C10 - A STUDY ON HOW TO ENSURE THE DRAINAGE PERFORMANCE OF A DRAINAGE PIPE SYSTEM FOR LOW-RISE HOUSING AND A PIPING DESIGN METHOD OF THE SAME

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Abstract

In designing drainage pipe systems for 2 to 3-storey low-rise housing in Japan, there are problems yet to be solved in terms of ensuring good drainage performance and plumbing. The problems relating to the drainage performance include the likelihood of damage to the trap seal caused by poor aeration from the vent pipe, and the problems relating to the plumbing include the difficulty of connecting the house drain through many parts of the foundation section of a dwelling to the catch basin.

This study intends to gather design data required for developing a plumbing method for ensuring the drainage performance of a drainage pipe system for low-rise housing and a method for designing such a drainage pipe system, as well as presenting a proposal for a new drainage pipe system.

1. Background

Fig. 1 describes points to bear in mind and issues relating to the design and construction of a commonly used drainage pipe system for low-rise housing in Japan. At present in Japan, guidelines for designing and constructing drainage pipe systems for low-rising housing are yet to be regulated under SHASE-S 206 and the like, and it is often the case that housing companies and builders design and construct drainage pipe systems using their own methods. Fig. 1 points out the following five issues which are discussed in 1.1 to 1.5: ① provision of ventilation from the vent pipe, ② improvement of the air flow resistance of fittings for the drainage stack, ③ plumbing in the foundations where the house drain passes through, ④ ensuring of the conveyance performance of on-site pipework and improvement of the airtightness of the small-diameter catch basin (a small-size catch basin for residential use) , and ⑤ the influence of the offset stack and the descending section outside the house.

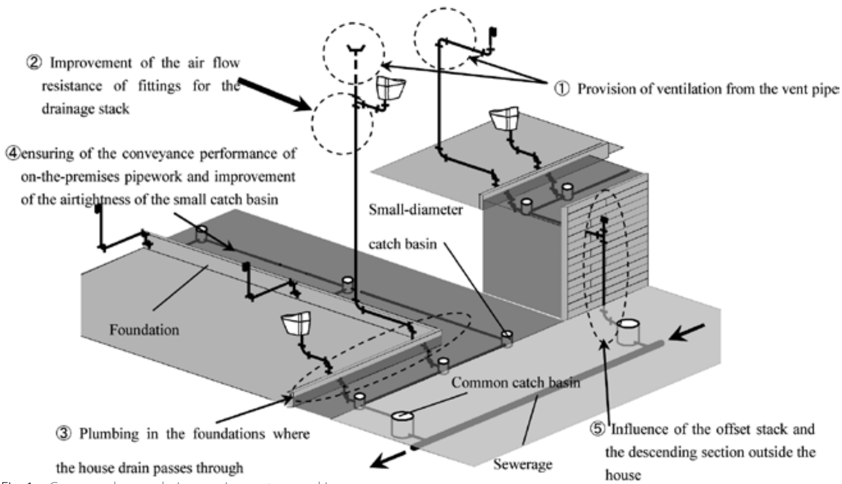

Fig. 1 – Common house drainage pipe system and issues

1.1 Provision of ventilation from the vent pipe

SHASE-S 206-2009 (Water supply and drainage sanitation standard) laid down by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan includes an explanatory note concerning the selection of an appropriate drainage vent system, and the note states that "drainage vent systems which comply with this standard shall be provided, as gravity drainage systems, with drainage pipes and water pipes with the exception of one-storied house with a small number of fixtures to be installed", suggesting that low-rise housing should be provided with drainage ventilation. However, SHASE-S 206 is a standard for general buildings, and currently in Japan, there are no standards to define whether or not to install vent pipes to existing 2 to 3-storey houses in terms of architectural confinement. The recent major trends are to install an air-admittance valve slightly lower than the lower edge of a washbasin or a sink, as shown in Photo 1, in order to prevent any siphon effect, and to install an air-admittance valve near a toilet, as shown in Photo 2. In Japan, studies on how the provision of ventilation may or may not affect the drainage performance of a single sewage drainage system for 2 to 3-storey houses was reported on the basis of experimental data in the previous documents[3)4)]. In particular, the latest super water-saving toilets use only 5 - 6[L] of water but their maximum fixture drainage flow rate q_{max} and average fixture drainage flow rate q_d are higher than those of conventional flush toilets. Hence, these higher rates raise concerns with regard to their influence on drainage performance.

