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Wind effects on mechanically ventilated asbestos containment zone

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SUMMARY:
Asbestos abatement from buildings is performed under controlled conditions, maintaining a depressurization within the containment volume, to prevent the suspended particles from escaping into the outdoor environment. Although different government authorities have established the requirement for this depressurization, external wind effects can cause momentary breaching of this containment achieved by means of mechanical ventilation system. This paper aims at analyzing and quantifying these wind effects by performing wind-tunnel tests on a reduced-scale model of an idealized building installed with a mechanical ventilation system. Tests are performed for two wind directions (i.e. α = 0° and α = 45°). The results show that negative internal pressure is maintained for the tested cases in all instances. However, further detailed analyses of internal-external pressure differences reveal that a breach in containment may occur at localized regions where high external suction pressure occurs due to the separation of flow at building edges.

Keywords: asbestos abatement, mechanical ventilation, wind-tunnel test

1. INTRODUCTION

Asbestos abatement from building interiors is to be performed under controlled conditions to prevent the suspended asbestos fibers from escaping into the outdoor environment, which is fatal to human health if inhaled. The containment volume is, therefore, required to be maintained at a lower pressure compared to the outdoor by installing a mechanical ventilation system. This is to ensure that there is no outflow from the containment through any unintended openings such as leakages and any outflow is only through a negative pressure unit (NPU) installed with high-efficiency particulate air (HEPA) filter. Different countries around the world have set guidelines for this depressurization requirement, reaching from 5Pa to 20Pa (e.g., Great Britain, Health and Safety Executive, 2006). However, atmospheric wind interaction with the buildings may cause momentary breaching of this mechanically induced containment (Papadopoulos et al., 2018), due to the high external suction pressures on building facades. This paper aims to systematically analyze and quantify the effects of wind velocity and directionality on the mechanically induced depressurization established in an asbestos abatement zone. For this, reduced-scale experiments are performed in an atmospheric boundary layer wind-tunnel (ABLWT) by measuring simultaneously internal (P_i) and external (P_e) pressures. The building for testing is also installed with a correspondingly scaled mechanical ventilation system.

2.METHODOLOGY

The tests are performed at a geometrical scale of 1:40 in the ABLWT facility of Eindhoven University of Technology with a test section of 27 m length, 3 m width, and 2 m height. An ABL wind profile, representing a moderately rough terrain classification (VDI-3783, 2000) is developed using roughness elements and spires (Fig. 1a). The tests are performed on an idealized building (18 x 18 x 18 m^3 full-scale equivalent) with an asbestos containment volume on the upper half (18 x 18 x 9 m^3), see Fig. 1b. The ventilation system is designed for this containment volume to establish a depressurization of 20 Pa and an air change rate of 6 h^{-1}. This ventilation system would thus comprise forty air inlets with check valves, four NPUs, one air inlet for tuning, an airlock for materials, and an airlock for people (INRS, 2018). In addition, 16 leakage openings are also considered. The building and the ventilation system are scaled (respecting geometric, kinematic, and dynamic similarities), following the methodology by Le Roux et al. (2012). Table 1 shows the scaling factors adopted, where $\bar{U}$ is the velocity scale, $\bar{P}$ is the pressure scale, $\bar{Q}$ is the volumetric flow rate scale, $\bar{V}$ is the room volume scale, $\bar{S}$ and $\bar{L}$ are the section area scale and length scale of the ventilation components, respectively, $\bar{t}$ is the time scale and $\bar{f}$ is the frequency scale.

Table 1. Scaling factors used to design the reduced-scale building with a mechanical ventilation system.

