The Same-floor Drainage for Independent Retrofitting of the Existing Apartment Buildings without S-I System in China

ZHU Ning a; JIANG Yong a; WANG Qiang b; GUAN Wenmin c

a. School of Architecture, Tsinghua University, Beijing, 100084, China
b. Student Community Management & Service Centre, Tsinghua University, Beijing, 100084, China
c. SPEC Plumbing Co. Ltd., Ningbo, 315514, China

Abstract. By 1998 the total floor area of urban residential buildings was 9.59 billion square meters in China. In this period, most of the apartment buildings in China adopted brick-concrete structure or shear wall structure without S-I-system, and limited the integrating means of retrofitting and reuse. Because of the strict control of area standard in urban residential construction at that time, the toilet area is always too small to carry the contemporary life style, which takes the first difficulty within independent retrofitting of the apartment building. Since the same-floor drainage system is widely used many new built apartment buildings, this paper aims to research and develop this system into retrofitting of the existing apartment buildings without S-I system in China. Based on the analysis to the household plans and their retrofitting design, two kinds of same-floor drainage systems are employed within the toilets, solve the problems of pipe connection, floor elevation and waterproof, and succeed to improve the function and space use of whole household.

1. Introduction

China's large-scale urban apartment buildings construction began in the 1950s. By 1998 the total floor area of urban residential buildings was 9.59 billion square meters [1]. Among them, a large number of residential buildings adopt brick-concrete structure or steel-concrete shear wall as the main load-bearing structure (figure 1). Because of the strict control of area standard in urban residential construction at that time, it was unable to carry the contemporary life style [2]. As its high similarity of household type, there are much greater potential values within retrofitting in the household scale.

Figure 1. Sorts of elevation of the apartment buildings in inner Beijing area

1.1. Non-SI system characteristics of existing apartment buildings in China

The basic theory of renovation of apartment buildings came from Skeleton-Infill system proposed by Professor Habraken of the Netherlands in 1961 to alleviate the contradiction between large-scale housing construction and diversified demand of living style [3]. After the 1970s, the Japanese Residential Communities developed their own KSI residential system by using the SI system of the
Netherlands for reference, so as to facilitate the renovation and maintenance of buildings, focusing on the renewal and reuse of products from the community to the residential unit to the interior of the house [4]. In this period, most of the apartment buildings in China adopted brick-concrete structure or shear wall structure (figure 2).

![Figure 2. Compared with S-I system (left), space inflexibility in the load-bearing walls system limited the integrating means of retrofitting and reuse (right).](image)

1.2. Main problems and difficulties in reform of toilet in apartment buildings

In these types of apartment buildings, the toilet area is always too small to contain the enough numbers of sanitary wares, and even the number of drainage outlets is insufficient. Taking 1974’s apartment building style as an example (figure 3), the net area of its toilet is only 1.36 square meters. The original design includes 1 squatting toilet, 1 water tap for rinsing, and 1 floor drain. There is no shower space, and even no wash basin. During more than 40 years, wash basin and shower spraying were gradually added to the bathroom, and some toilets were replaced, but still inconvenience to everyday life.

![Figure 3. Early squatting toilets using water outlet and cast iron pipes, required a large backwater bend to ensure the water seal of drainage branch pipes, using the roof part through the floor in the lower households to install and access drainage risers. In order to ensure the bedding and pedal of the squatting toilet, it has to raise the floor level around the toilet by 200-400 mm.](image)

1.3. The same-floor drainage system of the new-built apartment buildings in China

The same-floor drainage is a special technology for connecting drainage pipes to drainage risers on the same floor as the household space. The advantages of the same-floor drainage are as follows [5]:

- Clear property rights of household
- Waterproof safety with small leakage probability
- Flexible change of layout of sanitary appliances
- Low drainage noise
- No condensation underwater drip
1.4. The research method (figure 4)

![Figure 4. Routine of design and development to the same-floor drainage system in existing apartment buildings. It depends on the LDK integration in the plan as well as the number of bedrooms.]

2. Traditional same-floor drainage retrofitting: renovation in the expanding toilet area

2.1. Family characteristics

At most three generations and six people live together: two children under school age, two couples of young teachers, and one or two old people or nannies who take care of the children. Old people usually concentrate on activities in the kitchen and dining room, while keeping an eye on children in the living room. Therefore, a set of visual LDK space is very important. Considering the situation of large family population, as early rise, or bedtime, it is also very important for each sanitary ware to have independent use space (figure 5).

