of comfort in the naturally ventilated buildings, thus contributing to saving energy in air conditioning. Applying simple passive measures with minimum costs may led to achieving a summer time comfort which is acceptable even in dwellings of low surfaces and high occupancy degree.

REFERENCES

1. Bjarne W Olesen : International standards for the indoor environment. Where are we and do they apply worldwide?, www.ie.dtu.dk
2. Atze Boerstra, 2006, The adaptive thermal comfort criterion in the new EPBD IEQ Standard
3. Orme, Malcolm, Lddament, Martin W., and Andrew Wilson, Numerical Data for Air Infiltration & Natural Ventilation Calculation AIVC – TN -44 – 1994
4. EnergyPlus, User Manual, 2004, www.energyplus.gov
5. Claude Alain Roulet, 2004, Santé et qualité de l'environnement intérieur dans les bâtiments, Presses polytechniques et universitaires romandes
6. AUSTRIAN ENERGY AGENCY, Sustainable summer comfort, Comfort models