Ventilative cooling in shopping centers' retrofit

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Because of the customers' need of best possible comfort condition and satisfaction, shopping centers are conditioned by means of basic HVAC systems, often without considering the potential of natural ventilation to reduce energy consumption related to cooling and ventilation. Within the European project CommONEnergy, EURAC researchers are dealing with ventilative cooling strategies as retrofit solutions for shopping centers.

Keywords: Ventilative Cooling Potential, Ventilate Cooling Design Method, Shopping centers retrofit, Integrated Modelling Environment (IME), Cooling Energy Savings.

Introduction

Nearly all retail locations use full air HVAC systems to ensure adequate air exchange, primarily for hygienic reasons, and indoor comfort temperatures. Considering the trend towards longer opening hours and increased number of opening days, the electricity consumption due to ventilation and conditioning systems is expected to continue to rise across Europe.

Specific inefficiencies, related to cooling and ventilation topics, concern mainly energy losses in ventilation, absence of free cooling strategies and unmodulated airflow for different periods of the day.

Generally, mechanical ventilation systems are preferred to natural ventilation strategies because more controllable and reliable, since they are not affected by the uncertainty of natural forces. Thereby, within the design process the team never focused neither on opening sizing nor on control strategies definition for natural or hybrid ventilative cooling systems. So far, shopping centers design has included a small proportion of automated windows, sized for smoke ventilation only. Depending on the external climate conditions, acceptable levels of thermal comfort and IAQ can be reached without or with partial use of the mechanical systems, leading also to operational and maintenance cost savings.

According to the British Council of Shopping Centre (BCSC, 2012), in the UK climate annual electricity usage is known to be up to 50% less where natural ventilation is employed over mechanical ventilation depending on the mechanical systems. Furthermore, natural ventilation uses typically between 2–5% less plant space versus 5–8% used by HVAC, which can be utilized and improve net to gross ratios. Therefore, the CommONEnergy project (http://www.commonenergyproject.eu/) investigates ventilative cooling strategies among the energy efficient solutions for the retrofit of shopping centers' common areas (shop galleries and atria).

As case studies we referred to the reference buildings (**Table 1**) identified within the CommONEnergy project as representatives of the EU building stock, showing the typology they belong to (Bointer,R, 2014), and the climate classification according to (Cory S., 2011).

Technical components

Technical components for ventilative cooling are already available on the market and, according to the IEA Annex 62 state-of-the-art analysis, are structured in:

- Airflow Guiding Ventilation Components, such as windows, skylights, doors, dampers, flaps, louvres plus special effect ventilators;
- Airflow Forcing Ventilation Components, such as such as buoyancy chimneys, solar chimneys, atria, Venturi roofs, powerless roof ventilators, wind towers and wind scoops;
- Passive cooling elements, such as convective cooling components, adiabatic cooling components, phase change components

Some of the component and concept available on the market are shown in **Figure 1**.

Design concept

A ventilative cooling strategy involves the whole building envelope. Vents and openings can be located on both façade and roof to exploit buoyancy due to temperature difference between shops and central spaces and along the atrium height. Applying ventilative cooling is dependent on building design and indoor spaces layout. Where implementing ventilative cooling strategies, it is important to take into account the following features regarding shopping centers' internal layout:

- Interconnected galleries and atria;
- Building shape, number of levels and ceiling height;
- Location of parking areas, possibly avoiding the inlet of polluted air.

The assessment of the most suitable ventilative cooling strategy should also consider that, from an architectural point of view, most of the shopping centers are generally similar to atria with large open spaces between shops that are often heated, cooled and ventilated separately from the mall central space. The shops are connected with the common central areas by means of open doorways through which natural air exchange occurs bridging the two spaces.

For instance, common central areas can be seen as unconditioned buffer zones that temperate the outside and inside climate, resulting in more relaxed ranges of interior conditions respect to selling area. The exploitation of airflow driven both by thermal buoyancy and by wind pressure can prevent overheating within these buffer zones if solar radiation is properly controlled.

