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Current Design of High-Rise Building Drainage System in Taiwan

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Abstract

The main purpose of the research is to find the solution of drainage issues in high-rise building through the observation and basic study of stack fluid mechanism. Firstly, we will investigate the existing high-rise buildings and summarize the design methodology from our previous researches. Through the observations and reviews, this paper would conclude the solutions for existing drainage problems and the theory of air pressure distribution in stack of high-rise building may be applied.

Keywords
high-rise buildings, drainage, stack, air-pressure, methodology

1. Introduction

Since 1985, Tai-power office building that is the first domestic building above 100 meters was constructed, high-rise building evidently appeared to the metropolis area of Taiwan from north to south. Moreover, Taipei 101 is seen as the milestone of high-rise building. The design of high-rise building is complex and high integration work and the success reveals the technical achievement of a country. Nonetheless, the importance of building drainage, which is a humble but very substantial issue, might not be ignored.

The gravity drainage system without any energy supply is commonly used in building all over the world, and the trap with simple structure is also preferred to set as a critical part for most of sanitary facilities because of its easy elimination of stench and vermin. Owing to the increasing of potential energy of height, inappropriate design of drainage system is facile to cause the sanitary problems in high-rise building and inconvenient utility. Particularly, people recognize the importance of healthy environment through the impact of SARS disease. The community infections of Hong Kong give us a great lesson that the problems of drainage system including the infectious disease caused from loss of seal water in trap, and we should not ignore the hidden troubles of building drainage.

In order to improve the drainage performance of existing high-rise building, investigation is necessary and appropriate design technology of domestic application must be conducted. The main purpose of the research is to find the solution of drainage issues in high-rise building through the observation and basic study of stack fluid mechanism. Firstly, we will investigate the existing high-rise buildings and summarize the design methodology from our previous researches. Through the observations and reviews, this paper would conclude the solutions for existing drainage problems and the theory of air pressure distribution in stack of high-rise building may be applied.

2. Mechanism and Theoretical Reviews

Appliance discharges to a vertical stack of drain may be described as unsteady or time dependent flow, and the form of the appliance discharge flow contributes to this flow condition. An actual discharge of vertical drainage stack has a complex phenomenon and may consist of triple phase flow feature with incorporated solid, liquid and air. Airflow in the drainage stack is promoted by through-flow mixing as well as the interaction of friction with the falling water and air. This mechanism causes the negative pressure on the upper floors and the positive pressure on the lower floors in the building vertical drainage system.

According to the previous researches, the airflow rate (Q_a) was identified as a critical parameter for a prediction model which can express the mechanism of vertical drainage flow. Therefore, the airflow performance in vertical drainage stack is the dominated issue and it needs to be solved. Hence while air flow rate is dominant in the vertical drainage stack it plays a critical role in the subsequent operation of vertical drainage stack where the mechanism may be assumed to be a quasi-fan machine, thus the laws of fan can be introduced to link with the vertical drainage flow. The laws of fan can be expressed by the hydraulic parameters such as air density, pressure, velocity, gravity, resistance coefficient, lift, and et al. Practically, the operation energy for airflow within fan is mainly from electric power, thus potential energy of height is the dominating power for conducting the airflow in vertical drainage stack. This antithesis mechanism can be expressed as quasi-fan theory, namely the initial model of vertical drainage flow was conducted from the lows of fan machine alike.

The mechanism of flow within vertical drainage is now schematically understood. Air pressure in vertical drainage stack is caused by series interactions between downstream water and through-flow air in vertical pipe. Fig.1 illustrates the image of flow state and the modified interaction, thus it conducts the main parameters with air pressure, airflow rate, and resistance coefficients, and they are the essential factors for prediction model of air pressure distribution in vertical drainage stack.

