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International Ventilation Cooling Application Database

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Abstract
The currently running International Energy Agency, Energy and Conservation in Buildings, Annex 62 Ventilative Cooling (VC) project, is coordinating research towards extended use of VC. Within this Annex 62 the joint research activity of International VC Application Database has been carried out, systematically investigating the distribution of technologies and strategies within VC. The database is structured as both a ticking-list-like building-spreadsheet and a collection of building-datasheets. The content of both closely follows Annex 62 State-Of-The-Art-Report. The database has been filled, based on desktop research, by Annex 62 participants, namely by the authors.
So far the VC database contains 91 buildings, located in Denmark, Ireland and Austria. Further contributions from other countries are expected.
The building-datasheets offer illustrative descriptions of buildings of different usages, sizes and locations, using VC as a mean of indoor comfort improvement.
The building-spreadsheet highlights distributions of technologies and strategies, such as the following. (Numbers in % refer to the sample of the database's 91 buildings.)
It may be concluded that Ventilative Cooling is applied in temporary European and international Low Energy buildings. Still it's not really widespread. Obstacles are challenges as regards noise, dust, weather and burglary, proving the research efforts of the Annex being necessary. The VC database forms a worthwhile basis for both dissemination and further research targets.

Ventilative Cooling; IEA ECB Annex 62; Hybrid Ventilation

1. Introduction

Within IEA (International Energy Agency) Energy in Buildings and Communities Programme (EBC, formerly ECBCS), there's Annex 62 Ventilative Cooling (VC) project. Annex 62 coordinates international research towards extended use of VC, forming an attractive and energy efficient solution to reduce the cooling load and avoid overheating of both new and renovated buildings.

Within this Annex 62 the overarching joint research activity of building an *International VC Application Database* has been carried out, which is presented in this paper. Ventilative Cooling covers a broad range of measures, applying ventilation flow rates to reduce the cooling loads in buildings, either by withdrawing heat from the building or by offering increased air velocities and thus increased personal convective and latent heat transfer.

At first glance, Ventilative Cooling seems to be an easy choice. At second glance it still is an excellent choice, but forming a truly sensitive system, which interdependencies have to be studied and understood thoroughly. Interdependencies exist towards climate zone, topography, building-use, -shape and -size, users' comfort expectations as regards thermal and acoustic comfort as well as security levels and many other aspects.

Facing this tremendous variety of parameters and options the idea of the *International VC Application Database* was to firstly offer an illustrative collection of buildings with VC and secondly compare the solutions applied, find typical "patterns" and draw conclusions on both application guidelines to be published and for further R&D to be carried out.

The first aim is addressed by the "building datasheet"-section of the VC database: So far slightly less than 100 buildings with VC applications have been identified and have been documented in precisely structured description-forms, the "building datasheets". The paper in hands presents two of them in chapter 3.

The second aim is addressed by the effort of a simplified correlation analyses, investigating frequency distributions of specific building qualities and VC solutions. The paper in hands presents first conclusions in chapter 4.

In order to support both targets the database was structured carefully towards utmost comparability of its entries, which is presented in chapter 2.

2. Database Structure

The database defines a rigid matrix of specific building qualities for each building entry. The matrix is applied to both the building datasheets and the ticking list of the Excel-based database itself. The main topics of this matrix are:

- **General building Specifications**:
  Address, Building Category, Year of Construction, Special Qualities, Location, Climate
- **Vent. Cooling Site Design Elements**
  Solar Site Design and Wind Exposure Design, Evaporative Effects from Plants or Water
- **Vent. Cooling Architectural Design Elements**
  Shape, Morphology, Envelope, Construction & Material
- **Vent. Cooling Technical Components**
  Airflow Guiding Components, Airflow Enhancing Components, Passive Cooling Components
- **Actuators, Sensors and Control Strategies**

- Building Energy Systems
  Heating, Ventilation, Cooling, Electricity
- Building Ownership and Facility Management Structures
- Acknowledgements

Since the database was meant to be filled by different researchers, and in fact has been, it was crucial to offer precise explanation of each category's exact meaning. This has been done in a specific "building-spreadsheet manual".

Moreover, the database's categories closely follow the structure of chapter 5 within the Ventilative Cooling State-of-the-Art-Review, having been created at the beginning of the Annex 62 research. [1]

So far, there's number of close to 100 entries in the VC database, still growing. It is planned to present the building datasheets in public via the IEA Annex 62 web presence at Venticool platform. [2]

3. Exemplary Database Entries

3.1 Cork County Hall

The Cork County Hall is a 1960’s brutalist style office tower in the South of Ireland. One of Irelands tallest buildings, it underwent refurbishment in 2006 with the introduction of an automated double skin façade using glass cladding installed externally to the existing 1960’s concrete and window envelope. This provided improved solar protection reducing incident solar radiation and also enhanced the control aspect of the façade enabling night cooling as a strategy as well as removal of heat build-up in summer months. The external louvers incorporated a ‘hard’ coating to reduce the ‘g’ value (solar transmission reduced). The external operable glazed louvers protect the natural ventilation openings from wind and rain which allows the windows to be opened in any weather conditions.

