The influence of airstream upon elevators in the high-rise buildings

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ABSTRACT

The economy in China has entered a period of rapid growrh and high rise buildings are springing up like mushrooms. A major problem is to minimise the influence of airstreams on elevators in high speed systems. This paper reports on an investigation of existing high rise buildings in China (up to 66 stories high, and rises of 350 m) with respect to; wind existence in the high rise buildings; natural ventilation in the elevator hiostway; airstream influence and proposed solutions for their minimisation.

1. WIND EXISTENCE IN THE HIGH-RISE BUILDINGS

Windspeed is an unsteady variation value, which is influenced greatly by atmospheric pressure, tempeature etc. and is not easy to measure its accurate values in a short period of time. So this measuring and testing and the results are only for reference.

1.1 The wind directly blown into the ground waiting hall

The elevator position in the high rise building is at the place where there is a draught in the building, for example, elevator No.14 (Fig.1) in the Capital Mansion, Beijing is one of the elevators servicing up to the top floor of the building.

The stairs is next to the elevator. When the hoistway door of the elevator is closed, the wind in the building is coming from parking site through the corridor blows directly to the stairs. If the hoistway door of the elevator is open, the wind focuses at the hoistway door and blows into the hoistway directly, then causes the

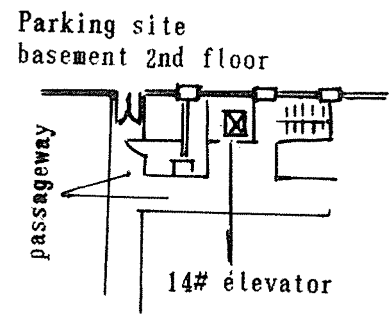

Fig 1

door not to be closed tight automatically.

1.2 The draught passing through the passageway

The layout of elevators in high-rise buildings, especially for the group-controlled elevators are usually located at the opposite sides and facing to each other for the convenience of passengers. The elevators hiostways at each side of the passageway are becoming ventilators, especially when the hoistways are at the end of the passageway. For instance, in Shanghai Hongqiao Hotel (Fig. 2) as well as in Shenzhen International Trade Centre, elevator No. 9 serving for high zone in the building. None of the hoistway doors at lobby of high zone elevators can be closed tight automatically during it is windy.

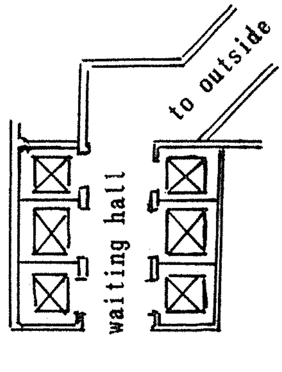

Fig 2

1.3 Wind caused by the waiting hall with a large volume of air

When the waiting hall has a large volume of air and the hiostway is the only air passageway (channel), although the airstream in the hall is small, the wind at the hoistway entrance is very strong.

For instence, in Capital Mansion, Beijing (Fig. 3). Even the windspeed in the hall is only 0.3m/s, but speed at the entrance of hoistway is up to 6-7m/s. It proves that the hiostway wind is caused by air volume in the hall (about 1050m^2). Such large volume of air centres to pass through the hoistway door of only 2.1m. The wind noise forming naturally at the hoistway door entrance is loud with highspeed of air streame, causing the hoistway door not to be closed tight automatically.

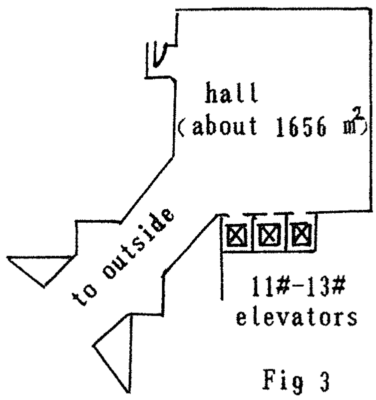

Fig 3

2. ANALYSIS OF NATURAL VENTILATION IN THE ELEVATOR HOISTWAY

In accordane with the theory of the air dynamics, if there is the air pressure difference P exist between the inner and outer of the entrance, then air will flow through the entrance, and the square of air flow speed is proportional with the pressure difference, ie,

$$P = \xi \frac{v^2}{2} \rho \qquad \text{Pa} \qquad (1)$$

where P - Air pressure difference between inner and outer of the entrance, Pa

v - Air speed flow through the entrance, M/s

ρ - Air density, Kg/m^3

- Partial resistance coefficient of the entrance.