Parameter	Scaling factor	Parameter	Scaling factor
$\bar{U}$	$\sqrt{2}$	$\bar{V}$	$1:40^3$
$\bar{P}$	2	$\bar{L}$	1:126
$\bar{Q}$	1:180	$\bar{S}$	1:225
$\bar{t}$	1:178	$\bar{f}$	178

External and internal pressures are measured and analyzed for two wind directions (α = 0° and α = 45°) for three wind speeds (4.4 m/s, 6.5 m/s, and 8.5 m/s in full scale at building height). External pressure sensors are installed close to each ventilation component on the facade and 26 internal pressure sensors are distributed on the internal walls and floor of the containment volume. Four Scanivalve MPS4264 pressure scanners (with 64 transducers each) are used to record internal and external pressures simultaneously for a duration of 180 s at a frequency of 800 Hz.

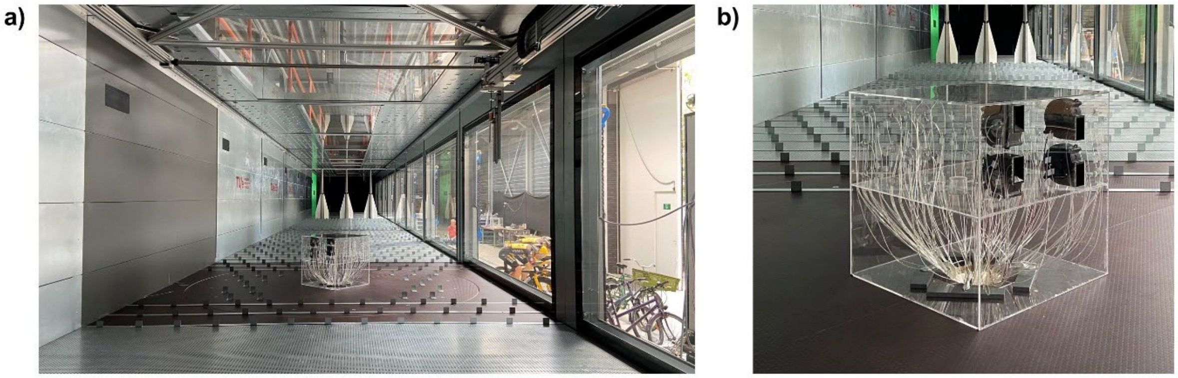

Figure 1. a) Photograph of the building in the wind tunnel; and b) close-up view of the building with mechanical ventilation system.

3. RESULTS AND DISCUSSION

The results are analysed and presented in terms of internal (P_i) and external (P_e) pressures. Irrespective of wind direction and velocity, P_i was found to be uniform throughout the containment volume (not shown in the abstract due to brevity). The boxplots of Fig. 2 show the temporal distribution of P_i, obtained at one internal sensor located on an internal wall, for α = 0° and α = 45° and for the three reference wind speeds. Overall, it is observed that P_i is maintained negative at all times and that the temporal average as well as the envelope of P_i is found to increase in magnitude with increasing reference wind velocity.

A breach in containment is likely to occur at locations where the magnitude of P_e is lower than P_i, i.e., when the differential pressure, ΔP is positive as per Eq. (1):

$$\Delta P = P_i - P_e > 0 \tag{1}$$

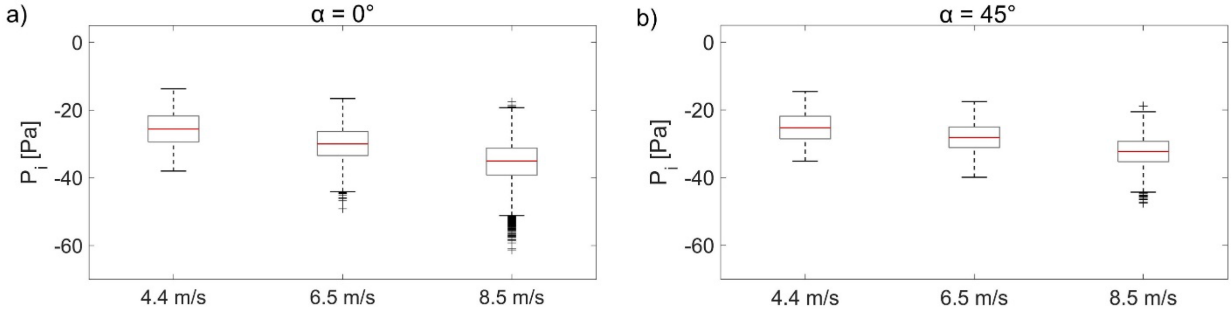

Figure 2. Internal pressure (P_i) distribution obtained at one internal sensor for (a) α = 0° and (b) α = 45°, with three wind speeds.