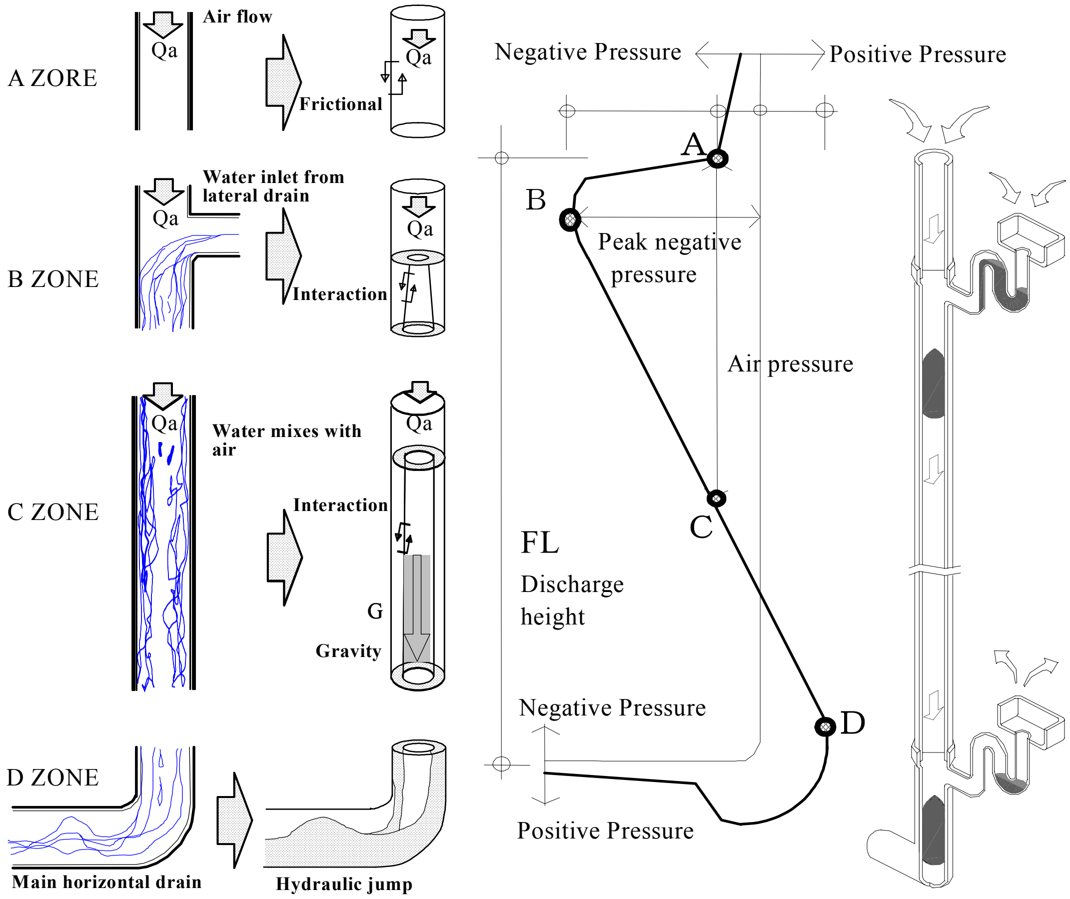


Fig.1 Mechanism of vertical drainage feature and inverted model

The guideline of National Plumbing Code (NPC) of US was used to set the permit flow rate as the regulation of drainage system [3]. Following initial work of the HASS 203 of Japan in 1970s, the method of steady flow condition was merged as the provision reference and evaluation technique, hence it conducted a series researches of steady flow method with reference to building drainage network. Consequently, a prediction model about the air pressure distribution, which occurred in the drainage stack by high-rise experiment tower (108m) and middle-high experiment tower (30m), was developed in Japan from 1990, then considerable progress has been made in predicting the air pressure distribution within vertical drainage stack [4][5].

According to the mechanism and feature of vertical drainage flow from the theoretical reviews, the profile of drainage stack was divided into four zones, and each zone is individually modeled due to the corresponding characteristics. Meanwhile, the air pressure distribution, which reveals the time average air pressure data with steady flow condition, does not involve the instantaneous air pressure fluctuation in vertical drainage flow.

3. High-rise Building Issues

The competition of construction up to the sky is never stop in the human history. People always notice and like to talking about the building of top height in the world. Figure 2 shows the holistic views of top ten high-rise building all over the world. Figure 3 is the situation of high-rise buildings in Taiwan. As mentioned above, Taipei 101 is seen as the milestone of high-rise building in Taiwan's develop as shown as Figure 3 and Figure 4. The design of high-rise building is complex and high integration work. People see the success reveals the technical achievement of a country.

