Computational Model For The Estimation Of Thermo-Energetic Properties In Dynamic Regime Of Existing Building Components

Costantino Carlo Mastino[1], Roberto Ricciu[1], Roberto Baccoli[1], Chiara Salaris[1], Roberto Innamorati[1], Andrea Frattolillo[1], Antonio Pacitto[2]

[1] D.I.C.A.AR University of Cagliari, Cagliari, Italy
mastino@unica.it, ricciu@unica.it, mastino@unica.it, rbaccoli@unica.it, chiara.salaris@unica.it, iroberto@unica.it andrea.frattolillo@unica.it,

[2] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Cassino, Italy
antonio.pacitto@unicas.it

mastino@unica.it

Abstract. The guidelines of the European community towards a low-carbon economic society identify one of the most important scenarios in the energy efficiency of existing buildings. The discrepancy between the requirement and availability of free heat (endogenous heat, solar radiation) in certain hours of the day and operating conditions, makes the steady-state hypothesis generally inappropriate. In particular, the oscillating component of the transmitted flow, compared to the average temperature difference, is regressive in winter and dominant in summer. From this it follows the reliability of the stationary forecast models in winter and the need for dynamic forecast models in summer. The dominance of the continental climate in the EU, compared to the Mediterranean one, led to the actual delay in the development of dynamic models, especially at a regulatory level. In this paper, a methodology for assessing the dynamic properties of a building component is evaluated. The methodology, based on heat transmission equations implements a numerical model for existing building components whose input data can be obtained from experimental measurements. The developed model has been used to estimate the energetic and thermal behaviour of a building envelope subjected to energy efficiency measures.

1. Introduction

In the world the design of buildings is increasingly addressed to the use of digital procedures. The European Community has recently published directives 2014/24/EU [1] that provide for the digitization of processes. Italy accepted these directives has made Obligatory the use of the BIM for public works by providing for different time deadlines starting from 2019 up to 2025 where all public works concerning buildings must be managed digitally. The flowchart of the procedures used in this work comprising: initial performance measurement, simulation of intervention solutions based on the use of the BIM model are described in Figure 1. Energy design is among the digital procedures and the verification of dynamic energy parameters, it is fundamental to the realization of nZEB buildings.

The Energy Performance of Buildings Is one of the Main Focuses of the European Union. In the year 2010, the Europe Council issued the Energy Performance of Buildings Directive [2] subsequently updated in 2018, setting the minimum energy performance requirements for new buildings and major renovation projects [3]. In Italy the Directive was implemented with the national laws n. 90/13 and successive Technical Standard, such as the UNI/TS 11300 series (Italian National Unification/Technical Specification) [4] and ISO 52016 [5], were enacted. These technical specifications/standards are based on dynamic mathematical models that are closer to the measured thermal behavior of the building.

