Aspects of improving the buildings' energy efficiency by specific heat capacity effects

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Introduction

Evaluating the mutual influence of the building and the environment is the basis for possible actions to harmonize and create space for improving sustainability. The methodology for calculating the energy performance of buildings is one of the most essential instruments for this evaluation. To this end, various methodologies aligned with the Energy Performance of Buildings (EPBD) framework are applied. EN ISO 52016-1, the key EPBD standard, provides a calculation method for calculating energy loads and heating and cooling needs using hourly and monthly methods.

The accuracy of the calculation is directly related to the quality and reliability of the input data.

On the other hand, significantly stronger dynamic effects, represented through the hourly method, are associated with pronounced daily and hourly variations of weather parameters and operational functioning of elements.

In particular, many advanced technologies and systems that meet the requirements for low-energy buildings produce dynamic effects that strongly influence the calculated energy performance.

To improve sustainable building design, methods must be developed for evaluating the energy performance of buildings under the influence of dynamic parameters.

This paper presents possible methods of generating climate parameter files (primarily temperature) that enable the application of simulation methods. In this way, data on the thermal capacity of building elements can be included in calculating the building's energy needs

Materials & Methods

EN ISO 13786:2017, which prescribes a method for analytically calculating the dynamic thermal behavior of buildings through a simplified calculation procedure for plane multi-layer elements based on the detailed characteristics of the building components and the period of the variations at the surfaces, using the matrix method procedure is used. Adding parameters to thermal transmittance *U[W/m²K]* and superficial mass M_s *[kg/m²]* calculated.

- thermal time shift φ *[h]*
- thermal decrement factor f_a *[-]*
- periodic therm. transmittance Y_{mn} *[W/m²K]*
- internal area heat capacity κ *[kJ/m²K]*

The internal heat capacity - ability of a building component to buffer heat during one day on a temperature swing of 1 degree, per square meter (kJ/m²K). The amount of heat that may be buffered calculated by multiplying this value by a temperature amplitude.

These parameters were calculated for five types of walls (W0, W1, W2, W3, W4) with nearly identical values of thermal transmittance U and different area heat capacities, which are calculated by integrating the heat fluxes over a day.

Beside, several deep learning models with different numbers of layers and neurons of different types are trained and tested in generating innovative climate data set obtained from a meteorological station in Podgorica, Montenegro.

Figure 1 displays a sample of the prediction of one trained and tested deep learning model compared to actual values for 2018 and the Reference Year (Filkenstein-Schafer statistics).

Results

Table 1 Properties of elements and calculated dynamic parameters

W0	λ [W/m.K]	ρ [kg/m³]	C [J/kg.K]	d [m]	R [m²K/W]
Rsi					0,13
Plaster	0,700	1600,0	1100	0,0250	0,036
Thermo block	0,340	1300,0	840	0,2500	0,735
Hard Insulation	0,110	450,0	1000	0,1500	1,364
Isover Uniroll C	0,034	60,0	1030	0,0500	1,471
Plaster	0,700	1400,0	1000	0,0250	0,036
Rse					0,04
U [W/m²K)	M_s [kg/m²]	φ [h]	f_a	Y_{mn} [W/m²K]	κ_m[kJ/m²K]
0,2624	470,5	-19,802	0,031	0,008	55,980

W1	λ [W/m.K]	ρ [kg/m³]	C [J/kg.K]	d [m]	R [m²K/W]
Rsi					0,13
Plaster	0,700	1600,0	1100	0,0250	0,036
Thermo block	0,340	1300,0	840	0,2500	0,735
Glass wool	0,035	50,0	1000	0,0500	1,429
Hard Insulation	0,110	450,0	1030	0,1000	0,909
Plaster	0,700	1400,0	1000	0,0250	0,036
Rse					0,04
U [W/m²K)	M_s [kg/m²]	φ [h]	f_a	Y_{mn} (W/m²K)	ς_m[kJ/m²K]
0,3017	447,5	-17,448	0,059	0,018	55,922

