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Source data for modeling of thermal engineering calculations

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Abstract. Increasing demands on thermal insulation. Their more accurate assessment by computers lead to increasingly bigger differences between computational models and reality. The result is an increasingly problematic optimization of building design. One of the key initial parameters is climatological data.

1 Modeling of thermal performance of buildings

Quantification of the heat loss of buildings started with central heating installations, as until then there were local heaters in each heated room which dimensioning was empirically done.

The first dimensioning of heating was necessary only after the start of central heating, although the first known hot-air central heating was already in the 1st century Before Christ in Rome. The dimensioning of heating in the Czech Republic has been modified since the middle of the last century by standards, eg. ČSN 10503 from 1949. Later, this dimensioning was guided by the new standard ČSN 06 0210 - Calculation of thermal losses of buildings with central heating. This standard originally dates back to 1961 and gradually changed the way knowledge of heating increased, and also as did the influence of the Soviet Union in the Czech Republic. It was canceled in November 2008, when there was a transition to European standards, and at the same time calculations were made in order to reduce energy consumption for heating. At the moment, the calculation of energy demand for heating goes according to ČSN EN ISO 13 790 Energy performance of buildings - Calculation of energy consumption for heating and cooling.

Little by little, however, it is found that the calculations made under this standard deviate significantly from real consumption. Paradoxically, there is even a situation where the building is better heat-insulated, the difference between the real energy consumption for heating and the calculative assumption is worse in the sense that real consumption is higher than predicted.

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2 Possible causes of differences in computational building behavior and real energy consumption for heating

Possible causes are many. Big role plays the difference between the projected state of a building from the real state, the absence of some thermal bridges or bridges in the calculation, the different ventilation modes, the different solar gains, the difference between the actual climatological conditions from the real, the neglect of the thermal inertia of the building and many others.

Certainly, one of the major inaccuracies is the modeling of the thermal behavior of the subsoil under the construction according to the standard, which does not entirely correspond to the reality.

At the beginning of the last century and in the times before, people did not deal with the temperature in the soil, which was especially important for them to freeze the water under the terrain.

In the Czech Lands, the so-called non-freezing depth was determined empirically, i.e. the depth during which the liquid phase of the water was not frozen during the winter, to 100 cm for the exterior temperature - 20 °C.

For thermal technical calculations, the computational outdoor temperature of the adjacent soil to the building structure was defined in ČSN 06 0210 [1]. This was modified by Table A6 (see Table 1), assuming that the soil temperature is constant for the calculation outside temperature and that the heat from the building passes through the structure into the ground.

Table 1. Table A6 according to ČSN 06 0210.

Location of the adjacent soil layer	The temperature of the adjacent soil t_{ez} (°C) at the calculation temperature t_e		
	-12°C	-15 °C	-18 °C
under the floor	+5	+5	+5
- at the vertical wall: - to a depth of 1 m	-3	-3	-6
at a depth of 1 to 2 m	0	0	-3
at a depth of 2 až 3 m	+3	+3	0
at a depth 3 m	Like under the floor		

ČSN EN ISO 13 370 [2] according to which the assessment is currently being carried out continues in a different way, namely assuming that the heat escapes by the soil from the building to the environment, see Figure 1. For the soil, the general properties are defined in the standard; Either the specific properties of the soil can be used, or the Table 1 of this standard is used (see Table 2). If neither the approximate soil quality is known, it is proceed as if it were sand.

Table 2. soil characteristics according to ČSN EN ISO 13 370.

Description	Thermal conductivity λ W/(m.K)	Volume heat capacity ρc J/(m^3.K)
clay and clays	1,5	$3{,}0\times 10^6$
sands and gravel	2,0	$2{,}0\times 10^6$
homogeneous rock	3,5	$2{,}0\times 10^6$

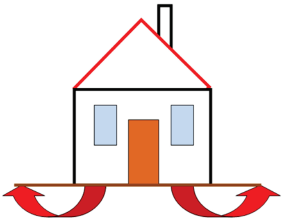

Fig. 1. Heat flow diagram according to ČSN EN ISO 13 370.