2.2. Technical difficulties and opportunity points

Because of the non-SI system, the original bathroom area is too narrow to carry out three-apart separation design. In addition, the same-floor drainage needs to raise the elevation by 80-120 mm, and lay the horizontal branch pipe with the diameter of 50 mm leaking to the plumbing riser. If all other rooms are raised with the bathroom, it means that not only compresses the net height of the use space, but also a lot of construction costs. Carefully studied the characteristics of the original house space, the above two problems can be solved in three favourable opportunities.

![Figure 5. Opportunity points: a) LDK interconnection ensures the area of basic activity space. b) As the window was turned into a door, the space of the toilet expands to the balcony as a bath room. c) Kitchen can also move to the balcony and give space to dining room.]

2.3. Renovation design and development

According to the requirement of the same-floor drainage technology system, the design of drainage pipeline connection, surface elevation and waterproofing of floor are mainly considered.

2.3.1. Drainage pipeline connection. There are four drainage points in the toilet (figure 6). The advantage of the same-floor drainage is that it can redesign the location of each sanitary ware without relying on the original toilet layout and drainage point, so as to make its layout more reasonable. Reform of the existing main plumbing pipe without disturb to neighbors above and under needs to employ hydrocyclone as the collection of branches of sanitary, while plugging into the root of existing pipe and connecting the branches pipes above (figure 7).
2.3.2. **Floor elevation.** Elevation design is the key to the design of the same-floor drainage, which determines the final completion of floor surface. On the one hand, it is necessary to ensure that the gradient of drainage is not less than 1.2% [6] (the washing machine has pressure drainage, without considering gradient), on the other hand, it is necessary to minimize the completed elevation for more net height. In order to make the 50 mm drainage outlet of the cyclone strive for lower drainage point, the concrete cushion of 30 mm downward is also cut out, in order to ensure accessibility, the height of the floor drain in the bathroom was raised slightly twice in three spaces, each time 15 mm [7], to meet the requirements of the floor drain elevation in the bathroom. It is worth mentioning that the location of the height difference, combined with the traditional method of crossing the gate stone, makes the height difference difficult to detect, and the crossing gate stone has a slight chamfer transition (figure 8).

2.3.3. **Floor waterproof.** Since the existing structural floor, including the balcony, employed a whole RC panel, there is no need additional membrane waterproof under or above the cement cushion layer. Only bathroom should it add whole unit waterproof to keep water penetrating the floor to the lower layers.

2.4. **Retrofitting achievements** (figure 9)

3. **Pressurized same-floor drainage retrofitting: renovation of the whole displacement of toilet**

3.1. **Family characteristics**
The family style is single or married residents without child (figure 10). Although the area of less than 40 square meters is not large, there is relatively abundant for everyday life, so comfortable, open space and quality of life are purpose of this retrofitting.

3.2. Technical difficulties and opportunity points
The living room cannot be directly illuminated. Near the entrance hall, the original small living space was more crowded. But the size of the bedroom, including a balcony, is too luxurious.

Figure 10. After the bathroom moves to the bedroom, the original living room, kitchen and toilet space can be fully integrated to form a typical large space of LDK. The entrance of the lobby can be dispersed in this space, which also solves the lighting problem of the living room.

The research team has come up with an idea. Since the same-floor drainage can make toilet redesigned, can it make the whole plan redesigned? There can be a try to move the bathroom to the bedroom. It faces the following problem that the gradient of the same-floor drainage leads to elevation increase. The farther away from the public riser, the more elevation of the floor increases. In addition, moving the bathroom to the bedroom means that the bathroom on this floor stands above the bedroom on the lower floor. It is necessary to strengthen the waterproofing of the bathroom.

3.3. Renovation design and development

3.3.1. Spatial layout of pressurized same-floor drainage: Using sewage crushing and lifting pump, it is possible to reduce the diameter of drainage pipes for long distance plumbing, and at the same time to place them in the ceiling space, and share the service space with other pipelines. Finally, the parallel riser conveys downward to the riser through the hydrocyclone, so that the floor elevation can be leveled with the living room, as long as the elevation of the bathroom can meet the inlet water level of the lifting pump (figure 11).

