IMPLEMENTING COMPARTMENTALIZATION AND VENTILATION STRATEGIES IN TALL MULTI-USE BUILDINGS TO CONTROL STACK-EFFECT RELATED PERFORMANCE ISSUES

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INTRODUCTION

It is becoming more common to have taller multi-unit residential buildings combined with hotel, retail, and/or commercial space. This case study looks at a 60 storey tower with residential, hotel, retail, commercial, and event space over a multi-level underground parking garage that has experienced stack-effect related issues during cold exterior temperatures. These issues include:

- Cold temperatures/drafts in the residential lobby and lower parking levels;
- Whistling through elevator and stairwell doors;
- Elevator doors not closing properly (causing elevators to stop working or causing damage to internal components);
- Corridor ventilation reversals (i.e. air flow from suites to corridors);
- Rattling/whistling and damaged latches/astragals on doors between suites and corridors;
- Whistling noises through suite range hoods;
- Condensation on glazing systems; and
- Garbage odour transfer.

Air pressure, temperature, and relative humidity sensors were installed across doors between suites/corridors and between stairwell shafts/corridors at various locations to allow tracking under varying exterior temperatures/conditions. Differential air pressure data was graphed and analyzed to identify the horizontal neutral pressure plane (NPP) location and to identify the conditions leading to the reported issues. A thermographic scan was also completed to identify openings or air flow paths across the building enclosure.

MAIN FINDINGS

Significant Openings at the Building Base Leading to High Stack Effect Air Pressures at Upper Floors

There are no operable windows or sliding doors on the hotel rooms in this building (i.e. Floors 6 to 17). This should cause the Neutral Pressure Plane (NPP) to be higher than the halfway height of the building (32^{nd} floor) because this lower section has less potential for air infiltration than the upper sections with operable windows and doors. Figure 1 shows the air pressure distributions developed from air pressure sensor data collected during a past winter. This same Figure shows the relative pressure contributions from stack effect and the mechanical corridor pressurization ventilation system, the combined pressure effect, and the corresponding NPP location (under average winter conditions or -4ºC). The NPP from stack effect pressures was at approximately the 26th floor (or about 6 floors below the building mid-height). This indicated that air infiltration at the building base was significant to offset the reduced infiltration associated with the fixed hotel glazing systems. The NPP moves further downward when the mechanical corridor pressurization is added to the stack effect pressures. This results in even higher pressures at the upper building levels.

Inadequate Seals/Separations to Control Stack Effect Pressures and Air Flow

Several continuous flow paths were identified that allowed air flow into, up, and out of the building. Locations with missing or inadequate seals/separations that are part of the identified air flow paths are summarized and grouped below depending on whether they: enabled infiltration below the NPP, were part of the vertical shafts, were incomplete internal separations, or enabled exfiltration above the NPP.

Locations of significant air infiltration identified below the NPP were as follows:

- Entrance Doors from all 8 Parking Levels to the Elevator Lobbies (sensors automatically controlled doors to open at both ends of the air locks upon approach);
- Main Entrance and Secondary Entrance to Residential Lobby;
- PL3 – Moving Doors;
- PL3 – Residential Garbage Room;
- Ground Floor & Floor 2 Stairwell Doors;
- Floor 3 Generator Room;
- Hotel Lobby Doors;
- Hotel Terrace Doors; and
- The loading dock area.

The main vertical shafts (i.e. that allowed vertical air flow) were as follows:

- Elevator shafts;
- Stairwells; and
- Garbage Chutes.

Inadequate internal separations between the vertical shafts and the spaces connected to the openings that allowed air infiltration and exfiltration were as follows:

- Floors P1, 2-17 - Service Elevator Lobbies (i.e. the residential and hotel elevator shafts were not separated from each other)
- Residential Suite Entry Doors;
- Elevator Machine Room Doors;
- Stairwell Shaft to Corridor Doors;
- Garbage Chute Room Doors; and
- Garbage Chute Shaft Walls.

Locations of significant air exfiltration identified above the NPP were as follows:

- Residential Suite Balcony Sliding Doors & Operable Windows;
- Upper Mechanical Room Doors; and
- Ventilation Exhaust Boxes (Bathroom and Kitchen).

