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A simple method for the comparison of bioclimatic design strategies based on dynamic indoor thermal comfort assessment for school buildings

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Abstract

Bioclimatic design strategies have been proposed for decades, on a qualitative basis, because a quantitative approach, ineludibly based on dynamic measurements or simulations, was too expansive and complex. If simulation considerably evolved, in the last years, in terms of speed, cost and diffusion of available tools, their utilization is still complicated by the managing a huge amount of hourly data. The passive behavior of a building, moreover, is not effortlessly synthetized: conditioned buildings may be easily compared just summing the hourly consumption of primary energy, while buildings with no thermal plant need more sophisticated statistical analyses because in these kind of buildings, it is particularly difficult to assess the effect thermal inertia. The existing school buildings stock has a strong need of energy renovation in accordance with Government vision of a community 24 hours a day use and consequently increasing the requirement of comfort conditions and energy consumption. Hence, a current school building heated and not cooled is considered as application field of the novel methodology and a classroom is used to test different energy retrofit solutions compared against a base-line, in terms of capacity to decrease the indoor air temperature variation. The analyzed simulations have been thus compared with ideal comfort conditions by an original analysis approach based on a visual tool as a support for designers in choices comparison to simply assess and visualize the performance of building technologies.

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Keywords: Thermal comfort; thermal inertia; school building; bioclimatic architecture; energy performance and data analysis

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1. Introduction

The attention to existing school buildings in Italy is increasing due to National strategies targeting at improve the conditions of the more than 42,000 schools composing the educational building stock which in the 35% of the cases are in need of maintenance and heavy refurbishment to achieve levels of environmental well-being, health, attractiveness and cost-effectiveness. Energy efficiency is a main driver of the Government actions [1] which focus not only on the control of the running costs, but moreover in enhance pupils' awareness on environmental problems, general wellbeing and learning performance through the accurate design and renovation of schools' spaces [2]. Extensive studies [3][4] show that improving indoor conditions and spaces quality promote to increment of the learning performance of the pupils until a 16% [8] and controlled thermos-physical and indoor air quality parameters (e.g. ventilation [5], lighting [6], acoustic [7], CO_2 and VOC) affect significantly the upgrading at classroom level by 50% [9]. The strong correlation between user and built environment defines comfort levels and proficiency of workers [10] and students [11][12] and health and safety of the indoor spaces is nowadays a core topic. An additional and correlated issue is related to the characterization of occupancy profiles [13] in the school buildings aiming at optimize the space organization strategies and identify in a proper way the effects in term of energy consumption [14] in order to predict the variability of the energy performance owing to users' behaviors and fluxes [15]. Even so, energy saving measures results in significant costs and extended payback time and often the cost related to envelope refurbishments are harshly higher than replacement of thermal plants or addition of smart control devices. However, the bioclimatic approach entail undeniable benefits (i.e. affordability and easiness of implantation) pursued by passive regulation of the heat gains and indoor comfort conditions through the thermal mass. Educational buildings are mainly equipped with heating systems for winter use nevertheless, the climate change and the extended use of the buildings reveal the need of mitigation measures for overheating in the middle and summer periods. The concept is to avoid the installation of a cooling system to accomplish with thermal comfort in the extended periods but to manage adaptive comfort conditions by thermal inertia.

1.1. Energy performance of the National school building stock

The 75% of Italian schools dates before energy laws and the distribution in the territory from north to south does not change. The 33% of the school buildings dates before L. 373/76 [16] and about the 50% has been realized after the law nonetheless, the energy quality did not improve dramatically. The 25% of the school building dates after '80s and thus towards the L.10/91 [17] (Fig. 1). Moreover, the progressive ageing of the schools means a crucial need of improvement and performance to accomplish current standards [18] and EU Directives [19]. The school building stock counts over 62,000 schools of which about 45,000 public, largely overtake the public housing sector with about 1 million TEP of energy consumption per year of which 70% of heating and 30% of electricity. The potential of reduction, with effects on energy, environment and social aspects is impressive. A first step towards energy efficiency can be implemented by promoting energy behavioral awareness with low cost actions and a 20% of estimated effectiveness [20]. Energy saving measures focusing on envelope and thermal plants can decrease strongly the consumption with additional costs however about 40% of the school buildings are in need of maintenance and the retrofit measures could be included inside this cost item. The cost percentage of energy retrofit measures in school buildings show that the control and upgrading of lighting and thermal systems have low costs in comparison with envelope solutions such as insulation of the vertical and horizontal opaque portions or thermal enhancement of transparent surfaces [21]. The cost of measures focusing on the envelope can affect by 10% to 46% the refurbishment interventions (Fig.2). Furthermore, the age of the school building stock, defines the typologies of envelope and the associated thermal plant. In fact the 70% of the national school buildings is realized with reinforced concrete frame structure with brick infill walls and it is equipped with a gas boiler heating system (efficiency η=0.9). In any case, for buildings realized after the 1976 a thin insulation layer in the opaque envelope can be expected [24] (Table 1). The average heating energy consumption for public schools is about 180 kWh/m^{2}year whereas the requirement for new construction is about 30-40 kWh/m^{2}year. Thus, it is not appropriate supplement with an additional cooling need this amount of energy inasmuch cooling systems diffusion had a dramatic growth in the last 15 year in the housing sector. The requirement of comfort is however pushing and the