Figure 1: External View of the refurbished building (left)
and detail of retrofitted second skin with automated glazed louvres (right)

The tall building can get very windy at the upper floors and the new external louvers make it possible to achieve effective natural ventilation. On the west façade, the effects of evening solar gain can be mitigated using ‘free’ cooling throughout the nighttime period. The control strategy relies on monitoring of external wind speeds, rain precipitation & air temperature. When conditions are acceptable the natural ventilation system is activated. Night cooling is also implemented and is controlled on air temperature. In summer operation before 12 noon louvres on the east façade track sun and reflect excessive solar gains away from the building while louvres on the west façade are open. After 12 noon the functions are reversed respectively. In winter louvres are open to allow beneficial heat gains into the building during the daytime.

Rain sensors drive the external façade louvres to the 45 degree position when protection is required. Finally the louvres close when outside air temperatures are less than 6°C or wind speeds are greater than 10 m/s. The project has been a major success in rejuvenating an old 1960's high rise naturally ventilated building. The old façade had no thermal retention properties. The natural light levels are much improved, with reduced glare while eliminating artificial light during the day on all perimeter offices. The operation and maintenance of an active façade is considerable. While providing a passive role in maintaining a comfortable indoor environment, it is important to keep the client informed of the need to provide adequate resources to maintain the louver actuators and clean the glass. The appearance of the building is very appealing. The new façade will extend the lifetime of the building for another 50 years. To investigate how the ventilative cooling system has performed a survey of occupants was completed.

Post occupancy evaluation survey

A post occupancy evaluation survey was completed in 2014 as part of Annex 62 subtask B & C activities. This involved an online questionnaire with a range of questions covering issues related to thermal comfort and the various perceived influential factors. In total 99 responses were received from a population of 500 building occupants. Table 1 below outlines 3 key summary questions with figure 3 presenting the results from the survey.

Table 1: Selected Questions from Occupancy Evaluation Survey

Question	Description
9	During the warmer months, how satisfied are you with the temperature in your workspace?
10	When you are dissatisfied, how would you describe the temperature?
17	If you could move to a workspace with air conditioning but no openable windows, would you?

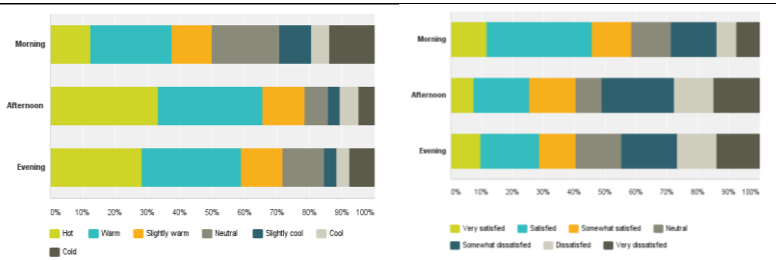

Figure 2: Results from survey questions 9 (Right) and 10 (Left).

From the findings we can see that during the warmer months there is a higher level of satisfaction in the morning (70%) with the internal environment with similar trends for the afternoon and evening. Approximately 55% of respondents were either satisfied or neutral during these evening periods. The overriding description of the internal temperature when people are dissatisfied is that it is “hot” or “too hot”. This would suggest that there is more work required to increase the “perception” of the ventilative cooling system in the building and to also reduce perceived internal air temperatures. However when occupants were asked whether they would move to an air conditioned workspace given the choice the overwhelming response (92%) was to remain in the naturally ventilated office space. This is encouraging and suggests that a higher tolerance is present when access to outside air is available.

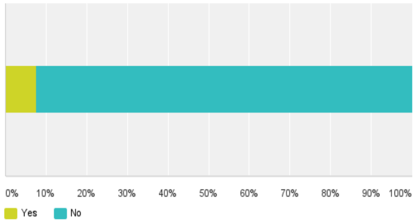

Figure 4: Results from survey question 17

3.2 Home for Life

Home for life is an experimental house built in Lystrup near Århus, Denmark in 2009 (urban environment). It is the result of an interdisciplinary project which synthesizes the parameters of comfort, energy use and architecture into a holistic entity. Home for Life complies with the Active House principles and fulfills the energy and indoor climate targets of 2020 Danish regulations (nearly zero energy building-nZEB) [3].

Fig. 1 South East view of the building

The climate of the area is temperate (Cfb Köppen-Geiger climate classification), moist with adequate precipitation in all months and no dry season. The summer is mild with the warmest month below 22°C.

