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Energy analysis of a decentralized ventilation system compared with centralized ventilation systems in European climates: Based on review of analyses

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ABSTRACT

In this study, the decentralized ventilation (DV) performance of a small air ventilator to replace natural ventilation for use in urban areas is analyzed and compared to conventional centralized ventilation (CV) systems in European climates. Selected European weather conditions were used to determine acceptable conditions for the operation of fan-assisted ventilation systems and to analyze the decentralized ventilation system's cooling and heating loads. Entire fan and pump loads of DV system are numerically calculated based on published data. Compared with a conventional centralized ventilation system, this system has shorter air transport distances and therefore entails lower pressure losses. In a decentralized system, fan speed and airflow rate are adjusted simply and effectively depending on indoor thermal conditions. A radiant panel with decentralized ventilation system (RPDV) is shown to have the lowest heating, ventilation, and air conditioning (HVAC) energy consumption because it not only minimizes supply and exhaust air pressure losses, but can also be operated as a fan-assisted natural ventilation system during periods when outdoor air can be used without additional thermal loads. Based on numerically calculated and measured data, this study newly adds fan and pump energy analysis of decentralized ventilation system compared to centralized ventilation systems. This study shows the fan and pump energy consumption with analysis of fan-assisted DV system considering outdoor weather condition in European climate.

1. Introduction and background

In general, ventilation strategies are categorized into three types: natural ventilation, mechanical ventilation, and hybrid ventilation [1]. Natural ventilation (NV) is an effective passive cooling strategy to save energy and to provide good indoor air quality. However, these systems also present a significant disadvantage in that they are highly influenced by outdoor environmental conditions, and their applicability is therefore unfavorable in conditions such as high outdoor air pollution, excessively cold or hot weather, rain, or exposure to ambient noise. Buildings in urban areas are generally exposed to high traffic noise levels, such that even in comfortable weather building tenants are close to the openings. Due to this, such buildings generally do not use NV systems. In order to overcome these disadvantages, hybrid ventilation systems are recommended.

Hybrid ventilation (HV) combines natural ventilation and typical mechanical ventilation to reduce HVAC energy demand based on outdoor thermal conditions [2]. During hot (or hot and humid) or cold seasons typical centralized mechanical ventilation mode is used whereas, during intermediate seasons, when outdoor air conditions are mild or cool, the system uses natural ventilation modes for saving building energy [2]. HV system can use a broad range of ventilation strategies for adapting to local climate conditions [2]. HV is also categorized into three types [1,2]: fan-assisted natural ventilation, natural and mechanical ventilation, and stack- and wind-assisted mechanical ventilation.

Typical decentralized ventilation (DV) is a type of traditional mechanical ventilation that implements in similar method to fan-assisted natural ventilation [2]. However, fresh outdoor air is supplied and distributed into the room by passing through a compact decentralized air-handling unit rather than being utilized directly. Many publications have presented and discussed these systems' potential as a viable replacement for centralized ventilation systems [2–7].

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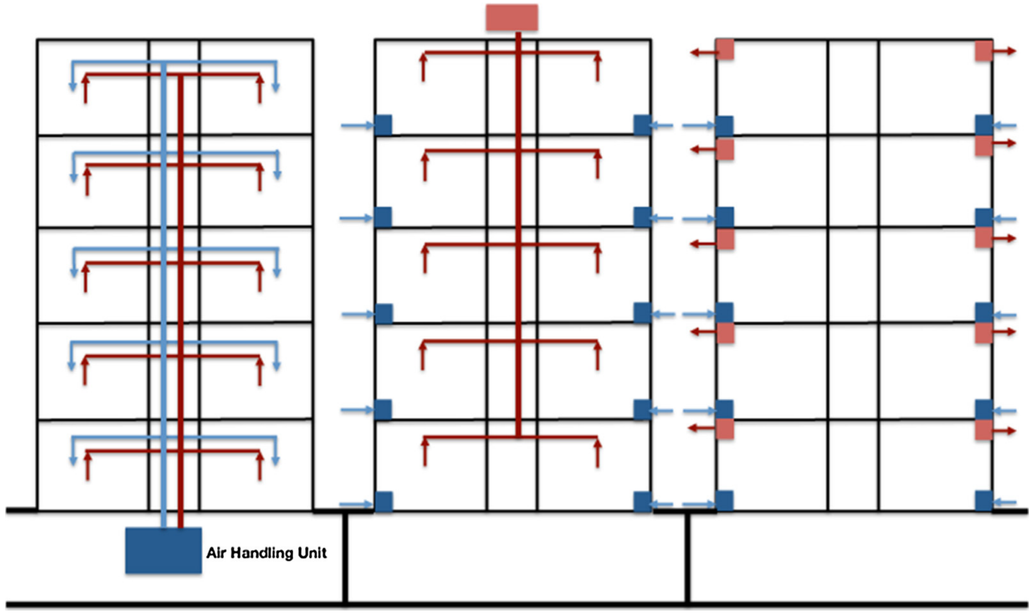

Fig. 1. Comparison of centralized, semi-decentralized, and decentralized ventilation systems, based on Mahler and Himmler [8].

