Under pressurisation

In the event of a fire outbreak in any high-rise residential building, the communal stairwell/staircase can serve as a vital evacuation route for residents and an operational avenue for those firefighters in attendance. For this reason, such spaces need to be maintained as smoke-free environments. Izabela Tekielak-Skałka evaluates the protection of stairwells from smoke ingress

LAST DECEMBER, the Department for Levelling Up, Housing and Communities put forward proposals to mandate second staircases for all new tower block developments over 30 metres in height. At the time, it was the latest move in the Government's updating procedure for statutory guidance underpinning Building Regulations to ensure the safety of occupants. A 12-week consultation process duly ensued and closed in mid-March this year.

Late last month, Michael Gove (Minister of State for Levelling Up, Housing and Communities) announced that any new regulations focused on second staircases would not be enforced ahead of 2026. As reported by Pinsent Masons LLP, developers will be afforded a circa 30-month 'transition' period (beginning when the revisions to Approved Document B are published), during which time Building Regulations applications would still be allowed to follow those fire safety requirements already in place.

Planning expert Nicholle Kingsley (Partner at Pinsent Masons LLP) explained: "Michael Gove's latest statement is an attempt to resolve some of the difficulties and uncertainties caused as a result of Government's changes in position since December 2022."

In the Government's initial consultation, the proposal was to mandate two staircases in all new residential buildings in England above 30 metres in height. However, in July, Gove confirmed the Government would impose the 'second staircase' ruling at the lower minimum height for buildings rising 18 metres or above.

According to Kingsley, uncertainty around the new rules has led to developments being put on hold, subsequently contributing to the fall in residential-centric schemes being put forward for construction.

The Secretary of State has made it clear that existing and upcoming single-staircase buildings would not later need to have a second staircase added if they're constructed in accordance with the relevant standards, well-maintained and properly managed. However, early compliance with the new requirements – even during the transitional period – may be preferred by some and, in any event, should at the very least be considered.

Pressure differential systems

Pressure differential systems are not common in the UK. Widely adopted across mainlaind Europe, as well as in the United States and the United Arab Emirates, they're deemed mandatory in Poland for the majority of structures of 25 metres and above in height.

At SMAY Ventilation Systems, we've conducted a great deal of research in order to mitigate those issues noted for such systems – ie system reliability, compatibility with evacuation strategies and, in particular, any failure to cope with the 'stack effect' in high-rise structures – and realise a fully-functional pressure differential system for adoption in high-rise structures.

To be clear, the 'stack effect' is best described as the directed movement of air in vertical spaces realised due to differences in temperature. This results in uneven pressure distribution, in turn engendering difficulties around maintaining the right pressure in a pressurised stairwell.

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For pressure differential system design and application in a low-rise or medium-rise building, the key task is to maintain an overpressure of 50 Pa in the protected space of the stairwell when doors are closed and to create airflow from the stairs to the fire floor when the door is open. Not so easy in high-rise buildings, though. where the main challenges are height, flow resistance and the aforementioned 'stack effect'.

As stated, the 'stack effect' influences the pressure inside vertical spaces within the building, such as stairwells and elevator shafts. The pressure difference is particularly evident in winter when outdoor temperatures can fall below the 0°C mark. As a result, the pressure increases in the upper part of the stairwell. At the same time, the pressure drops in the lower portion.

Research project

Back in 2012, we researched a pressure differential system in a 62 metre-tall building in Warsaw incorporating 23 storeys and two stairwells. Both were protected by a pressure differential system consisting of a multipoint air supply and a relief damper in their upper parts. Firefighting lobbies were equipped with air inlet points from a separate fan and transfer dampers employed in the wall between the lobbies and corridors to compensate for smoke and air extract from the corridors.

The core aim of this SMAY Ventilation Systems study was to discern the real pressure distribution during pressure differential system operation. In the event of fire, the pressure differential system in the stairwell would be activated. At the same time, the pressurisation system protecting the firefighting lobby and the corridor air extraction on the fire floor were activated. Fire ventilation on other floors remained inactive.