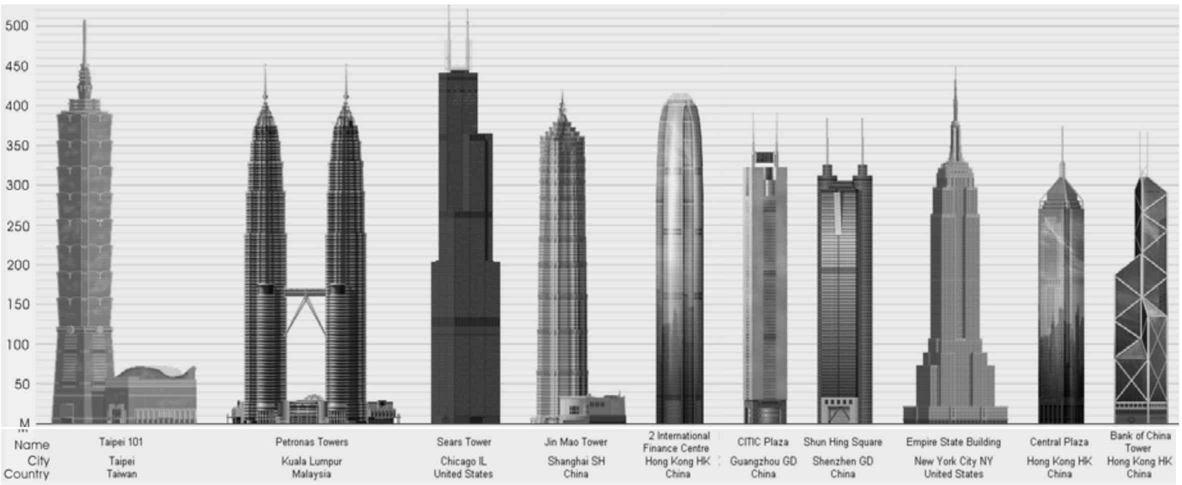


Figure 2 World top ten high-rise buildings

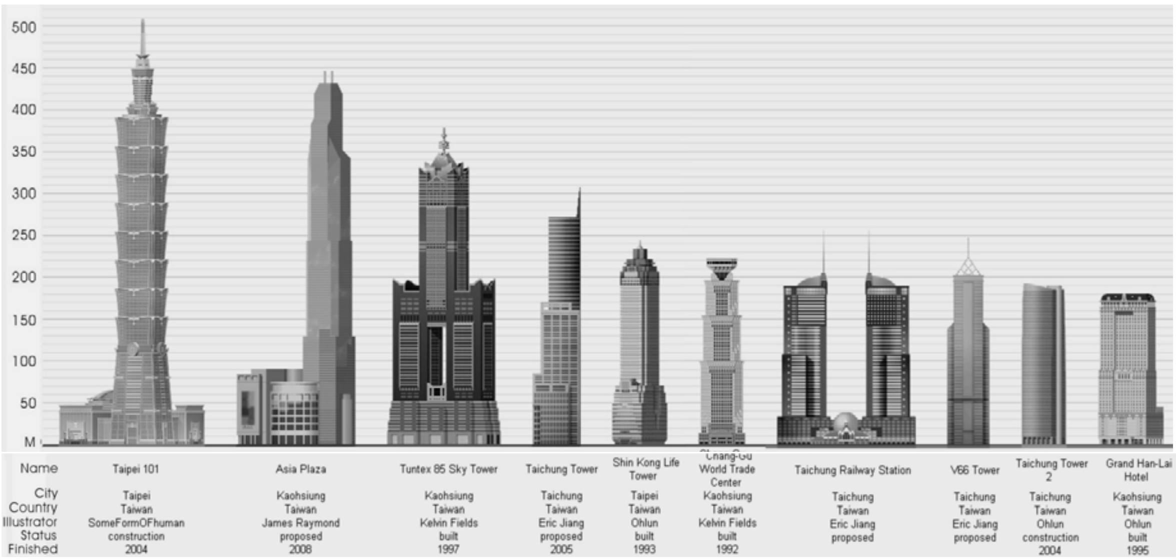
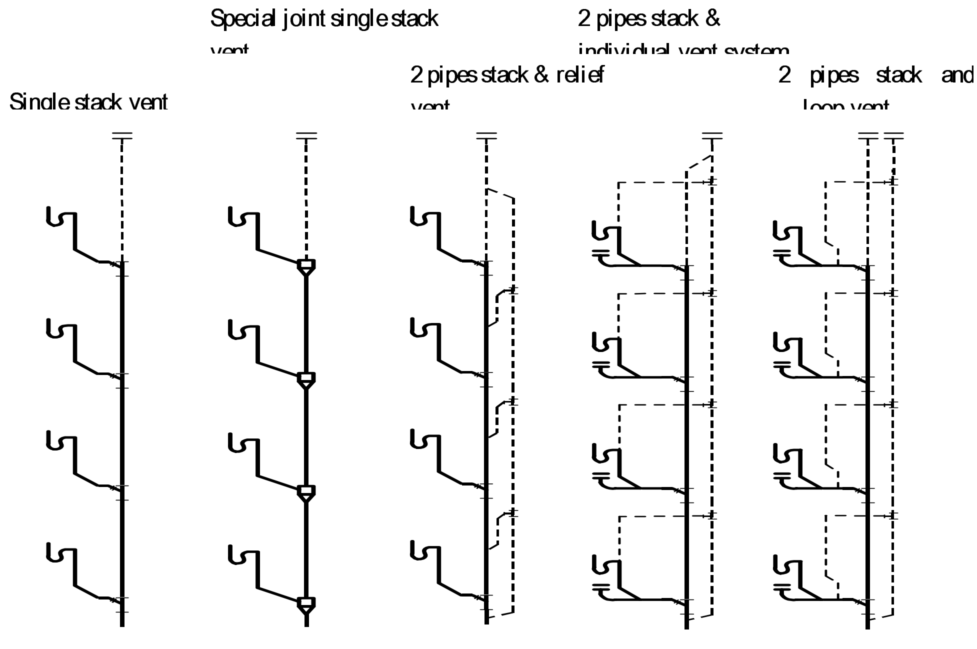


Figure 3 Taiwan top ten high-rise buildings

Primary investigation reveals that design methodology of high-rise building drainage system is still unclear in Taiwan. Building drainage problems such as destroy of trap seal, chaotic or block plumbing, sanitary performance and ill infection … are very possible existing in current buildings. Technical solutions and suitable design methodology need to be conducted for local issues at present.

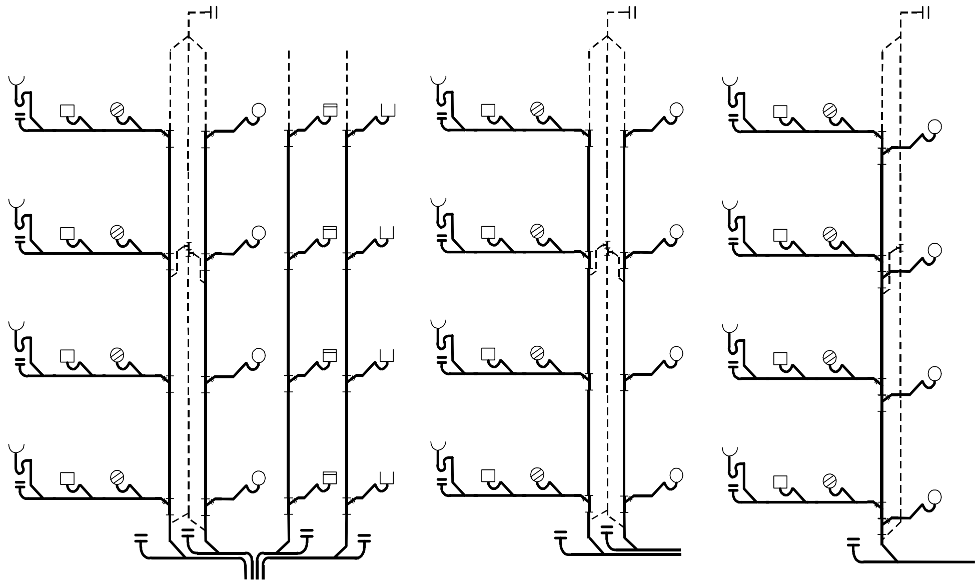
4. Investigation of Building Drainage and Vent Systems