this proves, the flow speed

$$v = \sqrt{\frac{2\Delta P}{\xi \cdot \rho}} = \mu \sqrt{\frac{2\Delta P}{\rho}} \qquad (2)$$

where μ - Coefficient of flow, $\mu = 1/\sqrt{\xi}$, the value of μ is related to the entrance's construction, generally less than 1.

The quantity of air through entrance

$$L = vF = \mu F \sqrt{\frac{2\Delta P}{\rho}} \qquad M^3/s \qquad (3)$$

$$G = L \cdot \rho = \mu F \sqrt{2\Delta P \rho} \qquad Kg/s \qquad (4)$$

where F - Entrance area, m^2

If there is no air pressure differece between the inside and outside of the building, then no air flow in to or flow out from the building.

If the air pressure is positive in the building, that means the inner air pressure is higher than outer of the building, then the air will flow out from the building, that will be called positive pressure, conversely, the air pressure is nigative, called negative pressure.

Since most case in the winter time, the air pressure is always to be negative in the building, so air always flow from outside into the building. Such as "Passageway Draught" in the Capital Mansion, Beijing, the strong air flow through the passageways in the building.

During the value of negative air pressure is at the range of 12.25-49 Pa, and the corresponding air velocity is at 4.5-9 m/s, then the door will not be easy to close.

As mentioned above, these phenomenas were occured in the Capital Mansion, Shanghai Hongqiao Hotel and Shenzen International Trade Centre. All of the elevator hoistway doors at lobbies were not closed easy during windy.

2.1. Nature ventilation under the hot pressure

As shown in the Fig.4 if there are two entrances A and B at the bottom and top of the hoistway, separately, the height between A and B is h, and the static air pressure at outside of the entrances A and B are Pa and Pb, and pressure at inner of the entrance are Pa' and Pb' respectively. Temperature and density inner and outer of the hiostway are $t_n \cdot \rho_n$ and $t_w \cdot \rho_w$ respectively. So, if $t_n > t_w$, therefore $\rho_n < \rho_w$.

If entrance B is closed and entrance A is open, then air flow through entrance A until the air pressure difference $\Delta Pa = Pa' - Pa = 0$.

According to the theory of air statics, the air pressure diffeence at entrance B,

$$\begin{aligned} \Delta Pb &= (Pb' - Pb) \\ &= (Pa' - gh\rho_n) - (Pa - gh\rho_w) \\ &= (Pa' - Pa) + gh(\rho_w - \rho_n) \\ &= \Delta Pa + gh(\rho_w - \rho_n) \end{aligned} \tag{5}$$

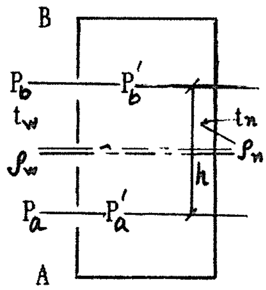

Fig 4

where $\Delta Pa \cdot \Delta Pb$ - Pressure difference between inner and outer of the entrances A and seperately,

$\Delta P > 0$, air out through the entrance

$\Delta P < 0$, air enter through the entrance

g - Acceleration of gravity, m/s^2

Fig.4

So, according to the equation (5), at the condition of $\Delta Pa = 0$, if $\rho_w > \rho_n$ (ie, $t_n > t_w$), then $\Delta Pb > 0$. Therefore, if entrances A and B are open together, then the air will flow out from entrance B. As the air flow out is to be followed, the static air pressure in the hoistway will be gradually decreased, (Pa' -Pa) is becoming from zero to negative, then air will flow into the hoistway from entrance A till the air quantities inlet from A is equal to the outlet from B. Air in from A, and out from B.