The percentage occurrence of a containment breach is quantified, with respect to the total duration of measurement (i.e., 180 s in reduced scale, corresponding to 8.9 hours in full scale, calculated based on the time scale indicated in Table 1), for all the locations of ventilation components where P_e is recorded. The analysis showed that the location and chances of a containment breach depend on the wind direction as well as wind velocity. Note that, the latter (effect of wind velocity) is not shown in this abstract due to brevity. Fig. 3a-b shows a spatial distribution of the duration of the containment breach for α = 0° and α = 45°, for a wind velocity of 8.5 m/s. Each dot represents the location of the ventilation component. It is observed that containment breach is more likely to occur at the regions of flow separation i.e., façade 1-2 and façade 3-0 for α = 0° and façade 2-3 and façade 3-0 for α = 45°. This is because in these regions the magnitude of the external suction pressures is high and exceeds the magnitude of the negative pressure within the containment zone. It can also be noted that the duration of the containment breach is higher where the time-averaged external suction pressure is larger.

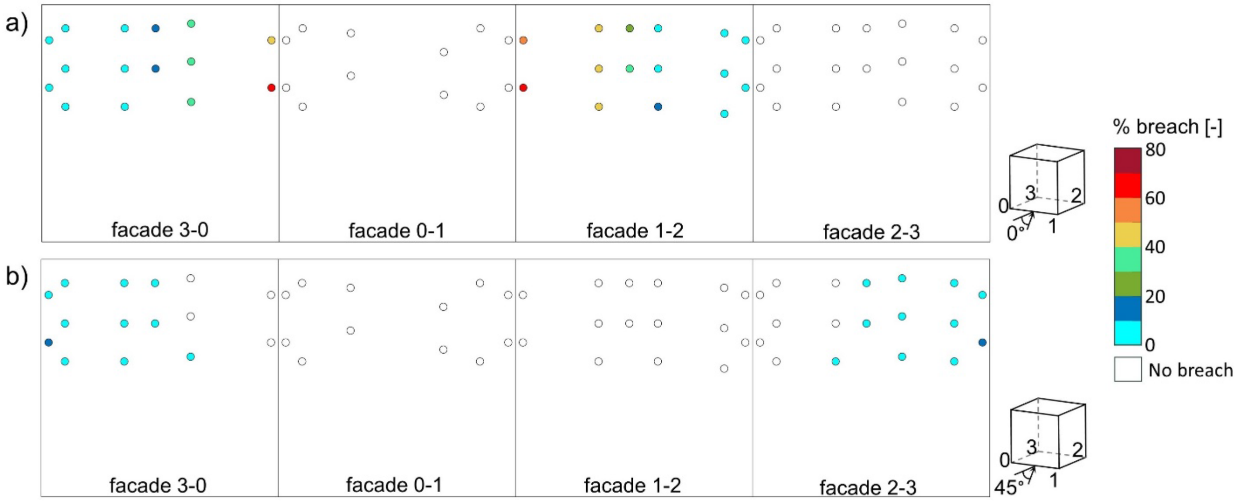

Figure 3. Relative duration of containment breach at the location of ventilation components for (a) α = 0° and (b) α = 45°.

4. CONCLUSIONS

ABLWT tests were performed on an idealized building installed with a mechanical ventilation system for asbestos abatement. WT tests for two wind directions (α = 0° and α = 45°) and multiple wind velocities showed that the internal depressurization established varies with wind direction as well as wind velocities. Although for all the cases considered the internal pressure was maintained to be negative in all instances, containment breach was found to occur at localized regions where high external suction pressure occurred due to separation regions. The implication of these findings on the asbestos abatement process will be discussed in the full paper.

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