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Air Quality and Pollution Dispersion using CWE

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SUMMARY: AIR QUALITY AND POLLUTION DISPERSION USING CWE

Four cases of computational pollution dispersion modelling were conducted for both indoor and outdoor air quality, in which the projects were located in New York, USA, Las Vegas, USA, Melbourne, Australia and New South Wales, Australia. Wind tunnel testing was also conducted for validation of various input parameters used in the computational modelling. The results of the modelling demonstrate how effective these types of simulations are in solving complex pollution dispersion/air quality problems, while using wind tunnel testing for cross validation and as definition of input flow boundary conditions. The results also show how the variety of simultaneous conditions can be solved in tandem, some which are physically not possible within wind tunnel testing due to scale and complexity of the modelling.

Keywords: Computational wind engineering, Pollutant dispersion, Ventilation

1. INTRODUCTION

Four cases of computational pollution dispersion modelling were conducted for both indoor and outdoor air quality, in which the projects were located in New York, USA, Las Vegas, USA, Melbourne, Australia and New South Wales, Australia. Wind tunnel testing was also conducted for validation of various input parameters used in the computational modelling. Quantities such as external wind, surface wind pressure, internal velocity, temperature, Predictive Mean Vote (PMV), Predicted Percentage Dissatisfaction (PPD), Age Of Air (AoA), CO, NOx, odor and cigarette smoke where analysed in the various studies. In this paper, the method and the results of the various tests are discussed.

2. COMPUTATIONAL MODELLING PROCEDURE

2.1. General Modelling Setup

1:1 scale 3D CAD models of the developments and surrounding context were generated and tested in Computational Fluid Dynamics (CFD) steady state modelling (see Fig. 1). Cross validation to 1:400 and 1:300 wind tunnel models from the façade cladding pressure studies was also conducted to define key parameters used in the simulations.

Variables such as atmospheric boundary layer winds, buoyancy, ambient temperature, reflected radiation, solar radiation, humidity, and evaporation are solved within the various simulations.