With a simple look at the picture, it is clear that there where there is no building, the temperature would have to be well below the freezing temperature at a depth of 1 meter, which does not correspond to historical experience. It is therefore evident that the heat flow from the building works by earth in a completely different way and it is influenced outside the building by many other aspects such as geothermal heat, heat accumulation of rocks, heat transfer through groundwater flow, petrography, earth anomalies such as karst formations, mining constructions and similar.

3 Climatological data

The climatological data are given by the standard and are based on the long-term temperature average from the measurements between 1900 and 1950. The peculiarity is that the average temperature does not count as an arithmetic mean during the day, but by the decree 194/2007 Coll. [3] is the average daily outdoor air temperature of a quarter of the sum of outdoor temperatures measured in the shade, excluding the radiance of the surrounding areas at 7.00, 14.00 and 21.00, with the temperature measured at 21.00 being counted twice.

For real calculations, real climatological data can also be used, which can be ordered from the Czech Hydrometeorological Authority, or it can be uses e.g. data stored on the MPO website [4].

4 Thermal gains

Heat gains in buildings can be divided into internal heat gains that are generated by people, heat generation by facilities such as lighting, technology, hot water preparation, and solar thermal gains.

Solar thermal gains are again quantified based on standard values based on long-term averages. Precise modeling of solar thermal gains again encounters several problems. The first is the substantial deviations of real sunlight from long-term averages [4], the second is that we only consider transparent solar constructions in the modeling of solar gains, while heat gains also take place through non-transparent constructions.

5 Temperatures in the soil

To accurately model the thermal behavior of the building, it is necessary to know the temperature of the soil in addition to climatic conditions. The Czech Republic has quite a few territories, but there are also places with a distinctly different geological subsoil. From the point of view of the thermal behavior of buildings, there will surely be a difference between locations with a higher geothermal temperature such as the region Karlovarsko or some parts of South Moravia and between lower geothermal temperatures such as limestone karst. However, relatively little space was devoted to the problem of the temperature of the building's subsoil. Several measurements were made in probes under buildings, but this condition was not confronted with the state outside the built-up part and was not compared with the calculation premise. The basis for further calculations of the actual course of temperature under the building is the provision of climatological data for the real temperature in the subsoil without the influence of the building, as well as for the thermal modelling of the above-ground building parts.

For this reason, I started to work with the Geophysical Institute of the Academy of Sciences of the Czech Republic, which has given to my initial data.

On the site of the Geophysical Institute of the Academy of Sciences of the Czech Republic in Prague - Spořilov, it is monitored since 1994 the temperature at selected depths in two experimental boreholes, 150 meters deep (GFU-1) and 40 meters (GFU-2), together with the measurement of air temperature and other meteorological parameters experiment. Since 2011, the drilling site has a depth of 50 meters (GFU-3) at the local Geopark. An experimental field for continuous heat transfer monitoring was put into operation in June 2002.

5.1 Drill holes GFU-1 and GFU-2

These are two separate drill holes close together, 140 meters and 40 meters deep. They are drilled in Ordovician sediments covered with the upper layer of clay. Deeper drill hole is designed for temperature logging with a portable probe hanging on the cable. The second drill hole is equipped with thermistor sensors at depths of 0; 0.05; 0.1; 0.2; 0.5; 0.75; 1; 1,5; 2; 2.5; 3; 4; 5; 7.5; 10; 15; 20; 25; 30; 35; 38.3 meters. The air temperature is monitored at 0.05 m and 2 m high. This station also registers solar radiation and rainfall. The data is transmitted online to the desktop computer. Temperature data from depths below 0.5 are stored 7 times a day, air temperatures and soil temperature to a depth of 0.5 m, as well as sunlight, are stored every half hour. The rain monitor has its own answering machine.