Past research and design codes show that apartment houses can have single-pipe or dual-pipe drainage vent systems (see **Figure 4**). Vertical drainage stack pipe can be single or multiple pipe due to the several types of discharge—sewerage, bath, kitchen, abstergent from the washing machine, rain water (see **Figure 5**)—and to prevent the drainage pipe from being choked by waste water with oil and cleanser. The vent pipe system includes four types: Loop vent, individual vent, stack vent, and relief vent and vent stack (see **Figure 6**).



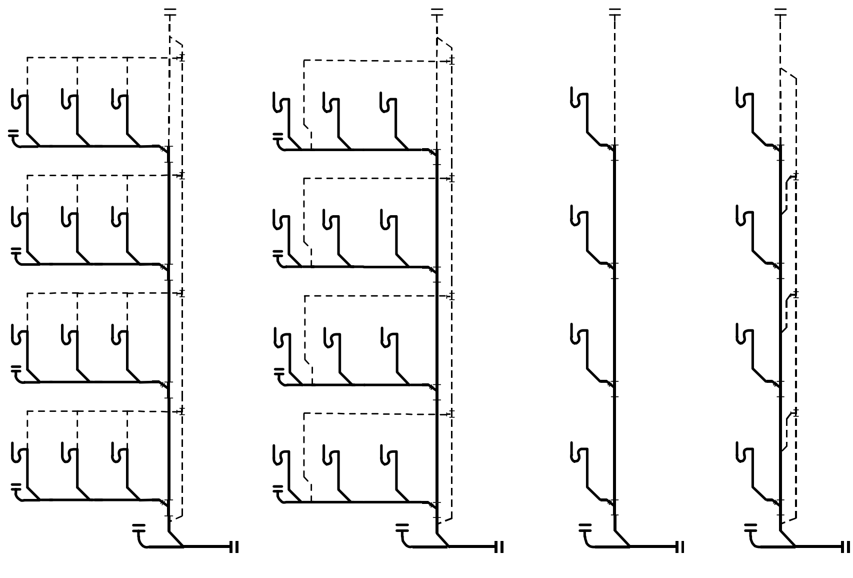
a. Single-pipe drainage & vent system b. Two-pipe drainage & vent system

Figure 4. Types of Building Drainage Systems



a. more than 2 drainage pipes b.2 drainage pipes c. single drainage pipe

Figure 5. Types of building drainage pipe for building drainage system



a. individual vent system c. stack vent system

b. loop vent system d. relief vent & vent stack

Figure 6. Types of the vent pipe for building drainage system

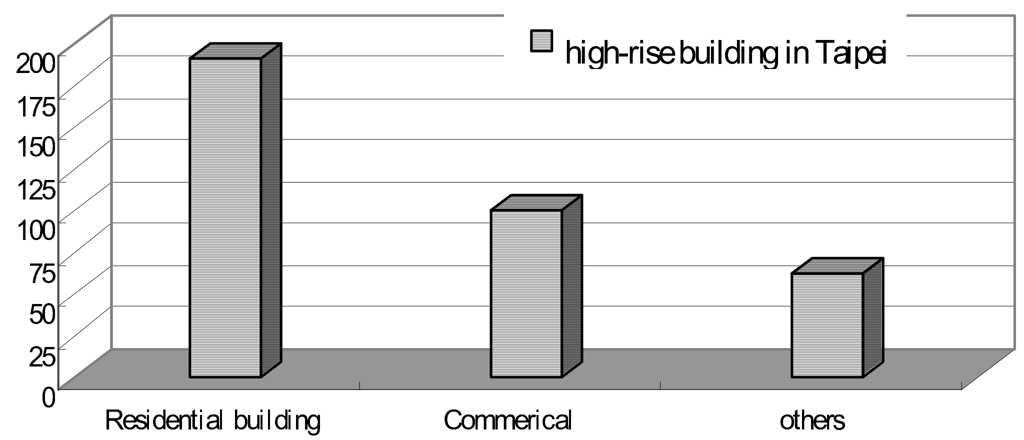
5. Investigation

This report focuses on the high-rise buildings, which are according to building code definition with over sixteen floors or fifty meters height. The further information concerning building drainage system was collected by investigation and interviews with plumbing engineers. Meanwhile, technical reviews and previous researches also offer the reference and understanding of current design methodology. This information would lead to the solutions for building drainage problems of high-rise buildings.