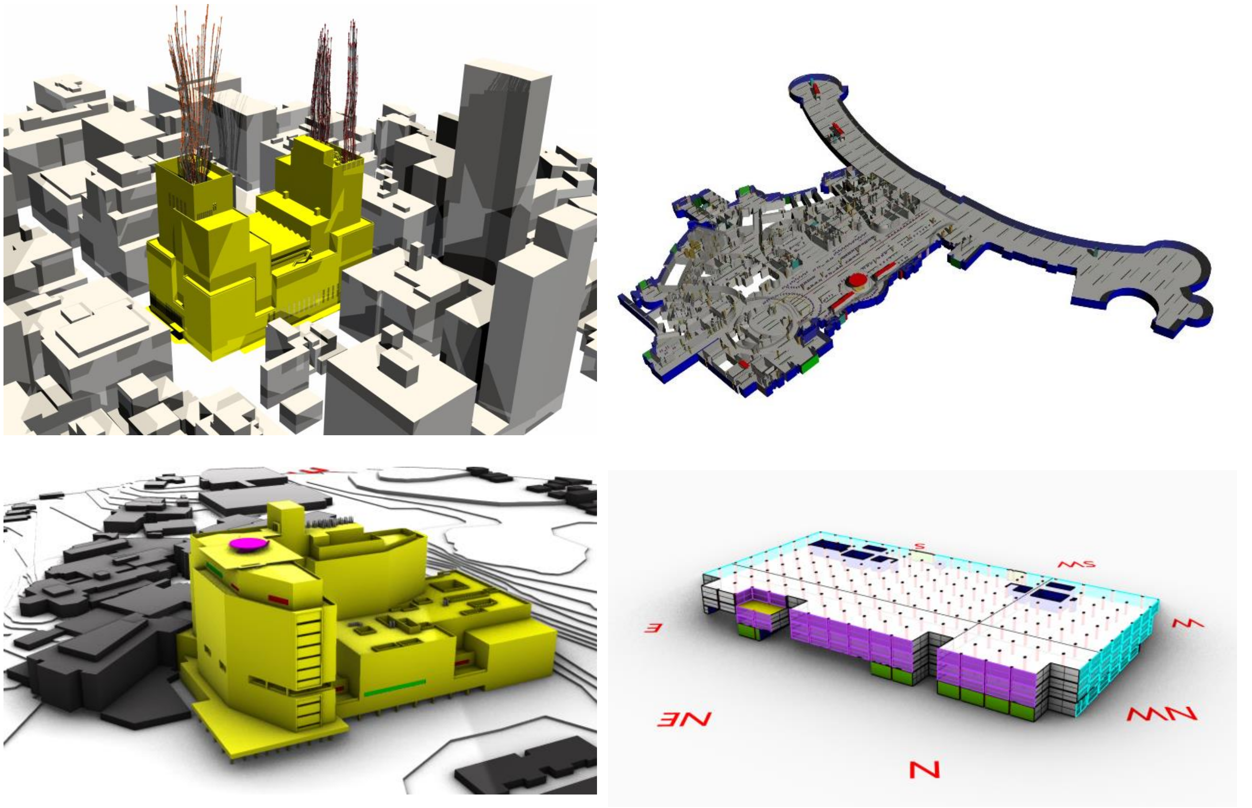

Figure 1. Outdoor Pollution Dispersion Stacks Model, New York, (Top left) Indoor Air Quality Model, Las Vegas (Top right), Outdoor Helicopter Pollution Dispersion Model, Melbourne (Bottom left) Outdoor/Indoor Car Park Natural Ventilation Air Quality Model, New South Wales (Bottom right).

3. RESULTS AND DISCUSSION

3.1. Case 1 - Outdoor Pollution Dispersion Stacks, New York

This study involved coupled simulations of the external wind, solar, temperature, odor and pollution dispersion including proposed external HVAC equipment, exhaust and inlet louvre layouts and were conducted to quantitatively assess the effectiveness of the proposed design as a result of the approaching winds and thereafter the resulting external environment conditions.

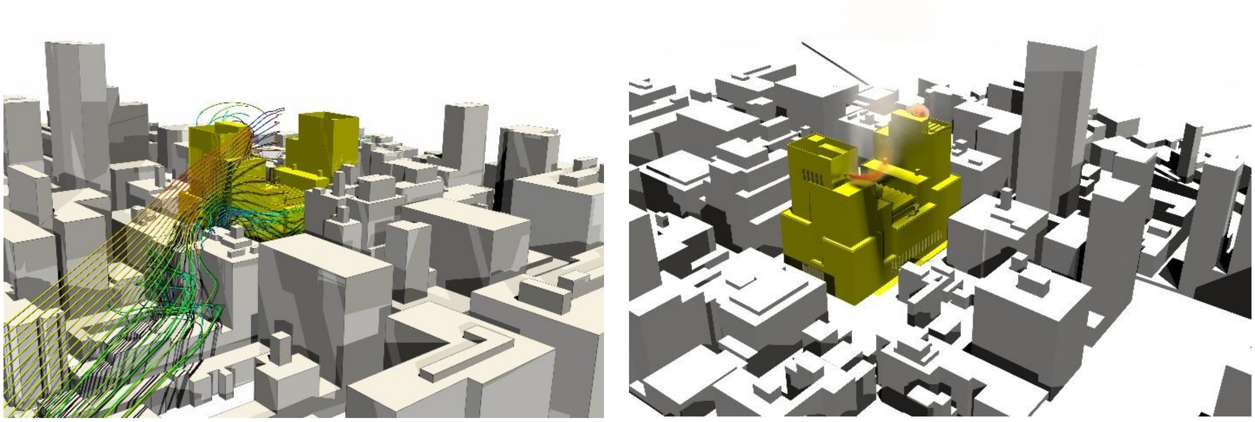

Figure 2. Outdoor wind CFD streamlines (Left) and NOx ISO volume dispersion from high level flues and chimney (Right).

The simulation's included modelling of the dispersion of gases from the boiler stack and flues, odor concentration dispersion from all low-level exhaust louvres and the temperature distribution on and around the subject development (Fig.2). The analysis indicated the proposed design configuration to be broadly effective in dispersing pollutant and odor for the more frequent wind conditions. Exhaust plumes may impede upon occupied levels of the development but are shown not to reach notable levels at ground level locations.

3.2. Case 2 - Indoor Air quality, Las Vegas

This study involved coupled stack effect, internal detailed CFD Simulations and Wind tunnel testing data to analyse the thermal stack effect and detailed cigarette smoke dispersion for both the Summer and Winter periods in the main area of a casino. The results of the analysis showed hotspots of high velocity in the transitional areas between the main casino floor and the back of house hotel entrances, largely the exfiltration of wind flow through the main entrances of the casino. However, the exfiltration of the air flow within the casino space also benefitted some areas as it actively removed smoke pollution from occupants (Fig.3).