W2	λ [W/m.K]	ρ [kg/m³]	C [J/kg.K]	d [m]	R [m²K/W]
Rsi					0,13
Plaster	0,700	1600,0	1100	0,0250	0,036
Thermo block	0,340	1300,0	840	0,2500	0,735
EPS W20	0,035	20,0	1000	0,1000	2,857
Plaster	1,000	1200,0	1500	0,0030	0,003
Rse					0,04
U [W/m²K)	M_s [kg/m²]	φ [h]	f_a	Y_{mn} (W/m²K)	κ_m[kJ/m²K]
0,2631	370,6	-12,859	0,087	0,023	56,229

W3	λ [W/m.K]	ρ [kg/m³]	C [J/kg.K]	d [m]	R [m²K/W]
Rsi					0,13
Timber (500 kg/m³)	0,130	500	1600	0,0250	0,192
Concrete 1800kg/m	1,150	1800,0	1000	0,2500	0,217
Rock wool	0,034	60,0	1030	0,1000	2,941
Perlite mortar	0,190	600,0	1240	0,0300	0,158
Rse					0,04
U [W/m²K)	M_s [kg/m²]	φ [h]	f_a	Y_{mn} (W/m²K)	κ_m[kJ/m²K]
0,2718	486,5	-11,686	0,068	0,018	38,291

W4	λ [W/m.K]	ρ [kg/m³]	C [J/kg.K]	d [m]	R [m²K/W]
Rsi					0,13
Lime-cem. Mort	1,050	1800	1000	0,0250	0,024
Reinf. Conc. (2%	2,500	2400,0	1000	0,2200	0,088
Rock wool	0,034	60,0	1030	0,1200	3,529
Marble	3,500	2800,0	1000	0,0500	0,014
Rse					0,04
U [W/m²K)	M_s [kg/m²]	φ [h]	f_a	Y_{mn} (W/m²K)	κ_m[kJ/m²K]
0,2614	720,2	-10,754	0,117	0,031	78,145