As last important consideration, typically the common areas are managed by a unique referent (e.g. owner, energy manager), which is also the one who makes the decisions during a retrofit easing the retrofit process. Furthermore, there is a higher degree of freedom in the common areas design compared to the "leasing" area,

Table 1. List of reference shopping centers' typology, location and climate (HD=heating dominated, CD= cooling dominated, H&CD= mixed dominated).

ID	Name of the shopping center	Shopping Center typology	Location	Country	Climate
CS	City Syd	Medium Shopping center	Trondheim	NO	HD
ME	Mercado del Val	Specialized and Others	Valladolid	ES	H&CD
GE	Genova Ex- Officine Guglielmetti	Specialized and Others	Genoa	IT	CD
KA	Centro Commerciale Katané	Medium Shopping center/ Hypermarket	Catania	IT	CD
MO	Modena Canaletto	Specialized and Others	Modena	IT	CD
DO	Donau Zentrum	Very Large Shopping center	Wien	AT	H&CD
BC	Brent Cross	Very Large Shopping center	London	UK	H&CD
ST	Studlendas	Small Shopping center	Klaipeda	LT	HD
GB	Grand Bazar	Small Shopping center	Sint-Niklaas	BE	H&CD
WA	Waasland Shopping Center	Large Shopping center	Antwerp	BE	H&CD
PA	Pamarys	Small Shopping center/ Hypermarket	Silute	LT	HD

where franchising companies characterized by their own standardized protocols, restraint the applicability of overall retrofit solutions.

Ventilative cooling potential

The potential of ventilative cooling strategies is evaluated for each reference building using the ventilative cooling potential tool (Belleri A., 2015). The tool, which is under development within the IEA EBC Annex 62 research project (IEA EBC Annex 62 - Ventilative cooling, 2014-2017), takes into account also building envelope thermal properties, internal gains and ventilation needs.

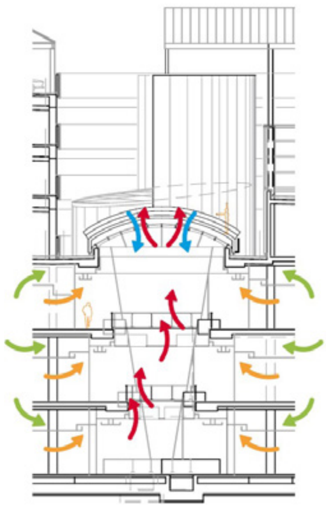
For each hour of the annual climatic record of the given locations, an algorithm splits the total number of hours when the building is occupied into the following groups:

- Ventilative Cooling mode [0]: no ventilative cooling is required because heating is needed;
- Ventilative Cooling mode [1]: natural ventilation can be exploited to meet the minimum ventilation rate required by the EN 15251 on indoor environmental quality;
- Ventilative Cooling mode [2]: ventilative cooling is needed and the ventilation rates needed to maintain indoor air conditions within the comfort ranges (calculated according to the adaptive comfort model – EN 15251:2007) are assessed according to the energy balance;
- Ventilative Cooling mode [3]: ventilative cooling is not useful and nighttime ventilation should be considered.

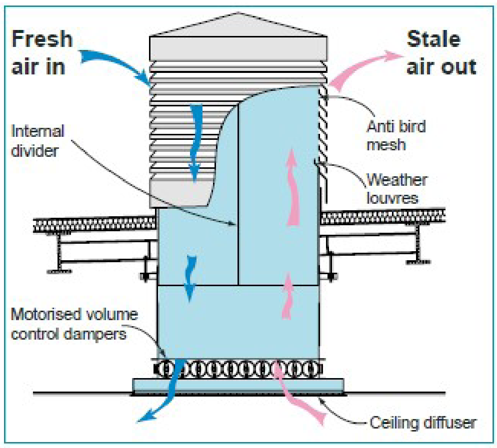
The graph in **Figure 2** reports the results of the ventilative cooling potential analysis for each reference building considering a specific lighting gain level of 30 W/m². The higher is the level of specific lighting gains the high is the cooling need and consequently the energy savings related to the use of ventilative cooling potential are higher. A parametric analysis for the definition of the ventilative cooling potential according to different levels of specific lighting gains is reported in (Avantaggiato M., 2015). Direct ventilative cooling strategy can potentially assure thermal comfort for the whole hours within a year in Trondheim and for more

