Problem of Air and Water Backflow in High-rise Building Drainage System

Prof. Daniel W.T. Chan, Leo K.C. Law and Eric S.W. Wong

Department of Building Services Engineering
The Hong Kong Polytechnic University

Abstract
Virus transmission through vertical drainage stack is believed to be one of the hypotheses for the SARS outbreak in the Amoy Garden. After the outbreak a review of building drainage system is triggered in the community. This paper starts with a review on the contemporary building drainage system design in Hong Kong, and after that a field study in a 37-storeys high-rise building is reported. When sulphur hexafluoride tracer gas was injected in a flat in 16/F, the gas was detected at 21 floors above the flat under injection (i.e. 37/F), when a suction force was induced in the room due to the sole operation of exhaust fan. The result allows a better understanding on the risk of contaminated air transmission through building drainage system. In addition, a case study of water back flow at the lower floor of a building is also reported. Observed on the vertical stack design, the excessive bendings at the bottom of the vertical drainage stack was believed to induce hydraulic jump that can push the water in the trap seal back to the building. The study result reveals the importance of a proper design, operation and maintenance of drainage system in order to prevent spread of soil waste and contaminated air within buildings.

Introduction
In typical high rise buildings sanitary drainage is provided through vertical drainage stacks, connecting various occupied rooms together. The prevention of cross-contamination among the rooms is principally through the inclusion of a trap with water seal inside. In Hong Kong, Building (Standard of Sanitary Fitment,

Plumbing, Drainage Works AND Latrines) Regulations Chapter 123I under Buildings Ordinance specifies that every sanitary fitment should be provided, individually, with a trap. The resulting typical water trap arrangement in Hong Kong buildings is shown in figure 1.

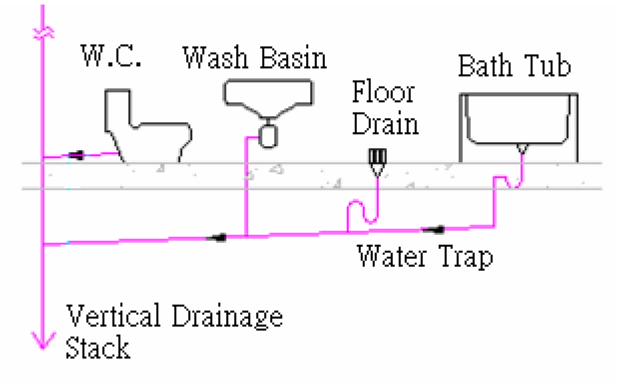

Figure 1 Contemporary water trap design in Hong Kong

This design cannot provide a function of self-priming for the floor drain trap, which was hypothesized to be one of the possible virus transmission routes in the SARS outbreak in 2003. On the other hand, the perceived down flow direction in gravity drainage system, and an observed lower number of reported cases from flats below the index floor, have imposed in an uncertainty on where the drainage system plays a role on virus transmission. As a result, the authors performed an investigation through tracer gas injection in a vertical drainage stack in a high-rise residential building in Hong Kong.

Tracer Gas Investigation Method and Results

Sulphur hexafluoride (SF_6) tracer gas was injected to the drainage pipe at 16th floor of a 37 storeys high-rise building. The bottle trap was removed during the experiment, and replaced by a fitting to house the trace gas dosing tube. It was confirmed that no other trap is presence along the 40mm diameter horizontal pipe. The 100mm diameter vertical drainage stack was maintained to be dry, to prevent the addition of moisture to the stack which would interfere the measurement result read from the Bruel & Kjaer model 1302 Gas Analyzer. The exhaust fan was switched OFF and the windows and doors were kept close during the investigation. SF_6 concentration inside the horizontal drainage pipe at this floor was kept at a range between 797 to 867 ppm.

At the topmost floor (37th floor) of the building, the SF_6 concentration at such horizontal pipe was also monitored. The exhaust fan was switched ON, the air velocity at the end of the 40mm horizontal pipe was found to be 2.75 m/s. The SF6 concentration inside was ranged between 228 to 266 ppm. Since SF6 is absent in the atmospheric air, the test result shows that the air from the 16/F can travel upward to the 37/F under the driving force from mechanical exhaust fan at such top floor. It was hypothesized that a similar upward flow would likely to be happened in the Amoy Garden case, if the vertical drainage stack was dry, the water trap of the index flat and the suffering flat(s) at the upper floors were dried, and the exhaust fan of the suffering flat(s) was switched ON to provide a mechanical force to drive the air up.

The risk of trap seal loss and water backflow in high-rise buildings

While the contemporary drainage design shown in figure 1 would impose a risk of water trap seal loss through evaporation together with the absence of self-priming function, the effect of positive pressure induced at the bottommost bending of a high-rise drainage stack should not be neglected. The authors performed another test at a 41 storeys residential building that, when a total flow rate of 138 L/min of water was discharged from the upper floors, the water trap at the lower floor, which was found empty before the experiment, was found to have an air flow velocity of 3.56 m/s, and a paper strip placed near the floor drain confirms that the air was flowing from the pipe to the occupied space. The water in the WC of the floor was also "shooting-out". The effect of hydraulic jump at the bottom bending of a drainage stack should not be neglected. Positive pressure inside a drainage stack should be properly attenuated through proper pipe design. Attenuators may be necessary if the air and water was back-flowing to the occupied space when the building was already occupied and being use.

In addition to residential buildings, the authors found that there was no immune to the problem of water backflow problem in other buildings, if unnecessary bendings were allowed in the piping network. We have come across a similar problem in a 17 storeys building in a tertiary institutional campus. Water "shoot-out" from WC at 3/F of the building was found during lunch hour, which was anticipated to be the peak hour of drainage stack utilization. An unnecessary bending was found at one floor below (figure 2), due to a lack of space in the pipe-duct service run. This also reveals the operation problem induced due to an inadequate space allocation for building services, at which the design team of future buildings should be aware of.

Figure 2 Unnecessary bendings along the vertical drainage stack

Conclusion

The paper reviewed the possibility of upward air flow in a vertical drainage stack, at dedicated condition, and the risk of air and water back flow if the water seal inside the trap was loss, no matter due to natural evaporation, or due to a high positive pressure at the lower part of the stack due to hydraulic jump in bendings.

References

Chan, D.W.T., Law, L.K.C. and Hung, H.C.K. (2006) Effect of Stack Contamination in High Rise Buildings on the Spread of SARS Virus. *WPC/ISH China Academy Plumbing Symposium*, Mar. 16, 2006, Beijing, China.

Chan, D.W.T., Law, L.K.C., Yeung, N. and Chan, E.H.W. (2005) A Review of Contemporary Drainage Practice in Hong Kong. *Healthy Building – Community Health and the Built Environment*, CII-HK Conference 2005, Nov. 30, 2005, Hong Kong.

Hung, H.C.K., Chan, D.W.T., Law, L.K.C., Chan, E.H.W. and Wong, S.W. (2006)

Industrial Experience and Research into the Causes of SARS Virus Transmission in a High-rise Residential Housing Estate in Hong Kong. *Building Services Engineering Research and Technology*, Volume 27, issue 2 (2006) pp. 91-102.

Law, L.K.C., Chan, D.W.T., Chan, E.H.W. and Law, F. (2005) Ingress of Air from Empty Drainage Trap to Residential Toilets. *Healthy Building – Community Health and the Built Environment*, CII-HK Conference 2005, Nov. 30, 2005, Hong Kong.