Results

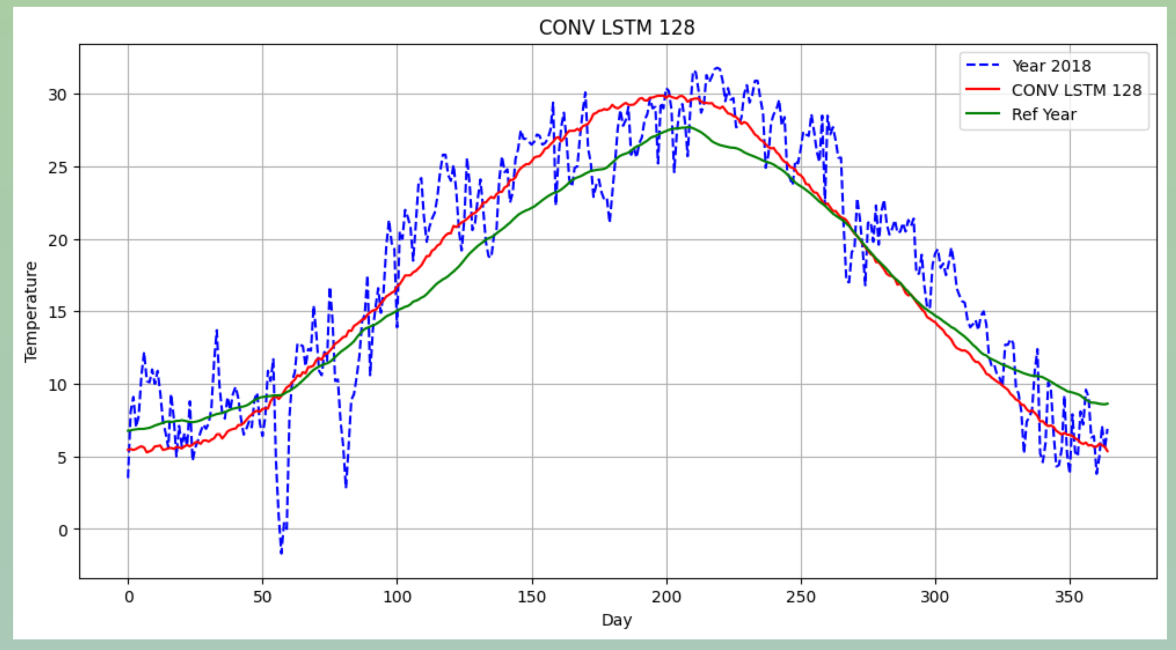

Figure 1 Deep learning model for temperature prediction

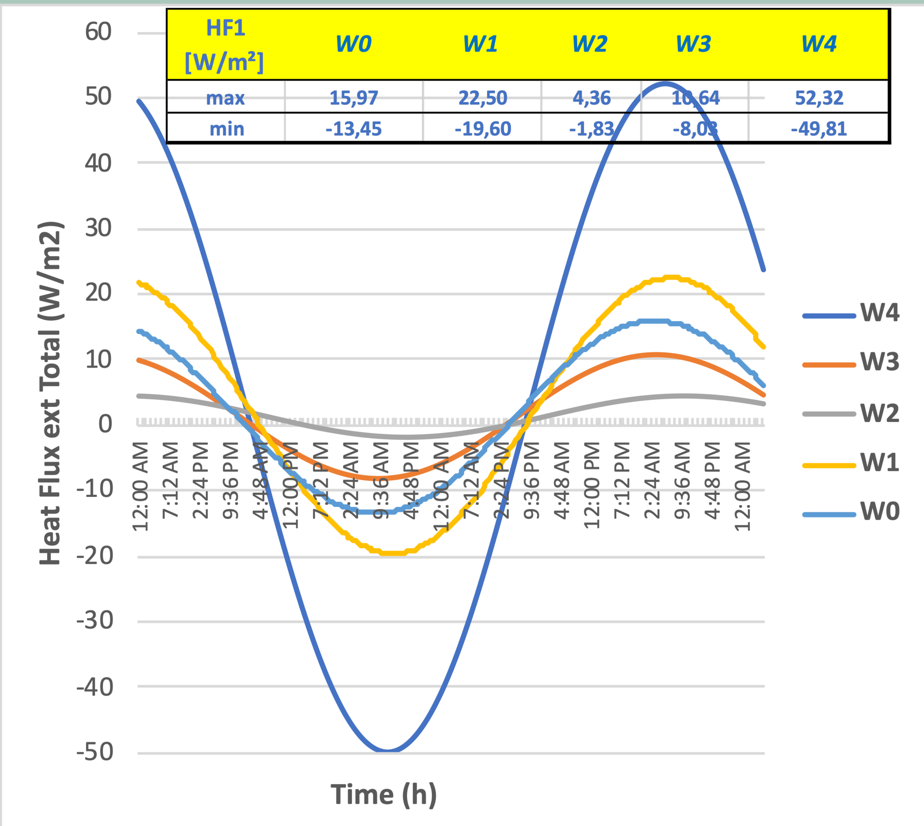

Figure 2 Daily Heat Flux on external side (T_{av} = 30,8 °C)

Conclusions

This paper aims to present the possibilities of dynamic simulation by applying innovative generated climatic data, such as hourly temperature values and their daily variations, and assessing the effects of the increase in specific heat capacity of built-in materials to improve thermal properties. It presents the significant impacts of the thermophysical properties of the materials, thermal mass, and the position of the layers in the building wall to achieve a better thermal performance of the walls. It was found that different wall configurations strongly affect dynamic parameters, such as thermal decrement factor and heat storage capacity.