A Breathing Pipework System – Building Drainage Pipework System

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Abstract

Drainage pipework systems (one-pipe, two-pipe, single stack, modified one-pipe and SOVENT) can breathe. What does it imply? The air surges within the empty pipework sections and also when it is interlocked by sewage flow during intermittent flushing actions. Air is frequently breathed in or out reversibly. The most harmful effect is the resultant back-pressure causing health hazard due to sewage might be momentarily forced out.

By reviewing the drainage flow cycle, it re-called some basic principles: conservation of mass, displacement law and conservation of energy, which might have been over-looked. Different drainage cycles in those high-rise buildings, high densely population residential buildings and hotels are very complex. The breathing cycle when it is co-related to the sewage peak flow reveals critically those harmful health and hygiene effects.

Study for the peak flow inside a drainage pipework system has to examine the total pipe length simultaneously. The peak may re-occur more than once till the sewage reaches an “exit”. Accumulative effect does exist from the aboveground pipework to the underground sections. Analysis to the pipework circuit has never been worked out together with the below ground drainage circuit. The drainage cycle, peak flow determination and the breathing drainage pipework system have to be completely reviewed to establish firm grounds by research development. Firstly, the processes and problems appear initially. To tackle the problem and theory enhancement could be done by research projects finally.

Keywords

Drainage pipework systems; breathe; interlocked; drainage flow cycle; accumulative effect; peak flow determination.
1. Introduction

Drainage systems have been misinterpreted with their associated pipework systems. Sanitary wares sewage disposal system should be defined and termed as a sanitary drainage system. This system will engage a pipework which is selected basically from one-pipe, two-pipe, single stack, modified one-pipe and SOVENT pipework system to handle its sewage disposal. Those are the typical five pipework circuit arrangements or simply the pipework configuration for an effective sewage disposal without injury to the health of the occupants. Pipework systems are always misunderstood as drainage systems.

2. Pipework circuit and the breathing processes

Drainage pipeworks are empty sections occupied by the air when there is no sewage flow. When a sanitary ware is flushed, sewage will then be discharged. Releasing firstly the air, the pipe space will be displaced by sewage nearly simultaneously. If the air is not released, sewage will not flow. After the air is discharged and when the sewage is drained down, the empty space will have to claim the air back. This is very similar to breathing processes: breathing out and sucking in air lastly, in order to complete a cycle of sewage discharge. These cyclic actions are interlocked. Air breathing out and flow discharge whilst sucking air and refill empty drain reversibly re-appear.

To consider further, no air return will result a syphonage (vacuum pressure). Sewage disposal resulting compression force acting on air will form a positive pressure at the lower part of a drain to cause the backpressure (compression force). Lower floors water closet trap seal water and other sanitary wares trap seal have been experienced momentarily forced out during the peak hour of usage.

3. Understand air existence

In a drainage pipework, the existence of air is very important. All drainpipes let their upper open ends plus a vent pipe facing to atmosphere in balancing the air pressure either by relieving when it is under positive pressure or sucking air back when it is under a vacuum (negative pressure). Since the ends are open, the air will be circulated and subjected to the atmospheric pressure. Self-regulation of air pressure inside a drain
pipe can be maintained easily within a fully ventilated pipework. But it is difficult for partially vented or pipework system providing with vent assistance equipment. It may be due to their low effectiveness and early deterioration, and also lack of prompt action. However, when the air discharge and breathing in have to go through a long section, air pressure variation is unexpectedly complicated and cannot achieve a self-balance within a short period.