Corridor Pressurization Ventilation Systems Not Operating as Intended

Pressure readings taken with and without the corridor pressurization systems operating determined that the corridor air pressures created by the mechanical ventilation system were between 10 to 15 Pa. The stack effect pressures significantly affected ventilation air delivery to the suites. Figure 1 shows the average pressure differences across the suite doors on Floors 20, 43, and 61 during average January exterior temperatures to be: -5 Pa, 39 Pa, and 55 Pa respectively. The flow is from the suites into the corridors on the 20th floor indicating that the ventilation pressures are overcome by the stack effect pressures. We expect this to be the case on all floors below the 22nd floor during average winter conditions. On the 43rd and 61st floors, the measured pressures across the suite doors are roughly 3 to 4 times higher than the pressures created by the ventilation system. This correlates with the thermographic scan that identified air flow through open bathroom and kitchen exhaust grille flaps in the suites above the neutral pressure plane (even when exhaust fans were off).

The pressures measurements on the different floors indicated that the corridor ventilation system is not effectively or efficiently ventilating the suites. The upper suites are over-ventilated and the lower suites are under-ventilated.

The over-ventilation from stack effect air flow in the upper suites (eg. 43rd and 61st floors) led to dry interior air conditions. Condensation issues were reported on exterior glazing systems between Floors 18 to 25. We observed that air flow in suites between the 18th and 22nd floor was typically from the suite to the corridor during average winter conditions (i.e. these suites do not receive ventilation air from the corridor pressurization system). Corridor ventilation air flow into suites between the 22nd and 25th floors is limited due to the limited differential pressures across the suite doors (i.e. may not be ventilated sufficiently to dilute generated humidity). The suites near the neutral pressure plane are more prone to condensation issues given that the limited pressure differences do not allow sufficient air exchange either way (i.e. from the corridor to the suite or from the exterior to the suite) to dilute generated moisture. This makes these suites more sensitive to unit owner operation with respect to dilution of moisture in the interior air (i.e. use of exhaust fans or operable windows or doors are required for ventilation, etc.).

GENERAL REPAIR STRATEGIES

The following repair strategies were intended to limit/control pressure differences and the air flow responsible for the reported issues. Compartmentalization combined with in-suite ventilation can reduce vertical and horizontal air flow through buildings, limit indoor to outdoor air exchange, reduce space conditioning costs, increase comfort (improved control over suite temperature and humidity), and reduce odour and noise transfer between suites. This approach is common in many new tall multi-use and residential buildings. Both, compartmentalization and in-suite ventilation, were recommended and are described further as follows.

Implement Barriers and Compartments

The intent of this strategy is to increase the resistance to air flow along the identified air flow paths. The continuous flow paths identified that allowed air flow into, up, and out of the building would be sealed/compartmented by implementing doors (swing and/or revolving to create air locks), seals (weatherstripping/sealants), barriers (sealed partitions), etc. Minimizing air flow from the corridors into the suites will generally cause the overall pressures across suite entry doors to increase. Pressures across suite doors could be reduced by: reducing corridor pressurization air flow volumes, sealing stairwell shafts (repair discontinuous or disengaged weatherstripping), sealing elevator shafts (either brush type door perimeter seals or full vestibules where brush seals are not effective), and sealing garbage chute room doors and shafts. Suite entry door closers may also need to be upgraded.

Implement Suite-Dedicated Ventilation Systems

This strategy would include implementing air seals between the suites and corridors and adding Energy Recovery Ventilators (ERV) so that window or door operation in one suite does not affect air flow or ventilation air flow in other suites. The ERV systems could be ducted and integrated into the existing exhaust fan duct layout to provide ventilation air from outside directly to each suite. This would lead to smaller variations in the amount of ventilation air flow delivered to suites. Indoor air quality would be improved since air delivered to a unit is not likely to have travelled through other parts of the building. Environmental conditions in the suites would be improved (i.e. they would not be too dry from over-ventilation or excessively humid from under-ventilation). Energy savings are also expected from not pushing excessive amounts of air out of exhaust duct runs in suites above the NPP. The garage area would also be neutralized as a source of air being delivered to the suites.

CONCLUDING REMARKS

Repair strategies are presented so that they can be used in other tall multi-use buildings with similar problems or so that they can be introduced in new construction to avoid similar issues. It is recommended that a member of the design team is tasked with providing/preparing compartmentalization strategies during initial design. This would involve identifying locations that require air seals (i.e. identifying the continuous flow paths that allow air flow into, up, and out of the building and seal/compartment as required) and preparing the associated air seal details. Barriers and compartments would ideally be installed during initial construction to control stack-effect pressures and air flow, but as a minimum, barriers could be roughed-in (eg. air lock or vestibule electrical servicing and vertical partitions above drop ceilings could be installed during initial construction) to allow subsequent cost-effective barrier implementation should problems arise.