(1) Kitchen sink (2) Basin

Photo. 1 – Air-admittance valve installed underneath

Photo. 2 – Toilet ventilation

1.2 Improvement of the air flow resistance of fittings for the drainage stack

Photo 3 shows a merging section between the drainage stack and the horizontal fixture drain branch, where significant air flow resistance is generated. Hence, the design of a drainage system with special fittings for high-rise and super high-rise apartment buildings is underway. Meanwhile, a small-scale drainage system with low drainage performance and fittings also needs to be developed for ordinary houses, and the authors actually presented an example, such as the one shown in Photo 4, at CIB W62 (Germany) in 2009 [5)]. Moreover, the combined drainage pipe on the middle floor is offset and then descends, whereby suction power increases, affecting the drainage performance. This point also needs to be considered.

Photo. 3 – Stack-horizontal branch merging section

Photo. 4 – Rotating-type fitting

1.3 Plumbing in the foundations where the house drain passes through

When leading domestic drainage into the small-diameter catch basin within the premises, the house drain has to pass through the foundations of a house, as shown in Photos 5 and 6, and this raises a construction issue in terms of how to treat the pass-through section. In order to overcome this construction difficulty, combined drainage systems for houses, which employ drain headers, etc. for gathering

Photo. 5 – Successively placed small-size catch basins

Photo. 6 – Pass-through section of the foundations

drainage pipes, have been developed.

1.4 Ensuring of the conveyance performance of on-site pipework and improvement of the airtightness of the small-diameter catch basin (a small-size catch basin for residential use)

The total length of on-site drainage pipes, which is relative to the locations of sanitary fixtures and common basins within the water circulation pattern of a house, is extremely long, and this fact, together with the trend of water-saving sanitary fixtures, raises concerns in terms of decreasing the performance of drainage conveyance. In addition, the high airtighteness of the small-diameter catch basin increases the positive pressure on the ground floor, which is another issue to consider.

1.5 The influence of the offset stack and the descending section outside the house

Building houses on slopes creates a drop between the end of the sewage pipe and the ground surface, and the drop therefore needs to be offset by descending the drainage stack further down to the ground, as shown in Photos 7 and 8. However, this results in increasing the total height of the stack system and therefore increases the suction of drainage beyond the offset plumbing, by which siphon effects would be induced and could possibly cause breakage to the trap seal.

Photo. 7 – Offset pipe

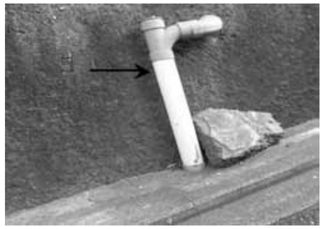

Photo. 8 – Offset pipe

2. Objectives of the study

With the background described above, this study intends to collect data which are conducive to the techniques of planning, designing and constructing drainage systems for low-rise housing.

To be more precise, with the main focus on a drainage system for low-rise housing, which has toilets connected thereto, the study aims to clarify the following points by experimenting with fixture drainage load.

(1) The influence of the configuration of the vent pipe used for the single stack vent system

(2) The influence of the configuration of the house drain on the drainage stack

(3) Further issues and suggestions concerning the development of materials for low-rise houses

3. Overview of the experiment

3.1 Experimental drainage stack system

Fig. 2 shows an experimental drainage stack system which comprises only toilets connected thereto and therefore simulates the drainage of sewage. This experimental drainage stack system is for a 3-storey building and employs a single stack method with JIS-DT fittings. The diameter of the stack is 75A, the diameter of the horizontal fixture drain branch is 75A (gradient 1/50), and the diameter of the house drain is 75A (1/100) in a standard configuration. As commonly practiced in the construction of low-rise houses in Japan, the house drain is connected through a pass-through section of the foundations, which is leveled (and therefore creating a drop), to a small-diameter catch basin (diameter 150[mm]). Furthermore, as shown in Fig. 2, the diameter of the house drain is either 75A or 100A. In the experiment, the vent pipe was used under different conditions which were combined and changed as appropriate: a closed state with no ventilation; an open state with some ventilation using an orifice plate providing opening diameters of 15[mm], 25[mm] and 40[mm] with respect to the stack diameter of 75[mm]; and an open state with ventilation using a low air flow resistance bellmouth.