The house is an $1^{1/2}$ storey single family building with a double-pitched roof with an off-center roof ridge. It has 190 m^2 of floor space and the opening area is equivalent to 40 % of the floor area (twice the area of a traditional house). On top there is a large south-facing roof surface for maximum energy generation. A solar heat pump and 7 m^2 solar collectors generate energy for heating and hot water, while 50 m^2 photovoltaic cells generate surplus electricity (9 kWh/m^2/year). It is a light wooden frame construction with additional steel beams. Dark colored natural shale is used for covering the envelope creating a uniform appearance of the building. Well insulated walls and roof, as well as energy efficient windows are used ($U_{env.}$ value of 0.07-0.1W/m^2K).

The interior of the house is divided into several zones. Kitchen and common rooms are on the ground floor and they are the core of the house. Living room, WC and facility room are on the first floor and can be easily accessed by the stairs. Several doors to the outside and large openings create good interaction between indoors and outdoors and multiple ventilation paths. The window openings and skylights are placed strategically to enhance the performance of natural ventilation by the use of wind and stack-effect, as well as ensuring high amount daylight entering all rooms.

During the winter, air enters, with respect to the ventilation needs, via the mechanical ventilation system with heat recovery. The air is circulated into the bedrooms and living rooms and exhausted from the kitchen and bathroom. During summer, fresh air enters through openings and controlled by sensors. This ensures that the home is not ventilated more than necessary (energy penalty). Natural ventilation replaces the mechanical system during summer and reduces energy consumption (hybrid system). Night ventilation and comfort ventilation is possible by automated window control, utilizing the stack-effect via the open staircase. Automated exterior sun screening is used to control the amount of light and heat entering the building through the windows.

Chain actuators operate façade and roof windows. Sensors that register temperature, CO_2 and humidity in all rooms and an outside weather station are combined with an intelligent control system. Outdoor weather station collects information also about the wind, rain and solar irradiation.

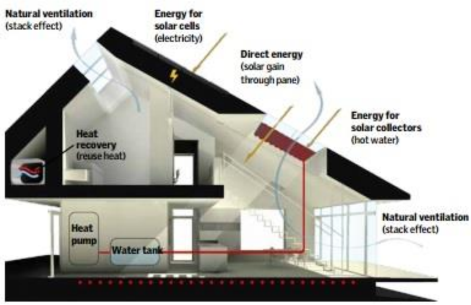

Fig. 2 Hybrid ventilation strategy and energy systems

4. Simplified Application Correlation Analysis

So far the VC database contains 91 buildings, located in Denmark Ireland and Austria. Further contributions from other countries are expected until CLIMA 2016 conf. The buildings have been identified by comprehensive and specifically educated desktop research. The building-spreadsheet highlights distributions of technologies and patterns of strategies, such as the following. (Numbers in % refer to the sample of the database's 91 buildings.)

- **Building Use** is dominantly office in (55%), educational (21%) and others (22%). Only 8% residential.
- **Location** is dominantly urban (60%)
- **Ventilative Cooling Site Design Elements** are applied in 65%, quite equally distributed between Solar Site Design, Wind Exposure Design and Evaporative Effects.
- **Ventilative Cooling Architectural Design Elements** are applied in 95%, dominantly by Morphology, Envelope and Construction & Material (66% to 78%), less by Form (49%).
- **Airflow Guiding Ventilation Components** are used widely in 99% of the buildings, dominantly by Windows, Rooflights, Doors (96%), significantly more seldom by Dampers, Flaps, Louvres (44%) or by Special Effect Vents (5%).
- **Airflow Enhancing Ventilation Components** are applied in 66%, fully dominated by atria (63%), with some chimneys (16%) and only very rare cases of others.
- **Passive Cooling Components** are used in 26%, dominantly by Convective Cooling Components (22%), with only very rare cases of others.
- **Actuators** are identified in 66%, dominated by chain actuators (57%), followed by Linear Actuators (9%).
- **Sensors** are identified in 88%, including the frequent use of Temperature, Humidity, CO_2, wind, rain and solar radiation
- **Control Strategy** is reported as hybrid in 58%, as automatic in 29%, as manual only in 4%.

5. Conclusions and Prospect

The Annex 62 joint research project of *International Ventilative Cooling database* illustrates that Ventilative Cooling is used not only in traditional, pre-Air-Condition Architecture, but also in temporary European and international Low Energy and Net Zero Energy Buildings. Still it's a technology far from being widespread. Obstacles are limited cooling load, challenges as regards noise, dust, weather and burglary, proving the research efforts of the Annex being more than necessary.

The work on the database will continue through 2016. The authors welcome any nominations of additional entries, especially from warm climates.

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