4. The cycle of drainage disposal

After using a sanitary ware or general ablution or washing with cold water, a flushing action follows naturally. The sewage discharge adhering to the drainpipe internal wall surface accumulates to form short water columns which continuously flows down a drain stack. Depending on the sewage quantity, the wall surface resistance will permit the sewage to form short water columns. They will form compression force to the air existed inside a drain. The author would like to term it ‘Piston Effect’ (Fig.1). You can always hear some bubbling noise or wind blowing inside a drain, which was formed by the compression of air. Air rushes back to the upstream (in escaping) in resulting the noise.
5. A breathing pipework system

When a sanitary ware is flushed, the sewage or wastewater will be drained away. Small and short water columns will be formed intermittently inside a vertical drain stack. The compression force will result positive pressure acting on the air inside a drainpipe. Air evacuates first then wastewater or sewage will be drained down. After the air gone, the water leaves the drain (Within a long drain pipe, the air is bouncing inside the drain while sewage continuously or intermittently is flowing along. But, when air does not reach an “exit”, air balancing cannot be achieved.), air will be sucked back finally. The worst scenario is a short period of discharge followed by a long period of discharge and continuous intermittently. Air balancing is unachievable.

Normally, drains itself in balancing and self-regulating the internal air pressure variation, will claim the air back in every drainage disposal cycle. Therefore, the drain will create a suction force in evacuating the trap water seal of any sanitary ware (as if the shortest route or a prompt response within the shortest period) to balance with atmospheric pressure or the need for air replenishment from where there is a venting provision of the pipework circuit. Of course, ideally, it will suck air from the vent pipe. Unfortunately, when trap seal was empty, foul smell will leak out and afterwards, the second round compression force can transmit and forced out air-borne virus when the next flushing action rose by wares.

Furthermore, on the other side, the magnitude of compression force will never be the same due to differences in the building height, variation in time that the peak discharge appears. Designers may have neglected the sewage flow is still on their way before reaching an “exit”. This will form vacuum at different positions within a drain circuit.

No matter of semi-detached low-rise buildings or tall high-rise buildings, sewage discharge is either a continuous or an intermittent flow. From Conservation of Mass to Volume, equal volume of air and sewage will exchange nearly simultaneously. Displacement Law is the basic theory to explain the exchange processes. When the sewage flow does not reach an “exit”, the air inside a drain pipe will bombard by the intermittent sewage flow by the ‘Piston Effect’ formed as discussed in item 4 above. The compression force with transient suction force will affect the whole pipework
circuit and the connected branches to the appropriate sections are subjecting to pressure fluctuating (Fig.2).

### Fig. 2 'Piston Effect' causes compression force affecting the whole circuit

6. **Consideration for peak period and its continuous impact**

A drainage pipework system is normally connected and extended to an underground drainage pipework system which are either separate or combine underground drainage pipework and manholes system. Sewage flow from a high-rise building flows variously from several hundred meters aboveground pipework to another several hundred meters underground pipework system when it reaches the building last manhole (There are many thousands cases, but this may be the worst case). The complete circuit will have to continue till reaching the Government sewer to the sewage treatment plant in reaching an “exit”. The term “exit” is so important and must be explained because the “exit” is a point where air is free to circulate in balancing entry and exiting air pressure. An “exit” can be simply explained as an open outlet point to the atmospheric. The sewage flows along a complete seal circuit. Only are entrance points at top of a vent
stack and “exit” point permitting free air circulation and air balancing, unless free outlets in the form of open vent is allowed. The author insists to allow for.

When the sewage is still flowing without reaching an “exit”, the air pressure will be unstable and is hard to balance. The air pressure fluctuation will affect the stability of any drainage system.

In traditional calculation and theoretical application, designers and engineers always predict the flow by applying guidebook in the sense of one peak flow determination only for the selection of drain size. The select drain size is adequate for the peak flow only. Absolutely, the size in handling the sewage is quite adequate but for air purging simultaneously is incapable in resulting of virtually sized inadequately. They have not considered the complete circuit in the path and time required to completely discharge to an “exit”. After the first peak appeared, the peak sewage flows rush down the drain but have to flow through a long distance till an “exit”. While the peak flow is discharging, the time of flow along the drain is lengthy at the same time. Moreover, the air purging and air replenishment are incomplete. Then, there appears another follow-up second peak flow rushes down while the first peak is still within the far end downstream in the same circuit. Numerous ‘Piston Effect’ affects the flow and built-up air pressure pushing back or sucking out the trap seals inside pipework.