Schematics of typical centralized, semi-decentralized, and decentralized ventilation systems are shown in Fig. 1. Typical centralized ventilation (CV) system is most commonly used, but has long supply and exhaust air distribution passages with ducts [2]. Semi-decentralized ventilation directly supplies outdoor air at the façade or under the floor or the ceiling and exhausts air to a general centralized exhausting system. Decentralized ventilation has the shortest air distribution passage as individual compact air handling units which have air filter, heat exchangers and fans control each room's air conditions [2].

In order to reduce ventilation energy demand, DV are usually combined with radiant panel systems to provide heating and cooling. Compared to CV, DV has four main advantages [5,7,9]. For starters, DV can simplify individual zoning control in spaces, as outdoor air supply volume can be simply controlled by fans in compact decentralized ventilation units (CDVU). These systems are less influenced by outdoor environmental conditions (e.g., high stack or wind pressure) than natural ventilation systems and thus can constantly supply air into a room. Second, DV minimizes duct space and therefore saves construction volume in buildings. In office buildings, the ceiling height is usually different from the floor height due to mechanical equipment and duct space. Eliminating this requirement allows the floor height to be lowered, which in turn reduces the construction volume, thus saving construction materials, while minimizing the construction time and room energy demand. For example, if DV saves 30 cm per floor in a multi-story building, a volume equivalent to approximately 1 extra story could be saved for every ten built [3,7,8]. Furthermore, DV significantly reduces pressure losses because of its shorter air passages. CDVU captures outdoor air at the façade, filters pollutants, heats or chills the air, and then blows it into the indoor space. In the intermediate seasons, CDVU can be used as a fan-assisted ventilator. Taking outside air from the façade, which has high thermal boundary layer, means to supply high thermal loads in summer and is inhomogeneous along the building height. Also odors and waste gases steaming from neighbor or cars etc. are more easily taken from the façade compared to centralized ventilation units. However, DV systems are not relatively influenced by outdoor environmental conditions. Although buildings are exposed to challenging environments for natural ventilation in the intermediate seasons, DV systems can be used in conditions such as high outdoor air pollution, in the rain and in high wind pressure because they include an air filter, electrical fans and a drainer. Furthermore, DV systems are connected to a damper, which reduces outside environmental noise and air fan noise.

Schematics of decentralized ventilation systems are shown in Fig. 2. And examples of such systems that have successfully implemented in Switzerland by the Chair of Building Systems at ETH Zurich and the company BS2 AG is also shown in Fig. 3. The main benefit of using façade type ventilation systems is their simple installation, but because of short distribution passage, they cannot distribute fresh air deeply into the space [2]. On the other hand, floor type ventilation can supply fresh air more deeply and does not occupy indoor space and but its system has higher construction time and costs than those of façade type [2].

The accompanying radiant ceiling panel systems usually carry a risk of moisture condensing on the panel surface, but in European countries like Switzerland there is no such risk because the average dew point temperature does not exceed the surface temperature

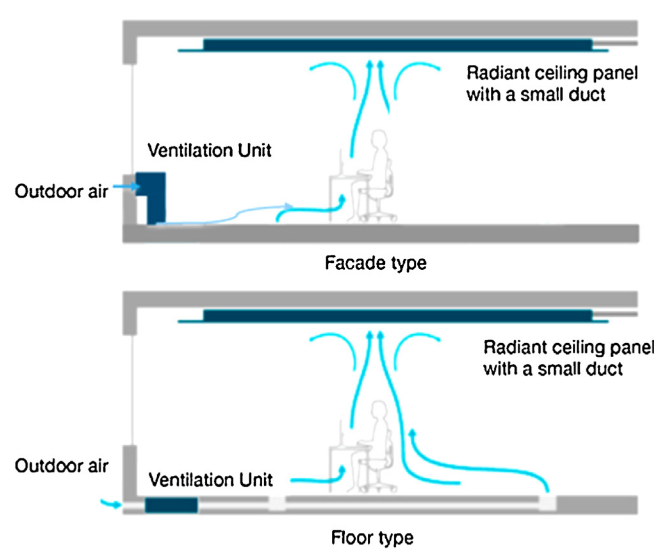

Fig. 2. Schematic of decentralized ventilation systems: façade type (top) and floor type (bottom) [2].