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Energy performance of buildings: modeling of dynamic summer behavior

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Abstract

In Europe about one third of total annual energy consumption is used in both residential and commercial buildings. Besides, buildings use more energy than any other sector as such are a major contributor to CO_2 emissions. Therefore, substantial energy savings can be achieved through careful planning for energy efficiency. In many countries building regulations already exist to ensure the reduction of energy needs for heating and for domestic hot water preparation. Hence, the interest in reducing summer energy demand has grown in the last few years, especially because of the widespread diffusion of low efficiency cooling systems such as split type units.

The summer behavior of buildings is mostly non-stationary and, therefore, the reliability of simple quasi steady state model predictions can not be taken for granted. Besides, this cooling demand interacts dynamically with occupants, climate features and system controls. Since detailed hourly energy simulations emulate the dynamic interaction, they have the potential to provide relevant information about the building summer behavior and to indicate the possible conservation measures for the reduction of energy consumptions. However, the detailed models require a better knowledge of properties and an increase of the number of input data. In order to broaden the use of building simulation in design process, it is essentially to clarify some aspects. For instance, one of the biggest objection versus the use of detailed procedure is: "*to what extent these methods are meaningful if input data are not reliable?*"

The purpose of this research is, then, to verify the reliability and applicability of time dependent energy balance for the analysis of the summer behavior of buildings in the Italian context.

The first part of the thesis focuses on the sensitivity of simulation results to uncertain weather data. Starting from historical series of weather data collected in meteorological stations in urban sites, a typical meteorological year for some Italian cities is developed. Special attention is given to the validation of raw data and to the handling of anomalous values, analyzing the criteria used for the generation of missing values and for the connection of different calendar months. This analysis highlights the key role of the realistic trend of variable evolution and the importance of taking into account the cross correlation between the different climate variables.

However, since weather data are often collected by regional meteorological center, the historical series are available only for the main cities. Unfortunately, due to the orography, especially in northern Italy, and to the particular shape of the cities (diffuse city), a considerable part of buildings belongs to areas with different climate conditions with respect to the chief city in the province. Even if some correction coefficients are given to adjust trends, weather data will always be affected by uncertainty.

With the purpose of assessing the influence of uncertain weather data to cooling demand, a sensitivity analysis is carried out. Several dynamic simulations of buildings with massive and light weighted envelopes and different orientations of windows are performed using perturbed weather data.

The second part of the research, instead, deals with the uncertainty of the thermo-physical properties of envelope materials. Since the introduction of energy certification of buildings and mandatory regulations has driven construction material manufacturers to provide and guarantee thermal characteristics of their products, the calculations of dynamic behavior of envelope is relatively easy for new constructions. However, building renovations are largely diffused and for existing components the assumptions about materials and their thermal properties are quite uncertain and can lead to inaccuracy in the application of calculation models for the unsteady thermal characteristics. For this reason a sensitivity of the conduction transfer function to the variation of material thermo-physical properties is evaluated by executing Monte Carlo simulations. Starting from the Direct Root Finding approach for the calculation of conduction transfer function, largely used in dynamic simulation software, several envelopes are tested with a Gaussian distribution of specific mass, specific heat, conductivity and thickness. Then the perturbed conduction transfer functions are used for the calculation of heat losses and heat gains through envelope via the TRY developed in the first part of the thesis.

Analyzing the final results is interesting to note the different shape of probability density curve of heat losses/gains for the perturbation of different thermo-physical properties. The outcomes show also a different behavior of the insulated walls with respect to non-insulated.

In conclusion, this thesis contributes to increase in energy modelers the capability to better predict the impact of input, in particular of weather data and of thermo-physical properties, and therefore make better decision and provide optimal solution with building simulations.