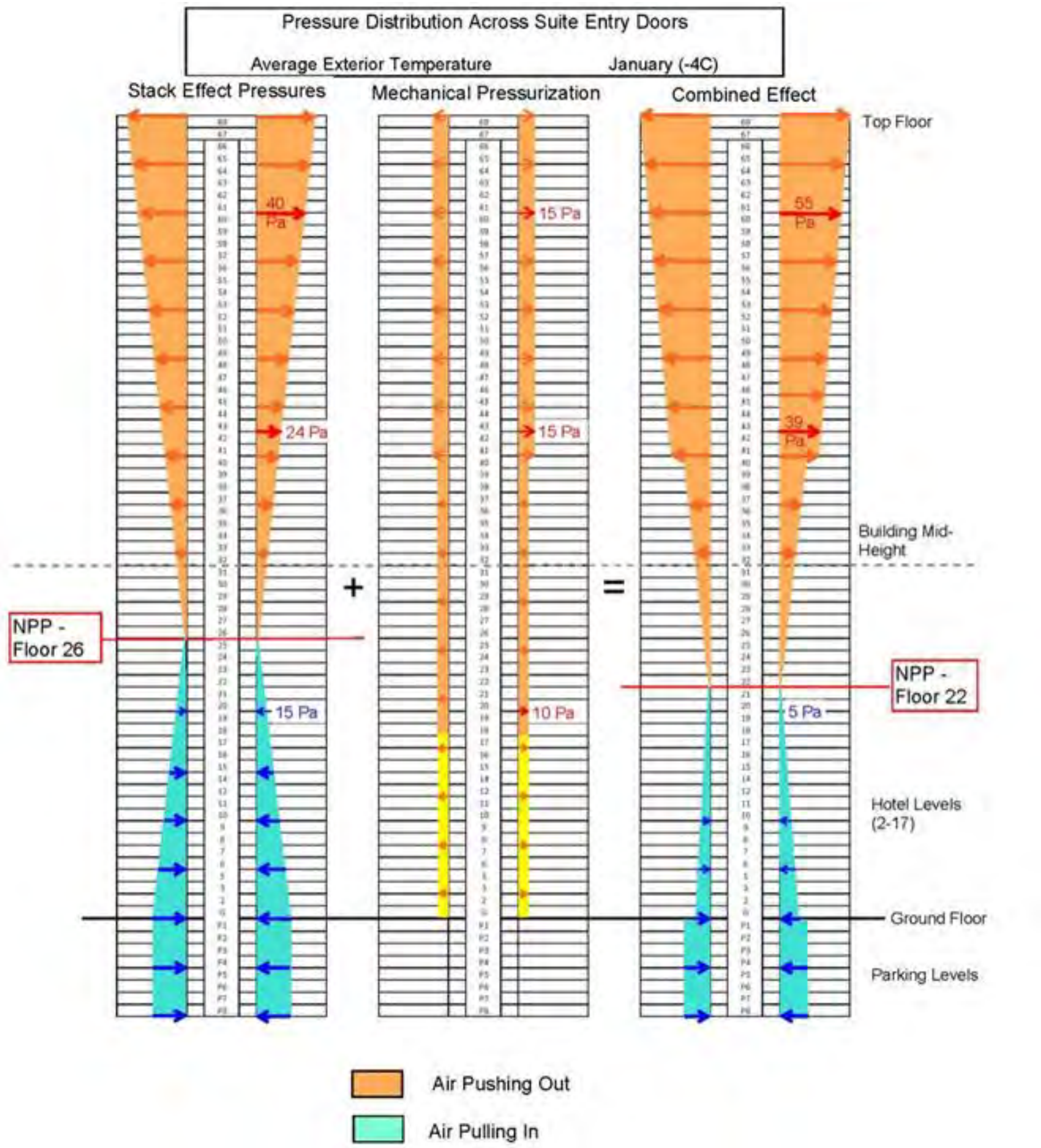

Figure 1: Pressure Distribution across Suite Entry Doors