According to authority records, there are 354 cases of high-rise buildings, which are over sixteen floors or 50 meters height in Taipei city. Table 1 shows the Taipei authority's records about these cases of high-rise buildings with utility categories before 2003. It reveals that residential buildings are the most occupation with 191 cases and 54.1%. The following is commercial buildings with 100 cases and 28.3%. The others are of 62 cases and 17.6%.

Table 1 High-rise building with utility categories in Taipei

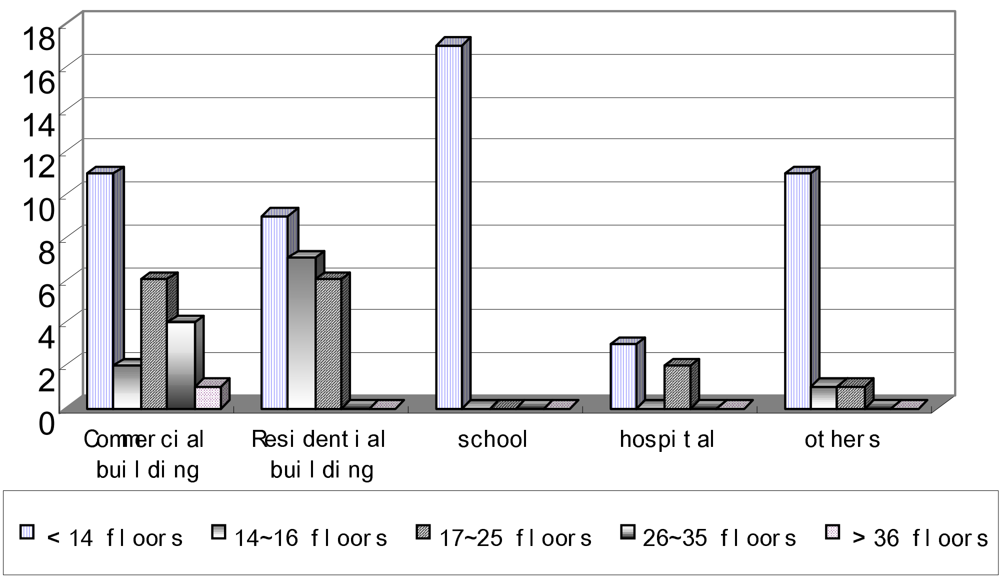
Utility category	Case numbers	Percentage
Residential building	191	54.10%
Commercial building	100	28.30%
Others	62	17.60%



As the detail study objects, 51 cases were arranged due to interviews of professional companies and plumbing engineers. The floor height and utility categories are shown in Table 2.

Table 2 Interview cases with floor height and utility categories

Floor height	Commercial building	Residential building	School	Hospital	Others
< 14 floors	11	9	17	3	11
14~16 floors	2	7	0	0	2
17~25 floors	6	6	0	2	1
26~35 floors	4	0	0	0	0
> 36 floors	1	0	0	0	0



6. Analyses and Discussion

According to the previous categorization of building drainage system, the system design including four types, which are combined single and double-barreled stack, separated double-barreled and individual stack as shown as Figure 7.

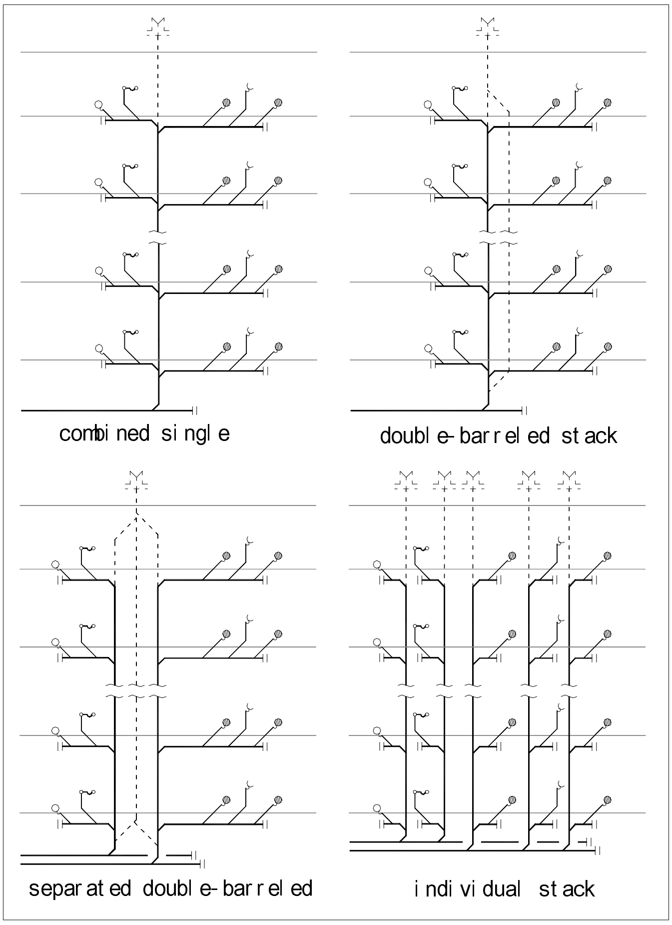
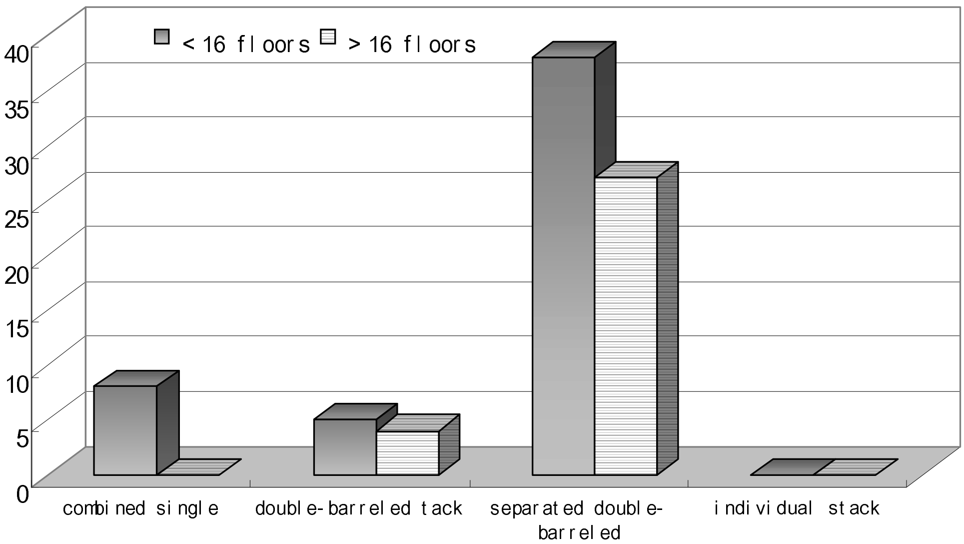


