BALANCING FIRE SAFETY AND SUSTAINABILITY

THE ROLE OF NATURAL VENTILATION IN MODERN BUILDINGS

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INTRODUCTION

The integration of natural ventilation strategies into modern sustainable architecture has introduced new challenges for fire safety design and operations. Systems such as operable façades, stack ventilation, and double-skin façades are increasingly used to reduce energy demand and improve indoor environmental quality. However, these featuresintroduce greater uncertainty in fire dynamics, smoke movement, and firefighter intervention tactics [1].

QUESTIONS

While natural ventilation improves sustainability, it also creates unpredictable fire and smoke behaviour. This work explores its implications for fire safety through the following key questions:

HOW DOES NATURAL VENTILATION ALTER TRADITIONAL FIRE GROWTH AND SMOKE BEHAVIOUR IN BUILDINGS?

CAN NATURAL VENTILATION SYSTEMS UNINTENTIONALLY COMPROMISE COMPARTMENTATION AND EGRESS SAFETY?

WHAT DESIGN STRATEGIES CAN MITIGATE FIRE RISKS WITHOUT UNDERMINING SUSTAINABILITY GOALS?

STRATEGIES AND RECOMMENDATIONS

To align natural ventilation with fire safety, a combination of passive design, smart controls and performance-based solutions is essential:

Diagram of the stack effect (chimney effect) in a room [Wikipedia]

Photograph of One Angel Square (Manchester) with a double-skin façade. The building features an outer glass skin and an inner façade, forming a ventilated cavity in between. Automated louvers and operable windows in the outer skin open based on weather data, allowing air to flow into the cavity for natural cooling and exhaust [Wikipedia]

Naturally ventilated Sporting Grand Stand.

Naturally ventilated Airport Terminal.

FIRE DYNAMICS IN NATURALLY VENTILATED BUILDINGS

Natural ventilation changes fire behaviour by introducing uncontrolled airflow into compartments. This added oxygen increases the heat release rate and can accelerate flashover. Studies show that fires which decay in sealed rooms may become fully developed once an opening is introduced — a critical risk in high-fuel-load modern interiors. Open-plan designs and façade systems further complicate smoke movement. Instead of remaining in the room of origin, smoke finds alternate paths through natural ventilation openings. In double-skin façades, smoke can spread horizontally and vertically within the cavity, affecting multiple levels. These airflow routes — intended for passive cooling — can become smoke conduits during a fire, undermining compartmentation.

External conditions amplify this risk. NIST experiments revealed that a modest 10mph (16km/h) wind can drive flames through openings like a blowtorch, pushing hot gases into adjacent spaces at temperatures exceeding 600°C [8]. Similarly, the stack effect in tall atria rapidly lifts smoke to upper levels, threatening escape routes or triggering remote detectors and sprinklers.

Despite these risks, properly designed natural ventilation can support smoke control. Studies show that pressure-balanced cavity vents can limit smoke spread in double-skin façades, and CFD modelling confirms that early low-level venting reduces upper-atrium temperatures. With thoughtful integration, natural ventilation and fire safety can work hand in hand.

Automatic Closure Systems - Operable windows, vents, and façade dampers should be linked to smoke or heat detectors. When triggered, automatic closure can restore compartmentation and reduce oxygen supply, limiting fire growth – essentially preventing the fire from becoming ventilation-controlled.

Integrated Smoke Venting - Atra roofs and vertical shafts should include dedicated smoke vents, which may be passive (e.g., ridge vents or skylights) or mechanical. Double-skin façade cavities can also serve as vertical smoke exhausts when properly designed. CFD smoke modelling helps optimise vent size and activation timing for worst-case scenarios [9].

Enhanced Suppression and Detection - Codes such as NCC 2022 mandate full sprinkler coverage in atrium buildings, and designers should consider extending protection around façade openings and balconies. Intelligent mist systems and detectors near vents can provide rapid response and early smoke warning. Fire protection must match the openness of the architecture — sensing and suppressing fire wherever it may spreadworst-case scenarios [9].

Performance Based Design - A performance based approach is essential for fire safety in naturally ventilated buildings. Fire modelling and, where feasible, full-scale testing can identify critical risks—such as wind-driven smoke spread—before construction. In the absence of prescriptive code coverage for features like double-skin façades, engineers must demonstrate compliance with performance requirements. Sharing validated outcomes helps guide future codes and supports the safe integration of sustainable design features [10].

A fan, simulating wind, changes airflow and smoke conditions during experiments in a seven-story high- rise abandoned apartment building on New York City's Governors Island [Wikipedia]

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REFERENCES