Since air in at entrance A, so $\Delta Pa < 0$; and air out at entrance B, so $\Delta Pb > 0$.

Therefore,

$$\begin{aligned} \Delta Pb + (-\Delta Pa) &= \Delta Pb + |\Delta Pa| \\ &= \Delta Pa + gh(\rho_w - \rho_n) + (-\Delta Pa) \\ &= gh(\rho_w - \rho_n) \qquad (6) \end{aligned}$$

Thus it can be seen that the sum of the absolute values of the pressure differences between the air inlet entrance A and the air outlet entrance B is related to the height difference between the two entrances and the air density difference $\Delta\rho = \rho_w - \rho_n$. Usaully, the $gh(\rho_w - \rho_n)$ is called hot pressure.

So,

$$\begin{aligned} Pa - Pb &= Pa' + \Delta Pa - (Pb' - \Delta Pb) \\ &= Pa' + \Delta Pa - Pb' + \Delta Pb \\ &= \Delta Pa + \Delta Pb + (Pa' - Pb') \\ &= \Delta Pa + \Delta Pb + gh\rho_n \qquad (7) \end{aligned}$$

For example, when Tianjin TV Tower was tested and measured on March 9, the temperature difference between the ground floor and the top floor was only 1° C, the elevator was operating without any wind interference. And another case, when Tianjin International Building was being tested in the last winter time, the lower zone of the building has been heated other than the high zone, the temperature difference was up to 20-30° C, so the air pressure caused by air flow from the ground floor to the hoistway was so large that the hoistway doors of elevators at lobby couldn't be closed automatically.

2.2 Concept of surplus pressure

If there is only the hot-pressure, then the pressure difference between inside and outside of the hoistway at same level is called the surplus pressure. Where the surplus pressure is positive at the entrance, then the air will flow out from the entrance, conversely, the air will flow into the building.

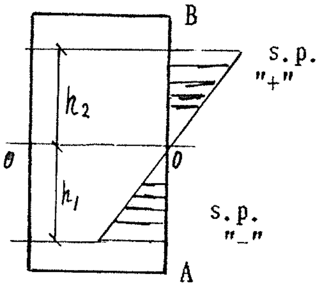

Fig 5

According to the equation (5), then,

$$Px' = Psa + gh'(\rho_w - \rho_n) \quad (8)$$

Fig. 5

where Px' - Surplus pressure at a certain entrance, Pa
Psa - Surplus pressure at entrance A, Pa
h' - Height difference between entrance A and a certain level, m

The negative value of the surplus pressure at the inlet entrance A will be increased gradually to the positive value of the surplus pressure at the exhaust entrance B, as shown in Fig. 5 above.

If we take the plane 0-0 as the datum plane, then the surplus pressure at entrance A will be

$$Psa = Pso - gh_1(\rho_w - \rho_n) = -gh_1(\rho_w - \rho_n) \quad \text{Pa} \quad (9)$$

surplus pressure at entrance B will be

$$Psb = Pso + gh_2(\rho_w - \rho_n) = gh_2(\rho_w - \rho_n) \quad \text{Pa} \quad (10)$$

where Pso - Surplus pressure at neutral plane 0-0, (Pso = 0), Pa
h_1, h_2 - Height distance between neutral plane 0-0 to entrances A and B respectively.

Above the neutral plane, surplus pressure is positive, air flow out and below the neutral plane, surplus pressure is negative, the sir flow in.

So, that is why the airstream at bottom and top of elevator landings are much stronger than at the others.