Figure 7 Building drainage categories

Due to above categories, the observed cases are arranged as shown in Table 3. The results shows that combined single stack system were rare adapted in high-rise buildings for avoiding the instant peak discharge. Although the combined single stack system is good for less fitting space. The most occupations of these cases are consternated on separated double-barreled individual stack. It means that current engineers have higher confidence in this system.

Table 3 Drainage categories for the observed cases

Drainage categories	combined single	double-barreled stack	separated double-barreled	individual stack	total
< 16 floors	8	5	38	0	51
> 16 floors	0	4	27	0	31



On the other hand, vent stack for air way is corresponding to the drainage stack. The categories for vent stack are shown in Figure 8. We also arranged the categories for the observed cases as shown in Table 4. It is obvious that double stack with connection type is the most popular in these cases.

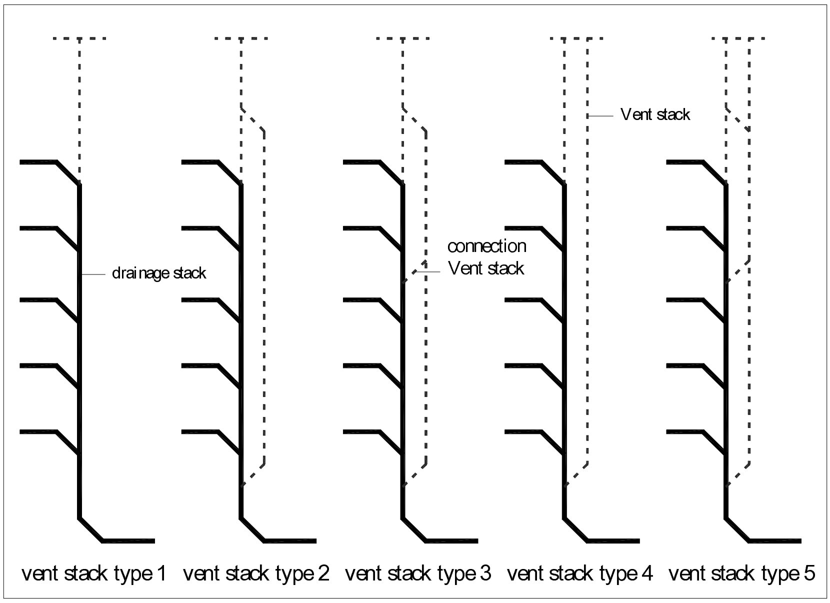
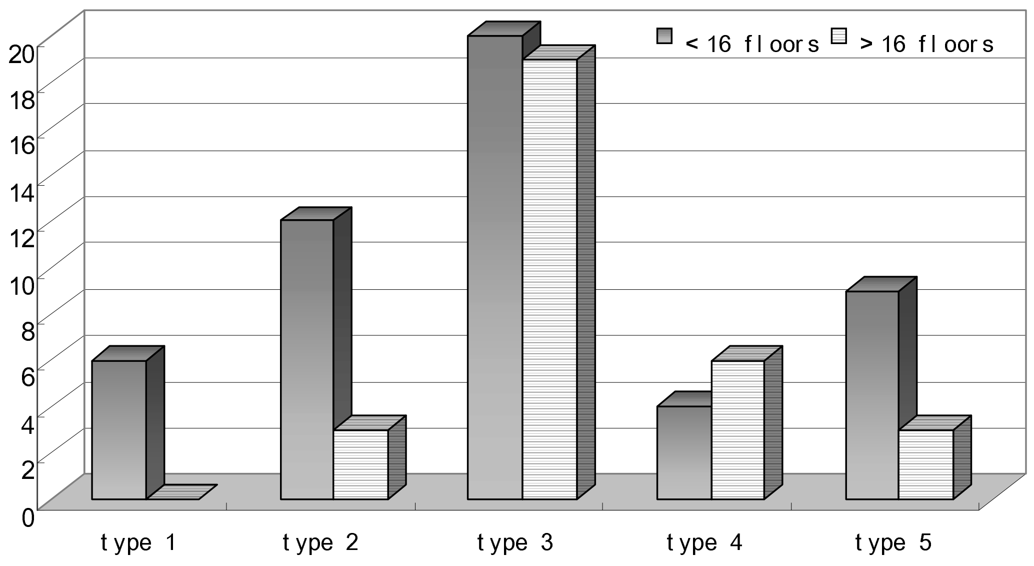


