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# The role of the thermal mass in nZEB with different energy systems

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**Abstract**

European and Italian standards establish high levels of energy performance of buildings that have to be designed considering their energy balance near zero. To achieve this goal, the reduction of energy demand, attainable by improving energy efficiency of the construction, and the use of renewable energy available both on site and off site are effective solutions to be applied. In particular, in buildings that use energy produced from renewable sources, due to their unstable and unpredictable nature, having the right strategy to compensate the variations is essential. A technical solution reevaluated as a consequence of passive design principles, is to provide an adequate thermal inertia in order to store energy when it is offered and to use it when the source is not available. In these cases, the ability of construction elements to retain heat becomes fundamental as they contribute to maintain internal comfort conditions. This paper aims to investigate how various types of heating and cooling systems, based on different modes of heat transfer, are able to interact differently with the thermal mass of the building, producing a different level of its activation. The investigation considers a case study used to carry out dynamic simulation by means of DesignBuilder which is a user interface of EnergyPlus. The model consists of a building with elementary geometry and a single thermal zone, delimited by walls with outside thermal insulation and a heat accumulation layer inside. The variation of the internal temperature by using different types of conditioning system is analyzed in order to individuate the technology that takes the greatest advantages from the thermal mass.


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## 1. Introduction

The recent legislation, accepting the provisions dictated by the Directive 2010/31/UE [1], imposes high standards of energy efficiency in constructions and compels the adoption of measures that could lead to building energy consumption close to zero. Having a zero energy balance means that the building must have a very low consumption and this limited energy should be covered largely by energy from renewable systems, so that the use of traditional sources becomes almost null. To reduce the energy consumption, the energy efficiency of buildings has to be improved, primarily. This objective should be achieved by providing a good insulation of the envelope and by involving a high level of thermal inertia in the construction. Thermal mass depends on density and specific heat of the materials and it measures the heat storage capacity of the element. When exposed to external heating, materials with high thermal mass, generally heavier and denser materials, are able to store more heat than lightweight materials. On the other hand, it will also take longer for materials with good thermal mass to release the stored heat once the heat source is removed [2].

Actually thermal inertia is one of the most important parameters for improving thermal comfort conditions and for reducing heating and cooling energy demands of buildings [3][4][5]. Several authors analysed the effect of the thermal characteristics on energy performances of buildings upon variation of insulation and inertia [6][7][8] proving that significant energy saving can be achieved depending, however, on the distribution of mass and insulation inside the wall. Other authors evaluated the influence of the position of a massive layer and of an insulation layer, also finding substantial differences in air conditioning consumption in intermittent regime for the different technical solutions [9][10]. Numerous studies demonstrated that the placement of the inertial mass on the internal side of the building envelope is recommended, both for energy saving and for comfort. Many researchers have shown that the solution with external insulation and high internal mass is preferable to the assembly with inner thermal insulation and external mass, as it allows greater energy savings [11][12].

Thermal inertia is generally proposed as a passive strategy for energy saving in buildings. The thermal mass has positive effects on the indoor conditions during the summer and winter periods. The energy available from the high solar gains during the day is stored and then is slowly released into the indoor environment at a later time. In winter, the stored heat is transferred back into the room during the evening hours, when it is most needed, satisfying part of the heating load and avoiding overheating and discomfort conditions during the high solar radiation periods of the day. In summer, heat is stored in the thermal mass, thus reducing the cooling loads peaks [13]. According to Karlsson [14], passive energy storage through high thermal mass can significantly change the power consumption pattern, which can give significant benefits. Heavy constructions, characterized by high heat capacity inside the envelope, offer various advantages: they can reduce energy consumption; the energy demand of the building may be decreased or shifted to times when loads are lower and indoor temperatures result more stable. Thermal mass is therefore an essential element of passive solar design, primarily because of the need to store the solar energy received by the building during the day and then to gradually release it overnight [2]. However, many studies show that passive thermal designs alone are not enough to fully exploit the potential for energy efficiency in buildings: in fact, harmonizing the active elements for indoor thermal comfort with the passive design of the building can lead to further improvements in both energy efficiency and comfort [15].

Thermal mass generally reduces the speed at which internal temperatures increase as a result of external solar radiation or internal heat emissions. Consequently, the same thermal mass may reduce the speed at which internal temperatures decrease when heating effects are removed [16].

This study aims to analyze the dynamic interaction between the thermal mass involved in a conditioned environment and the air conditioning system. The study is carried out by performing dynamic simulations on a simplified model by using DesignBuilder [17] which is based on the computation engine EnergyPlus [18]. The trends of indoor air temperature and radiant temperature are analyzed upon variation of the heating/cooling terminal units, which use different modalities of heat transfer. The analysis leads to verify the possibility of exploitation of the thermal mass in the structures to store the energy produced through renewable systems and make it usable when the sources are not available. In fact, a proper design of the building obtained by equipping the construction with suitable thermal inertia, may be insufficient if it is not adequately exploited. The most profitable solution is one which allows to minimize variations of the indoor temperature which should remain constant and close to the comfort values by means of the minimum contribution of the air conditioning system.