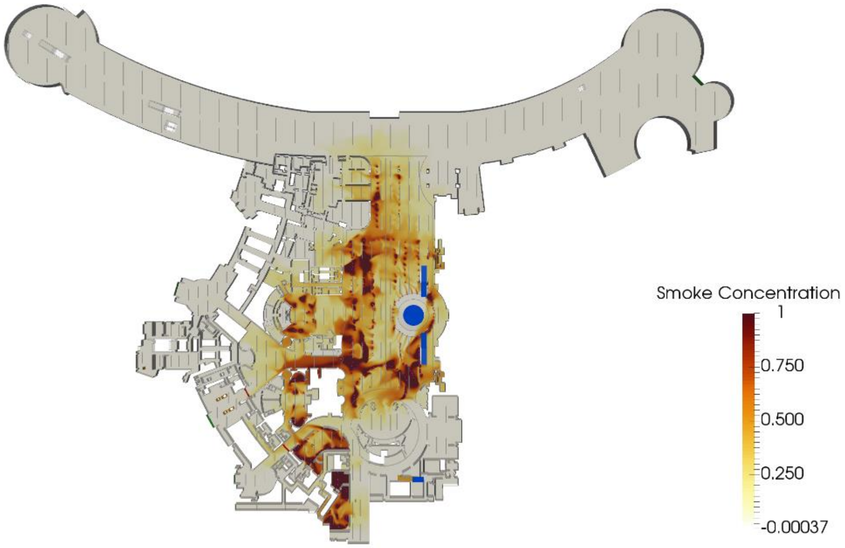

Figure 3. Indoor dispersion of cigarette smoke as generated from the main smoking area within Casino. The simulation accounts for the influence of the stack effect, external pressures at openings, heat loads within the building and mechanical system as well as the thermal properties of the external and internal building fabric.

3.3. Case 3 - Outdoor Helicopter Pollution Dispersion, Melbourne

This outdoor pollution study includes the effects of an idling helicopter in the models helipad. The results showed that HVAC re-entrainment is not only caused by low-pressure regions in the leeward side of the development, but also from the propwash of the rotorcraft.

Re-entrainment occurs as the flow from the exhausts, initially driven upwards by the atmospheric conditions and temperature difference, is recirculated back into the regions close to the air intakes of the buildings and/or pedestrian areas.

Fig. 4 shows the worst scenario (i.e. no wind): sources from the majority of the outlets, as well as the pollutants from the helicopter itself, are driven by the helicopter blades. Part of the flow from the isolation room stacks, the HVAC outlets and the kitchen exhausts is pulled towards the helicopter’s blades region and caught in the vortex recirculation.

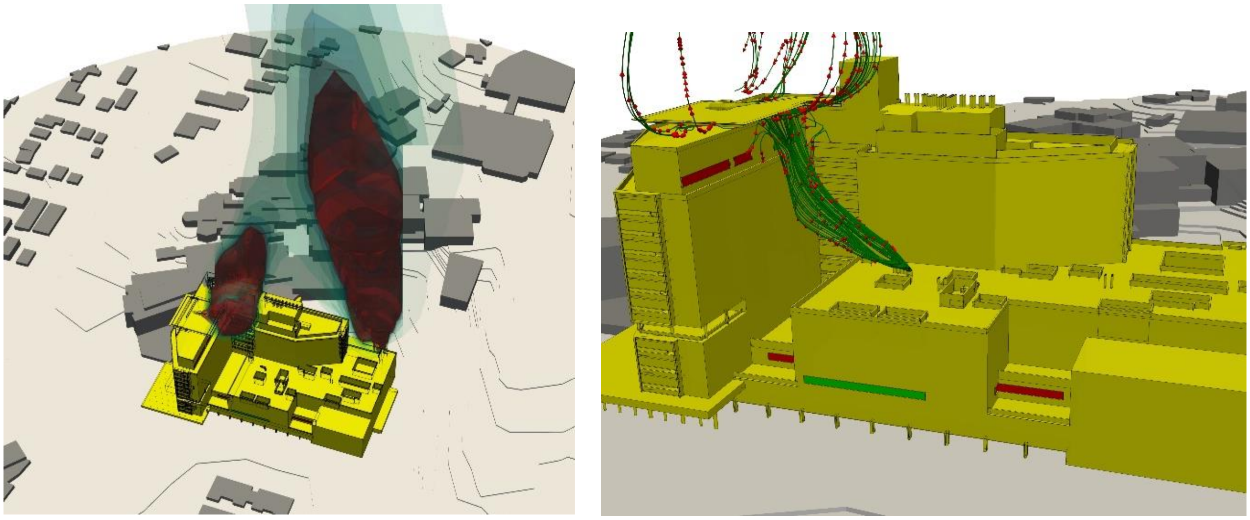

Figure 4. NOx ISO volume dispersion from helicopter and generator flues (Left) and CFD Odor streamlines (Right).