The area of the entrances are related to the height difference between neutral plane 0-0 to lower and upper entrances, i.e,

$$\left(\frac{F_a}{F_b}\right)^2 = \frac{h_2}{h_1} \quad \text{or} \quad \frac{F_a}{F_b} = \left(\frac{h_2}{h_1}\right)^{1/2} \qquad (11)$$

where Fa, Fb - Area of entrances A and B respectively, m^2

Thus it can be seen that the surplus pressures at the floor entrances of the elevator hoistway are not same.

If the air leak area of every hoistway door is same, both the absolute air pressures and speeds at the terminal landings of the elevator are larger than the other landings, especially much larger than at the middle landing.

Actually, however, the temperature and air density at each hoistway door corridor are not definitely same. Then the surplus pressures at the floor entrances of elevator are not regular. So, it should make a concrete analysis for the concrete condition.

This is what we called the stack effect in the high-rise buildings.

3. Influence of airstream upon the elevator hoistway

3.1 Wind causes the building sway

Fluctuations in wind forces acting on the high-rise buildings, especially the tower bulidings can cause excessive motion. The wind induced building motion can produce a resonant reaction in the elevator hoist, compensating and governor ropes, travelling cables and encoder tape. These elements may move far enough to contact or snag on beams, brackets or each other which can result in damage and elevator shutdown.

3.2 Stack effect

As mentioned above, since the elevator hoistway can be a free path for air currents throughout the building, the airstreams gethered flow through the hoistway to cause the hoistway doors at lobby can not be closed automatically by normal power means and make more noise during the elevator downward running.

3.3 Air turbulence and air ruffle in the hoistway

When the elevator car running in the hoistway, it causes the air flow in the hoistway to be trubulent, especially when a high speed elevator travels at a speed over 4m/s. Its seriousness is related to the roughness of the hoistway (including the smoothness of the hoistway walls, equipment mounted on the walls etc.) and the corresponding position of the car to the counter weight.

Since the projection area of the elevator car is about 50% of the section area of the hoistway, the so called 'piston effect' will obviosely. The smaller hoistway area is an indirect cause of the increase the wind velocity around the elevator resulting in a louder aerodynamic noise.

The most remarkable case of the noise of the super high speed elevator is the air ruffle sound on the periphery of the car due to the fast running in the hoisthway. When the car passes floor by floor, the snatchy sounds caused by the rapid change of the hoistway cross-section like sills are pronounced.

4. Proposal for the means of solution

The tested following proposed means have improved the elevator running qualities.

4.1 Reducing curvature in the rails and improving the vibration characteristics of the car are effective in reducing car horizontal sway.

4.2 Minimize the wind source outside

All the main entrances of the building are to be installed double doors in different directions and/or revolving doors in winter time to prevent the wind flow directly into the building.

4.3 Reduce the air volume in the ground waiting hall.

4.4 Reduce temperature difference between the upper and lower floors.

4.5 Ventilation holes in the hoistway should be adjustable.

4.6 Improve the elevator systems

4.6.1 Door system

Increase the counter weight or the spring force of the closing devices to assist closing of lower-floor elevator doors, and keep the sill slots clean. Also, the door panels should not be too light.

4.6.2 Reduce air turbulence and air ruffle in the hoistway.

4.6.2.1 Set up air partition panels in the hoistway

Air partition panels are to be installed along the interior side of the hoistway doors, keep the clearance front the car door to be constant.

4.6.2.2 Set up air shearing panels vertically above and below the car door.

Break the air and making the air passing through between the air partition panels and the car door unchanged.

4.6.2.3 Set up deflection panels on the top and beneath the car

Form the deflection panels streamline to lead the air flow smoothly to the sides of the car, so as to reduce the air turbulence and ruffle in the hoistway.

4.6.2.4 Make the cabin to be moved rearwards and forewards.

The cabin is designed to be moved smoothly rearwards along the car frame to the running position during the elevator is accelerating, and moved forewards to the stopped position during it is levelling.

The facts have proved that all the means mentioned above were obviously for the improvement of the high-speed elevators' running qualities in the high-rise buildings.

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