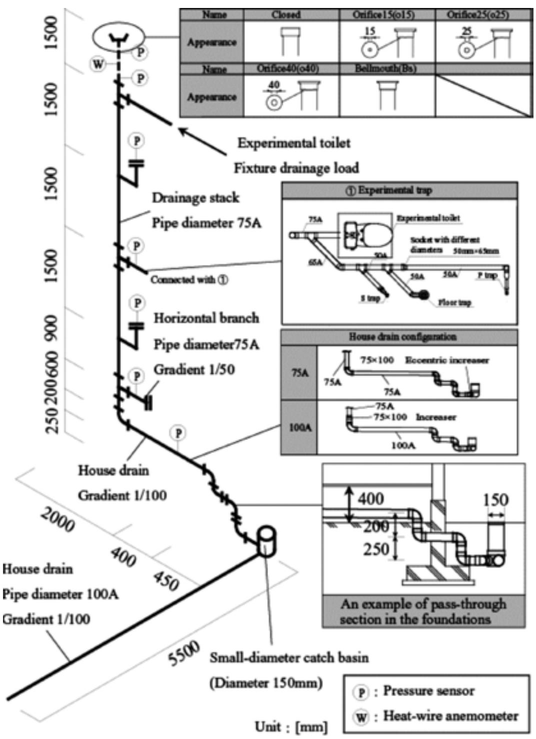

Fig. 2 – Experimental drainage system

3.2 Drainage load flow rates

In the experiment, fixture drainage load was applied from one toilet either on the 2nd floor or on the 3rd floor (single drainage), or from both toilets on both floors at the same time (simultaneous drainage). In the case of simultaneous drainage from both floors, the timing of applying drainage load was taken into account and the flow rate of the drainage load was determined so that either the maximum pipe pressure value *Pmax* would reach the highest or the minimum pipe pressure value *Pmin* would reach the lowest.

3.3 Experimental toilet

Table 1 shows the drainage characteristics of the experimental toilet when the toilet is connected to a drainage pipe with a length of 1[m]. During the experiment, the measurement was carried out in accordance with the standard of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan, SHASE-S 220 Testing method for drainage characteristics of sanitary fixtures. Incidentally, the experimental toilet is of a low-level cistern super water-saving type (siphon type) with a drainage volume of 6[L].

Table 1 - Drainage characteristics of the experimental toilet (connected to a 1[m]drainage pipe)

Discharge rate of fixture W[L]	Drainage time T[sec]	Drainage pipe average drainage time td'[sec]	Toilet-drainage pipe Average drainage volume qd'[L/s]	Instantaneous maximum drainage volume qmax[L/s]
6.01	12.9	2.00	1.82	2.09

3.4 Items to be measured

During the experiment, the variation of the wind speed Ⓦ in the vent pipe was measured using a hot-wire anemometer and the variation of the pipe pressure Ⓟ in the horizontal fixture drain branch on each floor and the drainage stack therebetween was measured using a pressure sensor. In addition, the horizontal fixture drain branch on the 2nd floor and the horizontal fixture drain branch on the 3rd floor each have connected thereto a floor drain trap for a waterproof pan for a washing machine (trap depth ("water seal depth" hereafter): [50mm], ratio of leg cross sectional area: 0.88), a P trap (water seal depth: :[60mm], ratio of leg cross sectional area: 1.00) and an S trap (water seal depth: [60mm], ratio of leg cross sectional area: 1.00), and they each had the water seal Ⓗ measured with a water level sensor and the water seal loss Δh measured visually.

The measurement criteria comply with SHASE-S 218. The maximum and minimum values of pipe pressure, *Pmax* and *Pmin*, which were generated in the drainage system, were recorded from which the maximum and minimum values of system pressure, *Psmax* and *Psmin*, were acquired. These values are defined to fall within ±400[Pa], and the water seal loss Δh is defined to be no more than ½ of the water seal depth.

3.5 Floors to be included when considering pipe pressure evaluation

Fig. 3 (1) and (2) show the comparison of pipe pressures when, in the experiment, the experimental toilet on the 3rd floor was flushed and the vent pipe had a bellmouth attached thereto. The comparison of *Psmin* and *Psmax* is shown in Fig. 4. Fig. 3 (1) shows the evaluation of pipe pressure when all the floors, i.e. the 1st 2nd, 3rd and, middle (in-between) floors, were taken into consideration for pipe pressure evaluation (measurement interval: 1.5[m] pitch), and Fig. 3 (2) shows the evaluation of pipe pressure when only the 1st 2nd and 3rd floors were taken into consideration (measurement interval: 3.0[m] pitch). According to Fig. 3 (1) and (2), when the middle floors are included, *Psmin* is approximately -300[Pa] between the 2nd and 3rd floors, but when the pipe pressure is evaluated on each of the 1st 2nd and 3rd floors, *Psmin* is approximately -200[Pa] on the 2nd floor, indicating a difference of approximately 100[Pa] as well as a variation in the location (floor) where *Psmin* is generated. Furthermore, according to Fig. 4, different conditions applied to the vent pipe cause differences in the pipe pressure, which are approximately between 50 and 100[Pa]. On the basis of these findings, this report includes the middle floors when considering pipe pressure evaluation, providing that measurement points are appropriately determined and that the height of houses is less than that of apartment buildings. Incidentally, measurement points in the house drain section are excluded from the evaluation of pipe pressure.