3.4. Case 4 - Outdoor/Indoor Car Park Natural Ventilation Air quality, New South Wales

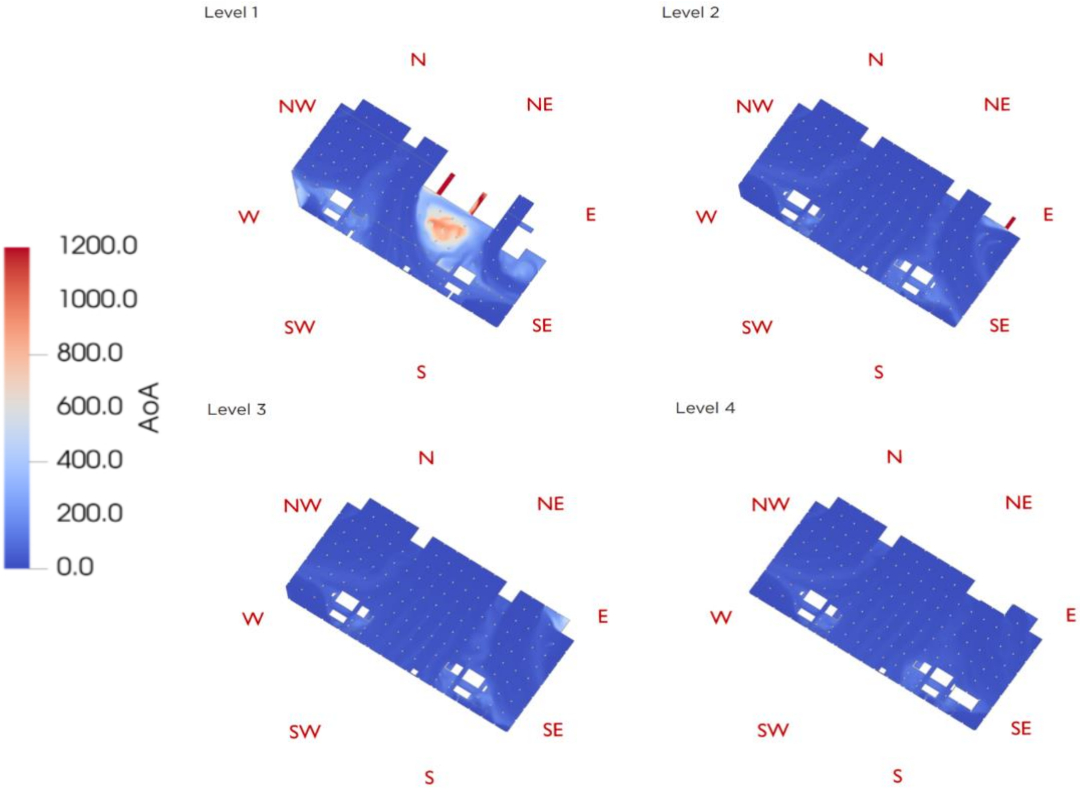

Figure 5. Internal AoA Contours at 1.5m height above ground through Level 1-4

The results of this study showed the measured stagnant air regions within the car park will be compared against the Age of Air (AoA) Scale. The AoA index quantifies the number of seconds that air is present in the car park. When fresh (young of age) air mixes with older air, the fresh air ages faster (gets polluted) and the aged air gets diluted (gets less polluted). A good air distribution system capable of 3 air changes per hour is sufficient to keep pollutant levels in a car park within acceptable range.

Therefore, an air residence time less than 1200 sec for the air leaving the car park is considered acceptable. Presented here is the NE wind case, which defines the flow in the car park for ~8% of the year in New South Wales. The majority of the space for all levels is predicted to have sufficient air movement. However, some isolated stagnated air regions are identified on Level 1 and 2. The maximum AoA seen exceeds 1200s for those regions (Fig. 5).

The localised areas with calmer air movement within the car park may require additional mechanical ventilation to maintain effective ventilation and reduce pollution build-up.

4. CONCLUSIONS

The results of the four cases of modelling demonstrate how effective these types of simulations are in solving complex pollution dispersion/air quality problems, while using wind tunnel testing for cross validation and as definition of input flow boundary conditions. The results also show the variety of simultaneous conditions can be solved in tandem, some which are physically not possible within wind tunnel testing due to scale and complexity of the modelling.