7. New concept

Let consider for the time lag of two peak flows. It may absolutely appear within a circuit. The factor of time lag occurrence also depends on the circuit. It varies from one circuit to another one. From the first peak to the occurrence of the second peak could be considered as a big leap from the traditional sizing theory. Under the “exit” consideration in achieving air pressure self-regulating and balancing conditions, the consideration of a complete drainpipe circuit will extend from aboveground to underground till the outlet to sewage treatment plant. Alternatively, an “exit” to balance the air pressure can be provided within a building and its boundaries, which is also admitted technically acceptable.
There appear two significant areas of consideration: flow path and the time required to reach an “exit” under the peak flow. The appearance of first peak sewage flow while it is flowing continuously without reaching an “exit”, a sufficient time is built-up for the formation of the second peak. This can explain why drainage problem was so difficult to be solved because the third peak may have been formed subsequently.

The accumulation time for peak flows and the timing of subsequent peak flows arriving later, the air release and air return (breathing and sucking effects), the practical analysis becomes very complex. From the past, the appearance of syphonage action and backpressure occurrence has drawn the attention of risk existence. The most important message is these complex situations (with mixed mode effects) cannot be assumed by simulation process to predict the anticipated working conditions due to the dependent cases. The permutation and combinations are quite complex.

For the consideration to a combination of various types of buildings of different peak flow pattern (from residential, commercial, hotel, institutional and industrial buildings), building height varying from 15 metres to 300 metres height difference, non-consistent users habits (European, American, Latin and Third-countries), celebration parties or Chinese cultural festival days (a big family dinner gathering at home) in producing abnormal and inconsistence peak flow, which are influencing factors. The target should be set out to collect data by carrying out operational research.

8. Major concerns

Engineers and designers do not normally concern about but it is difficult to master the total flow path where and when the sewage will reach an “exit”. However, this is the most significant concern in solving drainage problems in related to a breathing pipework system handling sewage and its overall routing after exiting from a building to an external Government sewer line. Moreover, air release and return points are provided or not within a self-contained pipe circuit for an independent building, sewage flowing excessive length in time accumulating and continuous subsequent sewage collections along the Government sewer towards a central sewage treatment plant, sewage from other buildings building up while air pressure was not released properly and total flow quantities accumulating at the same time from the contribution of the adjourning buildings on the flow path are co-related. These related discharges may affect to the
associated buildings connected to the same Government sewer due to the air relieving and back pressure effect, which is quite significant and serious.

9. Conclusion

The sewage quantity and air pressure built-up are directly proportional. Regarding the breathing pipework system, unless the air pressure is released and discharge air is replenished correctly and timely, the problem of backpressure causing flooding back and syphonage action sucking out the water seal in allowing the virus leakage path can be eliminated. It is warned the subsequent discharge will force out the virus naturally and automatically afterward.

The accumulating time and quantities are unpredictable and out of the control of a designer. It is not until the overall route is mastered. Mastering the theory of air exchange and sewage flow is not difficult. To progress to the overall control of drainage flow and cycles may be extremely hard. Designers cannot control the flow of other buildings on the main flow path. Other buildings along the main drain path can form side factors (in peak flow and peak time) causes backpressure and syphonage actions formation randomly. But, the accumulative effect undergoes tremendously and cannot be predicted accurately. To tackle this problem, operational research is in one goal and data collection from different buildings for analysis is in the second goal. Perhaps, the future intelligent building design with full monitoring on systems could help.