(a)

(b)



(c)



(d)

Figure 1. (a) Skylight window installation at Ernst-August Galerie in Hannover. Source: http://www.hs-montagen.de/archiv-montage-fassade-hannover, (b) Chain actuators for top hung windows. Source: http://www.topp.it, (c) Ventilation concept of the Ernst-August galerie in Hannover. Source: www.windowmaster.com, (d) Wind catcher application on Tesco supermarket. Source: Monodraught, 2015.

than 90% in seven climates over eleven. The cooling dominated climates of Genoa, Catania and Modena are the ones with the highest percentage of direct ventilative cooling with increased airflow rate potential use (ventilative cooling mode [2]).

Design method

Naturally ventilated buildings require a specific design service dealing with building shape, internal layout distribution and airflow paths along the building. Therefore, natural ventilation design shall be ideally part of an integrated design process since the early design stages.

Since shopping centers are mostly object of partial retrofitting actions, building shape cannot be modified and internal layout can be only partially modified. However, typical architectural archetypes of shopping centers such as atria and galleries revealed to be suitable for the integration of natural ventilation strategies.

Based on climate analysis previously described, the most suitable ventilation strategy can be assigned by identifying possible airflow paths and the air intake and exhaust locations. It is necessary to integrate the natural ventilation in the overall existing building design, especially in relation to area partitioning (shops, common areas, areas closed to visitors), air tightness, building geometry, HVAC system and envelope porosity.

Designers are faced with many and sometimes conflicting requirements by designing natural ventilation in shopping centers, related to urban regulation, indoor environment quality, aesthetic appearance, building standard and regulations (acoustic, fire, zoning..), safety, operative and maintenance costs and the need to maintain the shopping center open during the retrofitting works. Those constraints are related to the design complexity and can be easily identified through an integrated design process by discussing with design team, building owner, energy manager and other actors directly involved in the building design.

The scheme in **Figure 3** represents the design process adopted to define ventilative cooling solution.

Considering that an indoor space of a shopping center highly interacts among each other, a multizone based analysis of airflows is needed to evaluate the ventilative cooling strategy effectiveness and to assess potential energy savings.

The Integrated Modelling Environment under development within the CommONenergy project allows to predict airflows throughout a building by performing coupled thermal and airflow building dynamic simulations. Furthermore, by gathering in the same simulation model (i) building (ii) HVAC and refrigeration systems and components (iii) daylighting/shading/artificial lighting (iv) storage technologies (v) RES technologies (vi) natural ventilation and infiltration (vii) non-conventional envelope solutions (vegetation, multi-functional coating and materials, etc.), the Integrated