5.2 Drill hole GFU-3

It is a new drill hole from 2011. The depth of this drilling hole is 50 m

5.3 Experimental field

In June 2002 was pun itno operation an experimental field for continuous monitoring heat transfer. The set of models includes grassy and bare clay soil, sand and asphalt. Each model is 150 cm in diameter and 60 cm deep. It contains temperature sensors at 5 levels below the surface (0.02, 0.05, 0.1, 0.2, 0.5 m) and temperature sensors at 5 cm and at 2 meters above the surface. It also measures soil moisture, direct and reflected sunlight, wind speed, rainfall. The height of the snow cover is monitored by a television camera. The data obtained serves to determine the heat transfer between the air and the earth surface, the determination of the diffusivity of the subsurface materials, the influence of humidity, the wind cooling. The results will then make it possible to correct the relationship between the depth and climate history of the past.

6 Conclusions

From the results of temperature measurements in the soil, which cannot be completely mentioned here, because of the large amount of data, it is easy to deduce that the temperature fluctuations occur most at the surface and at least at greater depths. Graph 1 shows the course of soil temperatures in individual depths during 2013 measured at half an hour. Table 3 lists minimum and maximum values for each measurement depth. The temperature fluctuations just below the terrain are 33 °C, but at a depth of 5 meters it is already only 3 °C, with the difference decreasing with increasing depth until finally at a depth of 49.7 m the difference between the highest and the lowest temperature is only two hundred thousand Kelvin. This fact justifies the assumption that for a real modelling of the thermal behavior of buildings it would be appropriate to choose a constant temperature at a certain depth below the terrain and with this assignment to continue the calculations. Optimum depth and optimum temperature will be subject to further investigation.

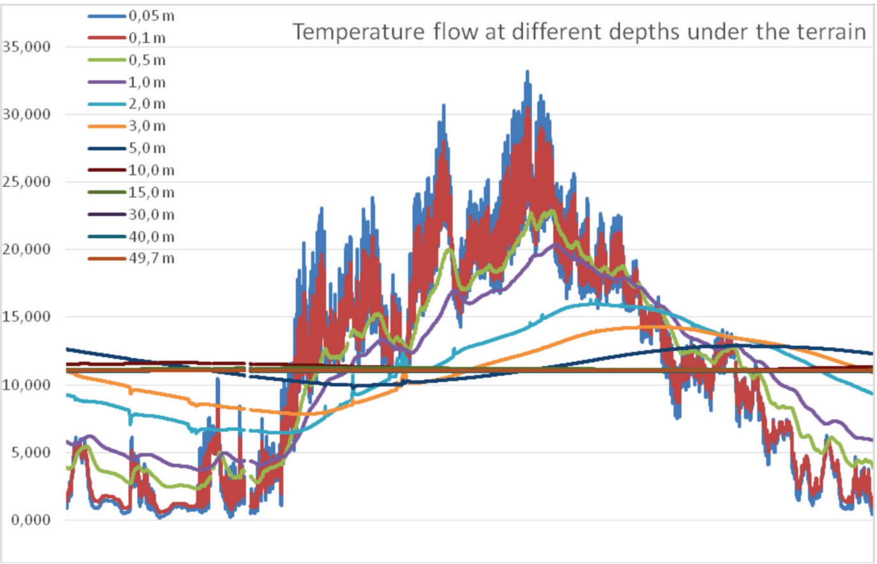

Fig. 2. Temperature flow at different depths under the terrain.

Table 3. Temperature in individual depths [°C].

	0.05 m	0.1 m	0.5 m	1m	2 m	3 m	5 m	10 m	15 m	3 0m	40 m	49.7 m
max	33.157	30.496	22.880	20.372	16,327	14,283	12,871	11,630	11,244	11,031	11,037	11,043
min	0.173	0.577	2.329	3.688	6,371	7,821	9,775	10,982	11,081	11,023	10,991	11,024

References

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