Figure 8 Categories for vent stack

Table 4 Categories for observed cases

vent stack	type 1	type 2	type 3	type 4	type 5
< 16 floors	6	12	20	4	9
> 16 floors	0	3	19	6	3



According to the partial detail observation, we concentrated on the loop vent design and concluded the current construction categories as shown in Figure 9. Owing to insufficient guideline for building drainage vent construction, the current design is not under regulation. This situation might cause problems in building drainage system especially for high-rise building.

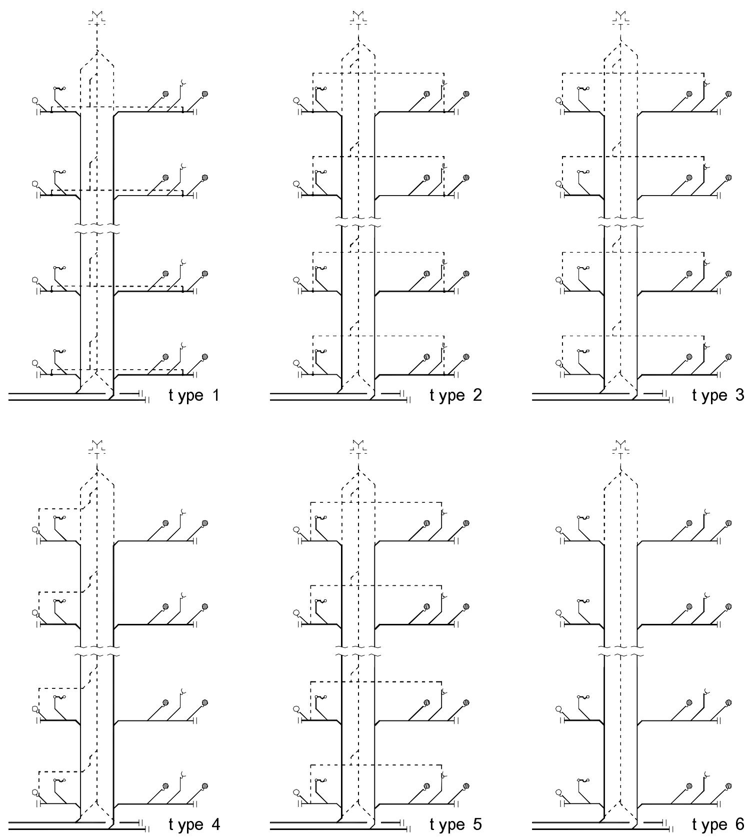


Figure 9 Categories of partial detail drainage loop vent construction

In Taiwan, building with reinforce concrete is the most popular construction. Figure 10 and Figure 11 show a typical partial detail of drainage plumbing construction. The most piping works are under the floor construction and involve into another authority space. Although it is habitually accepted in Taiwan, maintenance problems always happened in this unreasonable custom. It is obvious that stricter regulation needs to be conducted for refine this situation especially for high-rise building.

