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Passive downdraught evaporative cooling system integration in existing residential building typologies: a case study

Giacomo Chiesa[a]*, Mario Grosso[a], Alessio Bogni[a], Giacomo Garavaglia[a]

[a]*Politecnico di Torino, Department of Architecture and Design, Viale Mattioli 39, 10125 Torino, Italy*

Abstract

This paper analyses the integration of a passive downdraught evaporative cooling (PDEC) system in existing residential buildings through a case study, an existing 3-storey building located in a small city near Turin. This study was focused on the technological integration of a PDEC system in residential buildings rather than on its actual applicability, which proved to be very low to Turin's climate. Three main aspects are considered: a) a matrix of PDEC systems integration related to building typologies; b) the results of a laboratory testing in site conditions for evaluating the performance of PDEC systems and correctly dimensioning the evaporative tower; c) the design of an integrated PDEC-Building solution, showing that the described approach can be applied to existing designed buildings.

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Keywords: passive downdraught evaporative cooling; passive cooling; building system integration; PDEC monitoring

1. Introduction

This paper deals with the integration of a passive downdraught evaporative cooling (PDEC) system in existing buildings. A direct evaporative cooling technique such as the PDEC's is a well-known strategy for reducing the cooling demand in hot-dry climates, while indirect evaporative cooling systems or dehumidification-evaporation solar cooling systems [1] can reach good performance results also in mid-temperate climatic conditions [2, 3, 4, 5]. The expected reduction in cooling energy needs due to the use of PDEC systems in European cities was calculated to be between 25 to 85% according to local conditions [5]. Furthermore, the applicability of PDEC systems to the existing European residential building blocks was estimated as more than 70% [6].

* Corresponding author. Tel.: +39-011-0904371
E-mail address: giacomo.chiesa@polito.it

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This paper presents the results of a study on the integration of PDEC systems in existing residential buildings carried out through a typological analysis and an application to an actual case study. The climate characteristics of the case study site, necessarily selected close to the testing laboratory location, are more suitable for the application of indirect evaporative cooling or solar dehumidification-evaporation systems than for PDEC due to high humidity of the external air in the summer period. Nevertheless, the study's results were worth to be published for their importance in setting a method to assess the potentiality for technological integration of the PDEC system in residential buildings with construction and layout characteristics typical of Northern Italy and, by extension, of Central Europe. In the first part of this paper (§ 2), a matrix of different integration possibilities was developed by comparing the list of PDEC solutions derived from [5, 7, 8] to a classification of the principal building typologies used in urban areas of Northern Italy and Central Europe. In a second part (see § 3), a case study is described, consisting of a design solution for integrating a PDEC system in an existing 3-storey residential building composed of three blocks and localized in the Municipality of Beinasco (TO). This case study includes both a laboratory testing on a PDEC tower installed in the LaSTIn lab (Laboratory on Systems for Technology Innovation, Department of Architecture and Design, Politecnico di Torino) and the development of a design solution for integrating PDEC towers in the existing building. The laboratory testing was performed to study the functioning of the system in similar climatic condition of the building site in order to correctly dimension it.

2. Typological integration of PDEC systems in residential buildings

Building typologies, PDEC systems and building integration of PDEC are classified. A matrix of different integration strategies is presented in par. 2.2. and based on classes defined in par. 2.1.

2.1. PDEC classification in relation to building typologies

Based on the knowledge of the existing residential building stock in Turin's metropolitan area, it is possible to identify the following five categories of building shape/structure.

- Isolated buildings, i.e. residential single or double family buildings. This category includes isolated buildings with possible attached garage and/or warehouse and a garden.
- Terrace houses, i.e. row buildings composed of several single family two-storey houses placed side by side, hence with one (at the ends of the row) or two (within the row) blind facades shared with the adjacent house/s and the other two façades with opposite compass orientations.
- Courtyard buildings, i.e. multi-storey buildings aggregated around a common, usually rectangular, courtyard.
- Tower buildings, i.e. multi-storey buildings with predominant vertical dimension and a square or circular plan comprising, generally, three-four apartment per floor exposed to all compass orientations.
- Row buildings, i.e. multi-storey buildings with predominant longitudinal dimension. Apartments have one or two exposures (except the ones at the ends-of-the-row) with access from various staircases directly or through corridors. In old low-income building types, still present in Turin, access to the apartments occurs through long balconies called "ballatoi".

A PDEC system is characterised by a buoyancy-driven downdraught air movement due to an air temperature drop caused by water evaporation. PDEC systems can be classified in two ways: technological and typological. In the former, four categories are considered related to the used water-spraying system: wet pad; shower tower (coarse sprayers); misting tower (atomizer nozzles); and porous media [5, 9]. In the latter, four different positions of the PDEC system in relation to the building are foreseen, based on Ref. [5]: central atrium (open), central atrium (closed), attached PDEC tower and detached PDEC tower [5]. They are described as follows.

- Central atrium (open) – e.g. the Malta Stock Exchange, Malta. This type of PDEC position implies a central space where there is no discontinuity between the occupied spaces and the space where downdraught cooling by evaporation occurs.