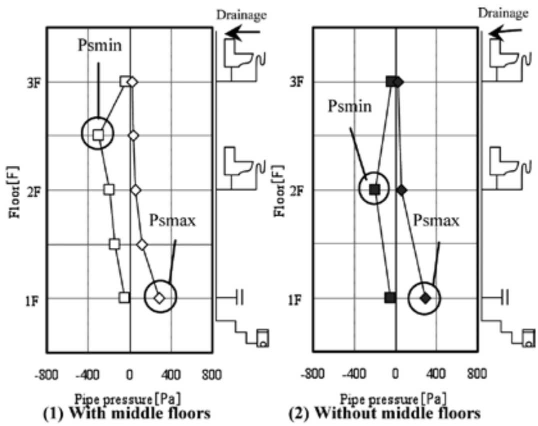

Fig. 3 – Floors considered for pipe pressure evaluation
(Single drainage from the toilet on the 3rd floor, with a bellmouth)

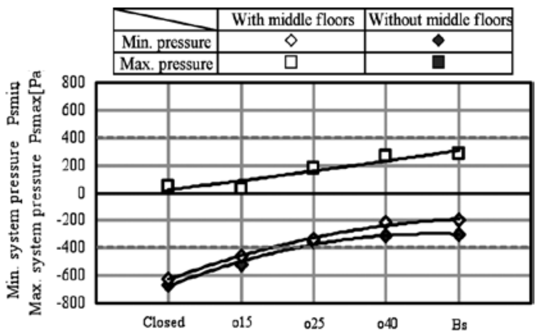

Fig. 4 – Comparison of Psmin and Psmax in the vent pipe

4 Experiment results and considerations

4.1 Pressure distribution trends

Fig. 5 shows pressure distribution examples when, in the experiment, single drainage was applied from the 3rd floor and the diameter of the house drain was 75A. As the opening diameter of the orifice plate (symbol [○] in the diagram) increased from the closed state, the floor where *Psmin* was generated changed from the 3rd floor to the middle floor between the 2nd and 3rd floors. Moreover, when compared with the closed state, when the opening diameter of the orifice plate was increased to approximately 25[mm], the negative pressure fell under the reference value of -400[Pa] which is specified by SHASE-S 218. As for the positive pressure, the maximum value thereof was approximately +289[Pa] on the 1st floor, thus, falling under the reference value of +400[Pa].