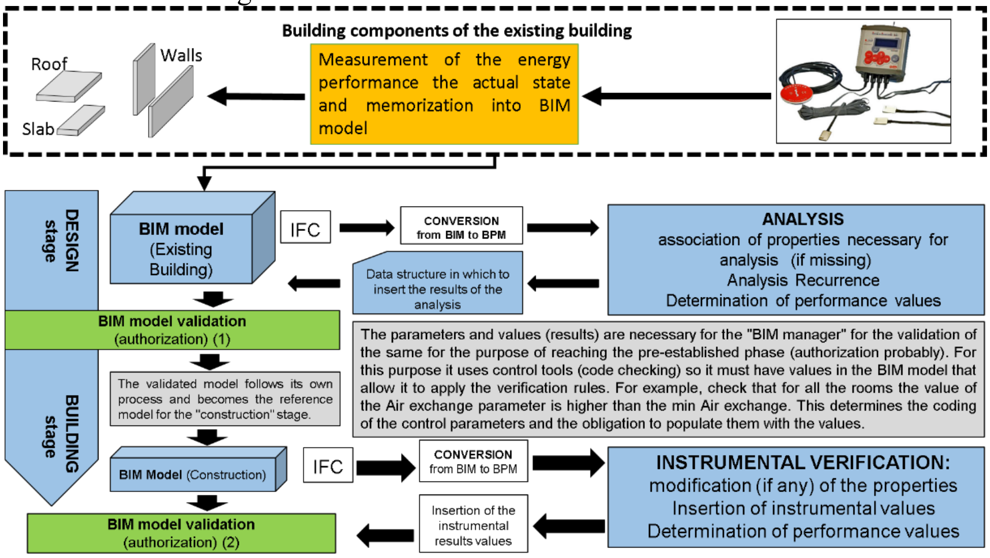

Figure 1 - Flowchart - Data measurement and BIM model

For buildings, these technical standards were developed recently [5-6] and are more useful for temperate and sunny climates. The most important component of the building, which characterizes its dynamic behavior, is the external wall. It can be either be massive or lightweight and protected from sunlight or not, but should serve to preserve the thermos-hygrometric comfort of its inhabitants [7p6]. At present, the steady-state thermos-physical model standard uses transmittance U (W/m²K) based on the measurement of the rate of transfer of heat through the walls of buildings [8p7]. This model utilizes the three mechanisms of heat transfer: radiative, conductive and convective. In most situations, the exterior walls of buildings transfer heat exclusively by a conductive mechanism. The current dynamic use of the private dwellings, public and services buildings by the people, which is associated with the prevalence of the sunlight in the Mediterranean climate, also depends on dynamic weather patterns and seasons. All of the abovementioned effects lead to a preference for dynamic physical models. According to ISO 13786and other researcher's works [9-12], it is possible to use the matrix method to evaluate the periodic thermal heat transmittance, the phase shift that between the temperature peak and the incoming heat flow peak and the decrement factor (which indicates the ratio by the module of thermal transmittance and periodic thermal transmittance). Ricciu [13] as shown the wall placed in the climate chamber with the open shells and the sinusoidal. In the last several years, Italy has built less than 0,5% of the existing buildings [14]. In this case, it is very likely for thermal increases to occur in the existing buildings, rather than in the new ones. Most of the existing buildings have no historical or technical documentation. UNI 10351 [15] and UNI 10355 [16] report thermal characteristics of the different component for old typical building walls or typical masonry stratigraphy. However, in general, it is impossible to establish exactly the correspondence between the existing walls and the recommended in UNI 10351 and 10355, unless it is through the trials of coring [17]. This test is highly invasive, and it is considered dangerous to the preservation of old buildings. In this work, the authors propose an inverse/indirect method to derive the thermal properties of building walls from the thermal measurements. The inverse method is based on the direct method proposed in ISO 13786, which utilizes the harmonic analysis of integration of the Fourier heat equation probably published for the first time in the 1906 edition [18]. The results, carried out through a rebuilding of the reverse harmonic method of the Fourier heat equation, allow to rebuilt the thermal properties of the wall by simple measurement of the temperature and thermal flux both on the outside wall and the inside wall. Hence, in this work, two main sections are presented: the direct harmonic method and the in- verse harmonic method. In this case, to understand more clearly the second section, the first section is detailed with some mathematical steps. At the end of the work, a practical application of the proposed method can calculate the transfer matrix of the thermal property of a "dummy" wall because the homogeneous and isotropic material has the same thermal characteristics of a "real" wall with all of its layers when the magnitude of phase shift and the decrement factor are known. This "dummy" wall has the same properties of a wall with several layers. In the application of nondestructive methods, Brian H. and Mohamed T. K., or Malhotra V.M. and Carino N. J. and Pia G. et al. [19-21], agree with the statement that is possible to measure the average density ρ of the component "in situ". In the procedure used by Ricciu and others [13], it is possible to have the specific heat c (J/kgK) of the wall in study-case. In this case, it will be possible to adopt the method for energy-retrofitting in a dynamic application. The model described by Ricciu and others [13] was implemented in the GEAR BIM Tools software, able to interact with the BIM models the interoperable data standard called IFC [22-23].