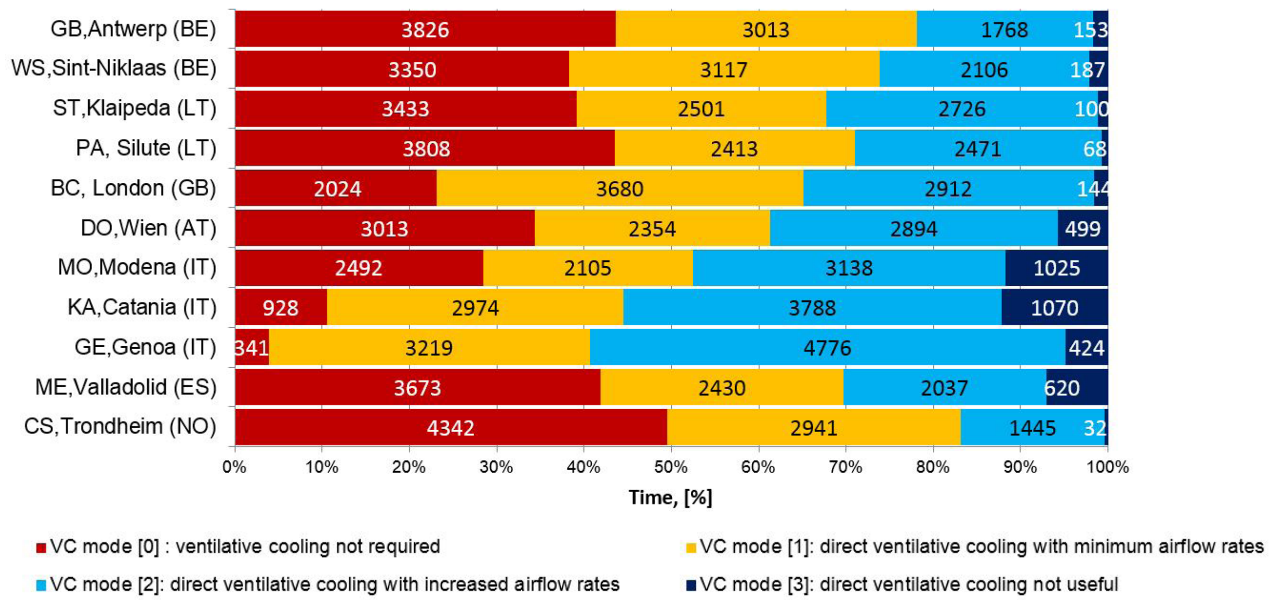


Figure 2. Percentage of hours within a year when direct ventilative cooling is required, useful or not useful in the eleven reference case climates when the specific lighting power is 30 W/m².

Modelling Environment allows to test the energy performance of ventilative cooling solutions in combination with other active or passive solution and to elaborate effective solution sets and control strategies.

Cost optimization can be performed by properly sizing each technical component (openings, actuators type, vents etc.). The modelling results are then used as basis for discussion with the building owner on the definition of the retrofit solution and its installation mode within the shopping center.

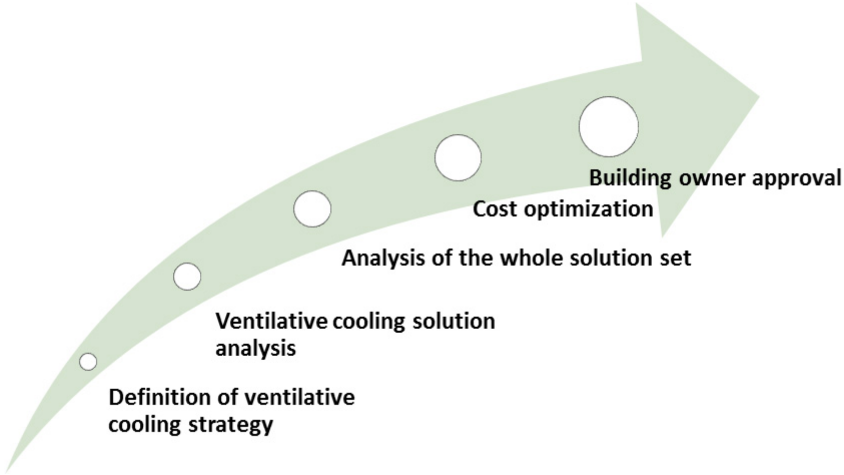


Figure 3. Ventilative cooling solution design process.

Conclusion

The CommONEnergy project investigates ventilative cooling strategies as energy efficient solutions for the retrofit of shopping centers. The paper investigates the retrofit opportunities to exploit ventilative cooling in retail buildings taking into account climate condition, architectural features and level of retrofit. As case studies we referred to the reference buildings identified within the CommONEnergy project as representatives of the EU building stock. Typical architectural archetypes of shopping centers such as atria and galleries revealed to be suitable for the integration of natural ventilation strategies. A climate analysis showed that the ventilative cooling potential is suitable for all the eleven climates analyzed with difference in the percentage of hours of utilization and in the airflows needed to offset the internal gains.

A ventilative cooling strategy involves the whole building envelope as vents and openings can be located on both façade and roof to exploit buoyancy due to temperature difference between shops and central spaces and along the atrium height. Technical components needed for ventilative cooling are already available on the market but the performance of a ventilative cooling strategy is strictly dependent on building design and indoor spaces layout.

Considering that an indoor space of a shopping center highly interacts among each other, a multizone based analysis of airflows is needed to evaluate the ventilative cooling strategy effectiveness and to assess potential energy savings. The Integrated Modelling Environment under development within the CommONenergy project allows predicting airflows throughout a building by performing coupled thermal and airflow building dynamic simulations. ■

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