Figure 11. Plan (left) and elevations of the pressurized same-floor drainage

3.3.2. Waterproof renovation of the original floor: Because the lower floor locates the bedroom, the same-floor drainage has to solve the problem that if the drainage pipeline would be damaged, it cannot penetrate directly to the lower floor, which avoiding the problem that the toilet cannot stand above other clean functional rooms in the building code. There will be also a violation of property rights of lower-class households, which originally should be the advantage of the same-floor drainage system. Thus, the bathroom employs two layers of waterproof to ensure not only the leakage of floor surface, but also the plumbing pipes (figure 12).
a) 10mm tiles with glue  

b) 5mm PP waterproof  
c) 100mm ceramsite concrete  
d) 50mm cushion (new fill)  
e) 2mm membrane waterproof  
f) Prefabricated hollow panel  
g) 20mm Alu-Polymer panel  
h) 18mm calcium silicate panel

Figure 12. Detail of two layers of waterproof above the structural hollow floor panel, in contrast of the former case as the RC floor panel.

3.4. Retrofitting Achievements (figure 13)

Figure 13. Through the overall move of the toilet space, LDK layout formed with good lighting conditions and space quality. At the same time, it improves the quality of bathroom, and does not disturb the everyday life of the upper and lower floor.

4. Discussions and prospects

4.1. Is there a contradiction between the overall movement of toilets and the relevant residential codes? The original residential code requires that there should be no other type of room under the toilet [6]. In principle, if all drainage pipes are included in the overall space of the bathroom, then a whole closed waterproofing on the structural board can solve the problem of pipeline leakage, and if there is leakage, it will soon cross above the waterproofing weak parts such as the threshold, which will have a significant impact in the own household room, reminding to stop water and repair urgently. As the signal is obviously easy to detect, it will not disturb the household in lower floor.

4.2. Noise effect of sewage pump

It adopts the strategy to block the noise transmission path period by period. Firstly, the sewage lifting pump places in the bathroom, a corner formed by two load-bearing walls and structural floors, so that the running noise will not resonate with other light walls in the bathroom. Secondly, apart from the wall outside, the 600 mm thick wardrobe is partitioned between the bathroom and the bedroom, almost completely blocking the sound transmission from the partition wall. Then from the bathroom to the bedroom, there are three doors to block the air transmission more. Ultimately, when all doors are closed, it is not easy to detect the operation of the sewage pump in the bedroom.

4.3. The application prospect of the same-floor drainage in the household renovation of existing residential buildings

Using the opportunity of batch renovation of public housing household replacement period by the Housing Management Department of Tsinghua University, this research began to study the technical system of renovation through several model rooms from year of 2014. From 2015 to 2018, mass promotion was carried out according to the mature technology in the pilot project, and 117 households were renovated by the same-floor drainage system. Compared with the traditional downward drainage system, the advantages of the new technology system are obvious and easy to follow, especially in the existing apartment buildings without S-I system.

5. References

[1] Shao T 2013 General situation and development trend of urban housing supply in China China Economic Times June 24 005
[2] Lü JH, Rowe PG and Zhang J 2003 Modern Housing in China 1840-2000 (Beijing: Tsinghua University Press)

[3] Matsumura S, Fan Y and Liu TT 2008 Regeneration of residential area: New retrofitting apartment buildings in Europe and America (Beijing: China Machine Press)

[4] Omi Y and Wu DH 2009 Housing construction and industrialization in Japan (Beijing: China Architecture and Building Press)

[5] Jiang Y, Guan WM, Zhu N and Chen DP 2018 J. Human Settlements in Western China 05 28–33

[6] Ministry of Housing and Construction PRC 2009 Code for Design of Building Water Supply and Drainage (GB 50015-2003) 4.3.4 and 4.4.10 (Beijing: China Planning Press)

[7] Ministry of Housing and Construction PRC 2012 Codes for Accessibility Design (GB 50763-2012) 3.5.3.7 (Beijing: China Planning Press)

Acknowledgments

This project is supported by the China National Key Research and Development Program (Project No. 2017YFC0702900) and the National Natural Science Foundation (Project No. 51978358 and 51578300). Thanks to the Housing Management Centre of Tsinghua University for providing a practical platform, and the technical support and integration are provided by the Research Centre for Sustainable Community, School of Architecture, Tsinghua University.