Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 111 (2017) 462 – 471

Energy Procedia

8th International Conference on Sustainability in Energy and Buildings, SEB-16, 11-13 September 2016, Turin, ITALY

The energy saving and indoor comfort improvements with latent thermal energy storage in building retrofits in Canada

Umberto Berardi[a]*, Mauro Manca[a]

[a] *Ryerson University, 350 Victoria street, Toronto, M5B 2K3, ON, Canada.*

Abstract

High-rise apartment buildings in Canada are an integral part of the residential building stock, and their dominance is continuing to grow as their market escalates. Meanwhile, the refurbishment of the existing multi-unit residential building stock is becoming a fundamental step in order to address Canadian energy saving targets. The aim of this paper is to evaluate the effectiveness for energy saving of increasing the thermal capacity of the building enclosure. In particular, this paper assesses the benefits of the adoption of Phase Change Material (PCM) in lightweight constructions in the climates of Toronto and Vancouver. The main aspect investigated is the contribution of PCM systems to lower the building cooling demand and to increase the indoor thermal comfort. Building simulations aimed at comparing different PCM systems for building elements such as floors, ceilings, and walls are reported. Different orientations and internal gains are considered in order to have a complete understanding of the potential benefits of the adoption of systems with high (latent) thermal energy storage capacity in building retrofits in Canada.

Peer-review under responsibility of KES International.
Keywords: phase change materials; thermal comfort; energy simulations; passive strategies; energy efficiency; buildings.

1. Introduction

It is often stated that the building energy consumption accounts for 32% of total global final energy use, with energy consumptions above 40% and greenhouse gas (GHG) emissions of 40% in some developed countries [1-3]. The Intergovernmental Panel on Climate Change (IPCC) stated that GHG emissions from the building sector more than doubled between 1970 and 2010, reaching a value around10GtCO2eq/y nowadays, mainly resulting from the energy

* Umberto Berardi. Tel.: +1 416 979 5000 (3263);
E-mail address: uberardi@ryerson.ca

Peer-review under responsibility of KES International.
doi:10.1016/j.egypro.2017.03.208

consumptions [3]. Looking at the global trends of the energy consumptions, the IPCC has reported that significant heating and cooling energy demand increases are expected globally by 2050, growing 179% and 183% higher than the 2010 levels in residential and commercial buildings respectively [1]. Given these trends, the role of buildings in promoting energy saving is obvious. This awareness is confirmed by the increasing commitment towards zero energy buildings [4]. However, it is also evident that the refurbishment of the existing building stock is the only way to reduce significantly the building energy consumptions.

This paper aims to assess the feasibility of adopting Phase Changing Materials (PCMs) in buildings in Canada during building retrofits. The choice of studying PCMs is due to the crucial role of thermal mass in controlling the internal comfort while promoting the reduction of the peak energy demand [5-7]. In this regard, given the trend in the Canadian building sector towards fast construction systems, the latent thermal energy storage could be particularly important for energy saving. In order to prove this value it is worthy to note that Toronto is experiencing an incredibly high construction development rate; in September 2014, there were 211 new high-rise projects across Toronto, while at the beginning of 2015, the number of high-rise proposals and projects across the city increased to 470, and for the majority of the new high-rise buildings, a completely transparent envelope with high solar heat gain and low thermal mass was adopted [7]. This architectural design trends, which have been common for the last two decades, have resulted in high energy demand given by the need of continuous recourse to the HVAC systems to deal with uncomfortable indoor conditions.

2. Literature review

2.1. General aspects of PCM

The research on PCMs has become one of the major topics in the building material field, as suggested by the exponential increase in the number of papers about this topic. PCMs have the capability to store and release energy in the form of latent heat thanks to a solid-liquid/liquid-solid phase change at their melting point temperature and they may hence be used as thermal storage systems in order to store excessive heat from inside the building [8-10].When the PCMs are at a temperature below their melting point, they are solid and behave like any other material, increasing their temperature as they absorb and transfer heat according to their conductivity, density, and heat capacity. When the surrounding temperature reaches the melting point of the PCMs, these start the phase change at an almost constant temperature accumulating heat until the material is completely melted. In practice, the phase change is often spread over a temperature range which follows a Gaussian curve [11]. The main issue for the actual effectiveness of PCMs is that the indoor temperature has to span a range that enables the phase transition. For this reason, every project in which PCMs are proposed must be studied individually, and dynamic energy modeling becomes fundamental to determine the functioning of the PCM [12].

Since the activation of the PCMs depends on many factors (including the outside temperatures, the building envelope properties, the building internal loads, and the PCM melting point), the choice of a too low melting point temperature induces an under-utilization of the material in the hottest months, while a too high melting point may cause the inefficiency of the PCM during the intermediate seasons. In order to encompass a larger temperature swing and to cover a longer period, PCM systems with different melting point temperatures have been coupled [13]. A study by Kuznik demonstrated that the optimal melting temperature should be based only on the average room temperature [14]. The overall enthalpy of the PCM is also an important issue since during the charging period if the PCM thermal capacity is too high, the melting process becomes slower and eventually it could even not complete.

PCMs are usually classified in three categories: organics, inorganics, and eutectics [15]. The organic PCMs are usually available in different melting point ranges, are chemically stable and do not show super-cooling effects but have a lower conductivity (about λ=0,2W/mK), which limits their ability to exchange heat [16]. Reversely, the inorganic PCMs have a higher conductivity and a smaller volume change, although they often show episodes of super-cooling, and are corrosive. Recently it has emerged the need for PCMs having a liquid phase change (so no solid to solid PCMs) to be contained in other construction materials or envelopes to prevent leakages and contaminations [10]. However, once encapsulated, PCMs can be integrated into porous materials such as plasterboards or finishing panels has already proven to be effective [17].