2. Energy benefit evaluation procedures through BIM Tools

The energy retrofit of existing buildings is a fundamental aspect to reason the objectives set by the European Board Has Recently Issued The EU Directive "Roadmap for Moving to Competitive -Low Carbon Economy in 2050" [24-25] Which Lays Down Recommendations to Achieve The Reduction of Greenhouse Gas Emissions Under 80 For Cent of the 1990 Level by Such a Date. Often for existing buildings the stratigraphies of building components and a way to ascertain the starting performance and to perform measures are often known. The procedure implemented, developed for the physical-mathematical part by Ricciu and others, allows through the use of the BIM model of the existing state and the data measured on the construction components the execution of intervention simulations to improve energy performance. This process is schematized in Figure 2

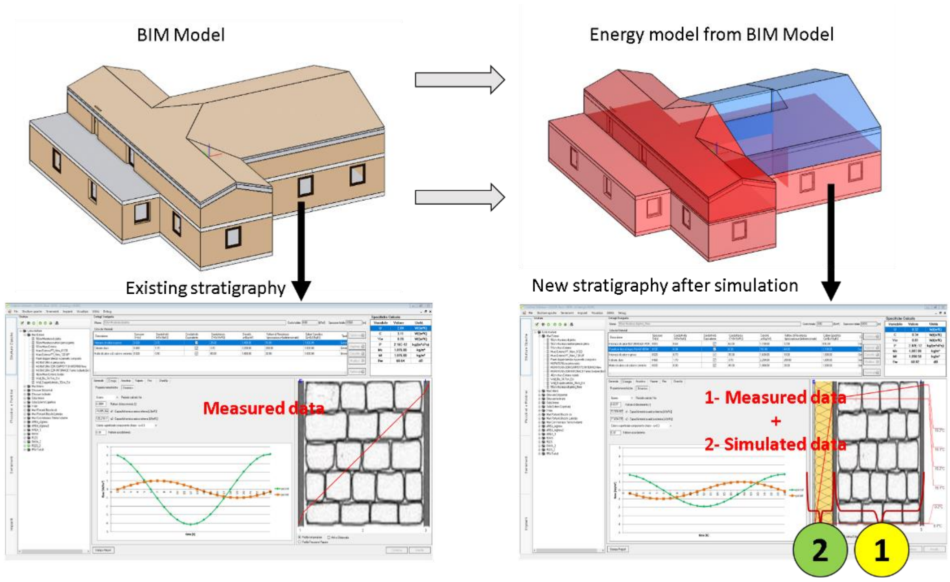

Figure 2- Generation of alternative solutions for stratigraphy based on the BIM energy model

The unified handling of a set of physical problems can be seen as an innovative aspect of the developed model presented here that integrates effectively with the three dimensional architectural CAD. The model does not need any ad hoc three dimensional geometric modelling, but can make use of the same model developed for the architectural project.
The physical, geometrical, environmental, characteristics, that are necessary for the simulation of the performance of a building, through the use of BIM are many. The tools that let use the geometrical data or more generally the data of the building from a three-dimensional model, modify and complete the information on the building, on climate, or on different environmental aspects with the need for energy simulations are numerous [26-28]. Several of them allow to import gbXML and IFC formats automatically or in a semi-automatic way to simplify the input of geometrical data and sometimes of those related to the physical properties of building components. A very important aspect when working with different data formats, is the congruence of geometric information data, which is not always guaranteed, taking into account the input mode required by the software or by the calculation model used for energy simulation [29]. This fundamental aspect, if not considered, can spearhead to results affected by errors [29]. The procedure tested in this work encountered a considerable advantage in using the data on the energetic performance of the measured construction components and entered within the BIM base data. The advantage of this approach consists in the fact that for the energy designer [30p16] it is faster to perform simulations and obtain scenarios of aid to decision-making. This aspect is reflected on the quality of the design result as it is possible to perform many more simulations and optimize the result compared, for example, to the beneficial cost ratio .

3. Conclusions

In this work the calculation model provided by ISO 13786 was analyzed with the methodology proposed by Ricciu and others. The method proposed by Ricciu and others allows you to relate the data measured with data on the design phase. The model so described, useful in the planning phase of interventions on existing buildings makes it possible to operate project choices on the thermo-energy performance of the casing based on the measure of the provision of the individual building components. The model has been implemented within the Gear Bim Oriented software. The elaborations allowed to evaluate the utility of the model starting from the measurement of the ante-opera performance stored in the BIM model of the study case. On the BIM model the energy simulations that allowed the energy needs of the envelope according to the standards provided by the EPBD Two, following the designed thermal insulation intevents.

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