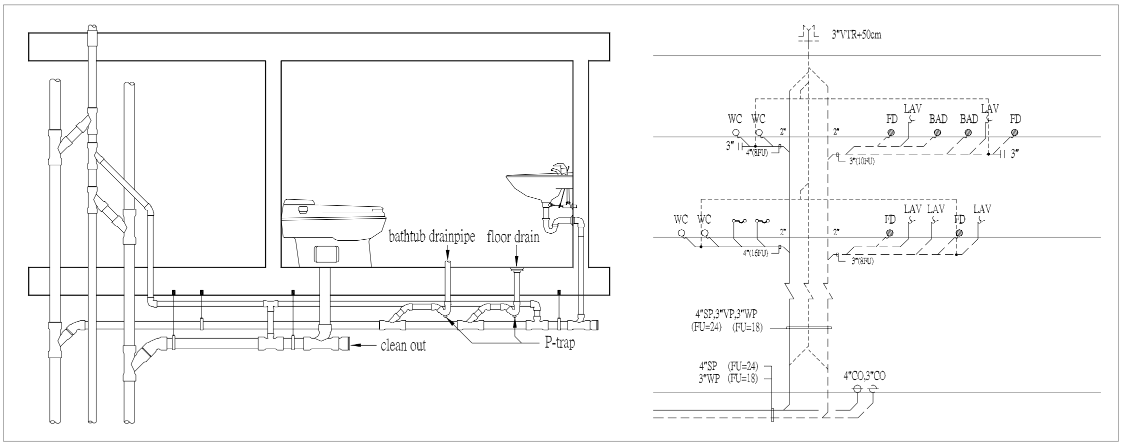


Figure 10 a typical partial detail of drainage plumbing construction

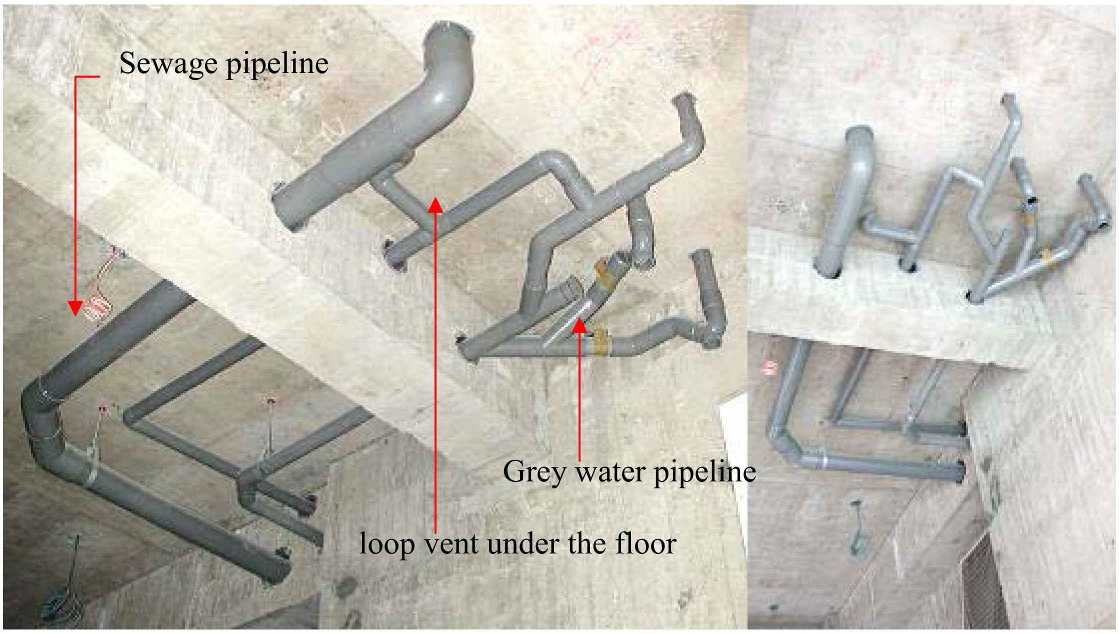


Figure 11 Picture of partial drainage piping work under floor

In order to avoid the air pressure variation and high impact of drainage owing to the height, engineers developed some construction of building drainage system for high-rise building. We categorized the current design cases and concluded them as six types as shown as Figure 12.

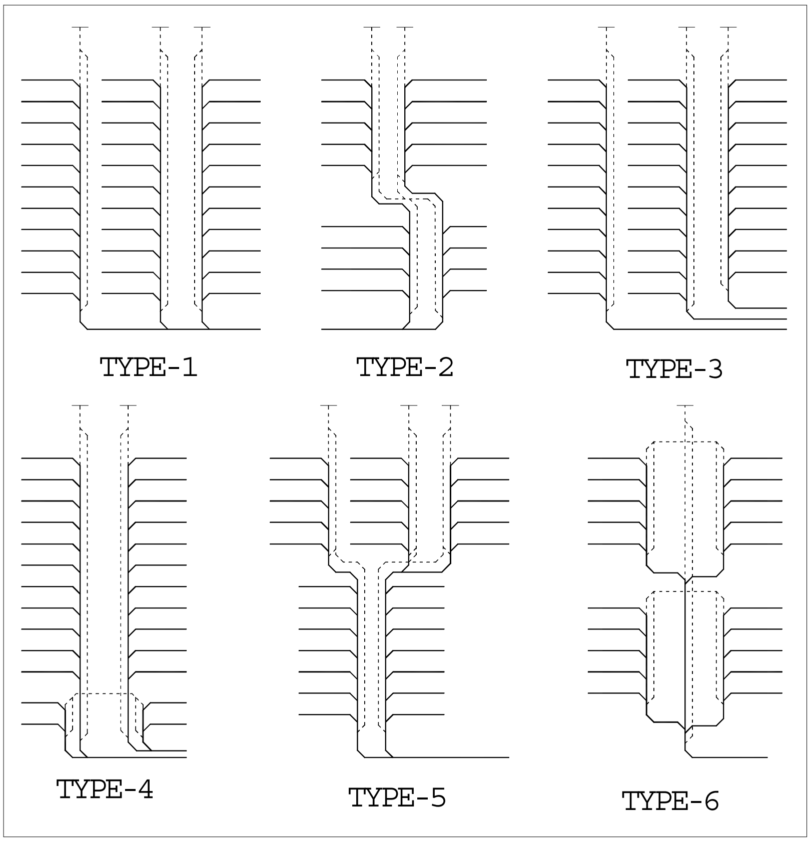


Figure 12 Drainage construction categories for current high-rise buildings

7. Conclusion

Pressure fluctuation control in vertical drainage stacks has been identified as important to insure sanitary drainage performance in early empirical studies. Chaotic plumbing and over-design are common in utility services within building envelopes from domestic investigations in Taiwan. The main purpose of the research is to find the solution of drainage issues in high-rise building through the observation and basic study of stack fluid mechanism. We investigated the existing high-rise buildings and summarize the design methodology from our previous researches. Through the observations and reviews, this paper concludes the current design of building drainage system from existing drainage constructions. Owing to insufficient guideline for building drainage vent construction, the current design is mostly not under regulation. This situation might cause problems in building drainage system. It is obvious that stricter regulation needs to be conducted for refine this situation especially for high-rise building.

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