The test rig was equipped with two pressure differential measurement devices. The devices allowed for measuring overpressure in the stairwell. The first measuring set was placed on the ground floor and the second on the uppermost floor. The temperatures of the outdoor air and the air inside the stairwell were recorded. The research included a full-scale test in the 62 metre-high building and computational fluid dynamics (CFD) analysis.

Examining the results

System testing was performed in winter conditions when the outside air temperature was between -18°C and -16°C. The temperature in the stairwell was +20°C. This temperature difference influenced the pressure distribution inside the building. A negative pressure of -45 Pa was measured in the lower part of the stairwell, and a positive pressure of +38 Pa in the upper part when the pressure differential system was inactive.

When the pressure differential system was activated, an airflow of 5,500 m^3/h was directed into the stairwell. The airflow changed the pressure distribution inside the stairwell. The pressure in the upper part of the stairwell increased to +70 Pa and -10 Pa in the lower part of the stairwell after activating the pressure differential system.

Clearly, the pressure was not increased to the expected level of 50 Pa in all parts of the stairwell. It's also worth noting that a negative pressure was created in the lower part of the stairwell, which means the stairs were not correctly protected.

Such operation of the pressure differential system in its simplest, but also most commonly used arrangement – ie multipoint supply and pressure relief damper – means there's a risk of smoke suction on the lower floors and excessive overpressure in the upper portion of the

building, which may result in residents being unable to open the door.

Numerical analysis was used to further investigate the pressure distribution inside the building. The analysis aimed to answer the question of how to improve the pressure distribution inside a stairwell in a high-rise building.

These analyses were performed in the Ansys Fluent simulation software. The model affords users the ability to consider many important issues, such as the geometry of the stairwell and any leaks, airflows and temperature changes. The stairwell model, all lobbies and the selected corridor were developed in the first stage of the process.

Numerical analyses

Numerical analyses were performed for numerous variants of the pressure differential system:

- the multipoint air supply with a total airflow of 5,500 m^3/h (ie the same as the volume used in the research) and the relief damper
- the Flow System, controlled by pressure sensors, with supply in the lower and middle parts of the stairwell and outlet points in the upper part (the idea of this solution is to create airflow inside the stairwell, with the flow intensity depending on the pressure measurement value near the air inlet)

The CFD simulations were performed for winter conditions and based on temperatures similar to those obtained from tests in the building. A much-improved pressure distribution was achieved using the Flow System rather than a system with a multipoint air supply. It allowed the overpressure to be maintained at the desired level inside the entire stairwell. Additional air inlets, such as the one used in the middle height of the stairs, were employed only to supplement the air flowing through leaks.

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The results highlight that it's worth conducting CFD analysis when designing pressure differential systems. Such analyses can be performed for various temperature conditions and fire ventilation systems. They allow for an easy prediction of the pressure differential system's operation.

Using this tool, designers can avoid errors such as too low or too high overpressure and realise the configuration of an effective pressurisation system.

Design essentials

What are the 'essentials' when designing a pressure differential system for a high-rise building? Here, we've presented the operation of the pressure differential system in winter, but this system should also function well in summer and during isothermal conditions.

The ventilation system in a high-rise building should operate slightly differently in each period. As such, ventilation systems based on a constant volume flow of air may only work correctly in specific periods.

A much better solution is an active pressurisation system that generates controlled airflow inside the stairwell. The airflow creates resistance, which may positively affect the pressure distribution inside the stairwell. Sensors and flow-regulating devices are needed to control this airflow. This is precisely why the active system is equipped with pressure sensors and fans 'co-operating' with a frequency converter.

The largest volume of airflow is required in winter conditions when the 'stack effect' is at its greatest. In isothermal conditions, the airflows supplied to the stairwell are far smaller.

Measurements and analyses show that the effectiveness of the pressure differential system strongly depends on the outside temperature. This is particularly evident in relation to high-rise buildings. Systems composed of a multipoint air supply and a pressure relief damper will not guarantee the correct pressure distribution.

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Watch the webinar entitled 'The Key to Safe Evacuation: Pressure Differential Systems' at *www.smay.pl/pds/*