The only solution is to release the problem (air pressure) at the appropriate points without impacting to the other buildings. In Hong Kong, majority of the drain stacks and sewer from aboveground to underground are not vented adequately and effectively. The vent provision in all drainpipe sections for both the aboveground and underground is inadequate. In preliminary solving the basic problem, each building sewage disposal system must be vented independent. Impact formed by subsequent discharges and flow accumulation is unavoidably but must not link to air pressure building up along the main sewer till reaching an “exit”- the sewage treatment facilities. Then the problem due to air pressure is less troublesome.
10. Recommendations

After mastering the discharge process and the breathing pipework system concept, the author suggests:

10.1 Solve by releasing the air

Trapped air if under a continuous boosting will create hazardous situations. Air cannot escape, will render a high pressure in jetting wastewater to a tremendous height (It was recorded waste water jet up to the ceiling level from a water closet inlet at first office floor of Hong Kong Bank Headquarters in Central, Hong Kong, 1986).

In allowing automatic air vent, air admittance valve, Positive Air Pressure Attenuator (PAPA), it seems a temporary measure. If these were put in wrong locations, they cannot perform their function effectively (at possible bombard locations). The temporary allowance to absorb air built up and replenish to the system again later were not totally effectively. In Photo 1, there appears some draw back from a series of PAPA to absorb the air surge. It is queried why vent pipe was not considered to assist to resolve the problem.

![Photo 1 - Placement of 3 to 2 to 1 PAPA on 2nd, 3rd & 4th floor to solve air transient problem. Can they be more effective than a vent pipe?](image-url)
10.2 Understand the effect of an underground drainage system

After mastering the impact of an underground drainage system will continue to receive the sewage from the above ground drainage system, the sewage will then flow through a long route to the sewage treatment facilities in Hong Kong. One example is drains gone through an internal underground drain of nearly two hundreds and the subsequent path to Government sewage treatment plant of several kilometres. The flow accumulations become larger and larger, and the greater the amount of air should be released back to the aboveground drainage system. If there is no provision of venting pipes, improper and in-effective release of air, sewage flow is interlocked by the air release and replacement by sewage. It may illustrate a typical very bad case.

Within a district sewage disposal system, various types of buildings, sewage accumulates from one to ten to even thousands of buildings are expected. Different building means for the different function usage, resulting different disposal peak flows and various peak times. However, the accumulation still occurs, which is a very complex situation.

To face the reality, the provision of vent pipes is recommended for the underground drainage system. In the past, vent is permitted at the first manhole and the last manhole for a group of underground manholes and drains system. The suggested additional vent pipes must be allowed to effectively vent the trapped air, release from boosting, let sewage discharge and replenish the air promptly.

The only draw back is the vent pipe may expose the virus transmission path to the surrounding which can be solved by dilution effect (reduce virus concentration). Vent pipe can be installed to face the wind direction at a height much higher than human beings. The aerosols have buoyancy force plus the wind effect serving for a dilution process so the risk can be reduced.

Let examine from the Law of Conservation of Mass. A drain of 300 mm diameter of a length of 300 metres has a volume of 21.026 m$^3$. If it permits 1/3 full flow of the drain capacity, the sewage handling capacity is 7.069 m$^3$ which will displace equal volume of
air. If the sewage flows at 1.0 metre per second, then the air will escape at 1.0 metre per second. Allowing vent pipe at first and last manhole is insufficient.

The requirement of vent pipes can be flexibly allowed to every 30 metres to allow for prompt release and replenishment.

From the Displacement Law and Conservation of Mass, air and sewage exchange their space instantly. The peak flow and occurred peak time cannot be predicted accurately and their re-occurrence was also difficult to be obtained. Hence, a simulation case is not accurate enough to preview the real situation. There are too many assumptions without really mastering the practical situation.

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Presentation of Author

Cheung Siu Hung, Lonnie is a lecturer in City University of Hong Kong. He possessed over 27 years experience in piping systems design, research and studies. In his last twelve years, he taught his students about his expert area – plumbing and drainage. He has continuously served professional institutions for more than fourteen years.