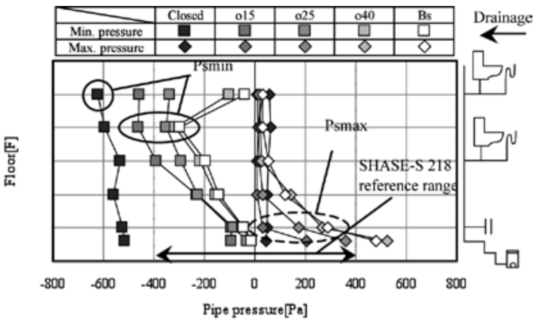

Fig. 5 – Pressure distributions with drainage applied from the 3rd floor

4.2 Comparison of max. system pressure and min. system pressure, and water seal loss

Fig. 6 and Fig. 7 show *Psmin* and *Psmax* when different diameters are used for the opening of the vent pipe and the house drain and when drainage load is applied from different floors. The diagrams also show the results when applying single drainage and when applying simultaneous drainage. Meanwhile, Fig. 8 shows the variation of Δh measured on the floors where the traps are installed, when single drainage was applied, with respect to different diameters used for the opening of the vent pipe. According to Fig. 6, when a drainage load is applied from the 2nd floor, the vent pipe is closed, and the diameter of the house drain is 75A, the negative pressure exceeds -400[Pa] on the 2nd floor and the floors underneath. However, as shown in Fig. 6 and Fig. 7, when the vent pipe is opened, the negative pressure falls within the reference range, as does the positive pressure, even when the diameter of the house drain is 75A or 100A. Furthermore, as Fig. 8 indicates, even when the negative pressure exceeds -400[Pa] and reaches -520[Pa] with a drainage load applied from the 2nd floor, as in Fig. 6, Δh of the floor drain trap for a waterproof pan for a washing machine is approximately 24[mm], which is less than half of the water seal depth. In addition, as for Δh of the toilet on the 2nd floor, from which drainage load was applied in the experiment, the water seal loss caused by siphon effects was no more than 14[mm], thus, not causing any breakage to the trap seal. Fig. 6 shows that with single drainage applied from the 3rd floor, the negative pressure exceeds -400[Pa] until the diameter of the opening of the vent pipe reaches 15[mm] from the closed state, and Δh of the floor drain trap for a waterproof pan for a washing machine is more than half of the water seal depth, as in Fig. 8, and therefore causing breakage to the trap seal. Similar to the case where drainage load is applied from the 2nd floor, the floor drain trap for a waterproof pan for a washing machine becomes broken and this means that the vent pipe needs to be open when single drainage is applied from the toilet on the 3rd floor. However, as in Fig. 7, the positive pressure remains under the reference value, even when the diameter of the house drain is 75A or 100A, with drainage load applied from the 3rd floor as well as from the 2nd floor. Furthermore, when drainage load is applied simultaneously from both the 2nd and 3rd floors, the pipe pressure exceeds ±400[Pa], even with a bellmouth installed to the vent pipe, and the floor drain trap for a waterproof pan for a washing machine becomes broken. Hence, the installation of two toilets to one drainage stack with a diameter of 75A creates a high risk even if plenty of ventilation is provided.

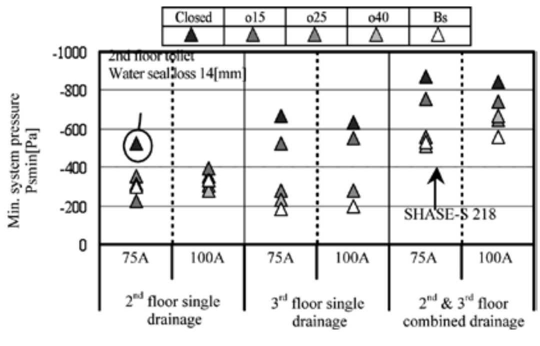

Fig. 6 – Comparison of Psmin under different conditions (toilet drainage)
* The 3rd floor is provided with a drainage pipe when drainage is applied from the 2nd floor

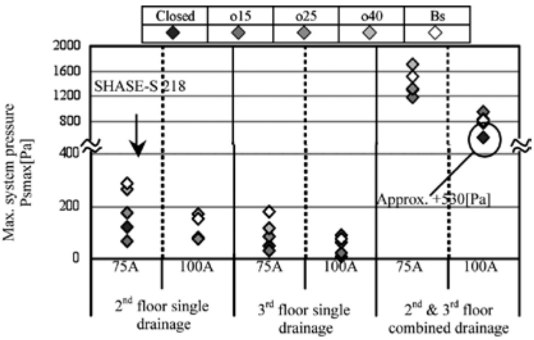

Fig. 7 – Comparison of Psmin under different conditions (toilet drainage)

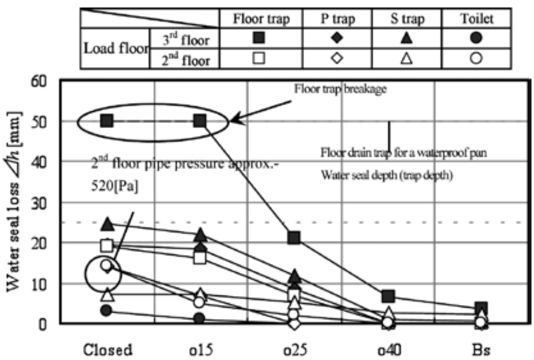

Fig. 8 – Water seal loss (2nd & 3rd floor single drainage from the toilets)

5 Further issues and suggestions concerning the development of materials for low-rise houses

On the basis of the issues raised and the actual measurement results, the following suggestions are given to indicate the future direction of the development of drainage systems for low-rise houses:

① Development of a combined drainage fitting, to be fitted along the horizontal fixture drain branch halfway up the house, for receiving the combined drainage which is created by merging drainage applied from approximately the 3rd floor level

② Development of a drainage header-like fitting which is capable of merging drainage from multiple drainage systems, e.g. for sewage and miscellaneous drainage, in the house drain.

That is to say, there is a need for the development of a drainage system for low-rise houses, which comprises ① and ②.

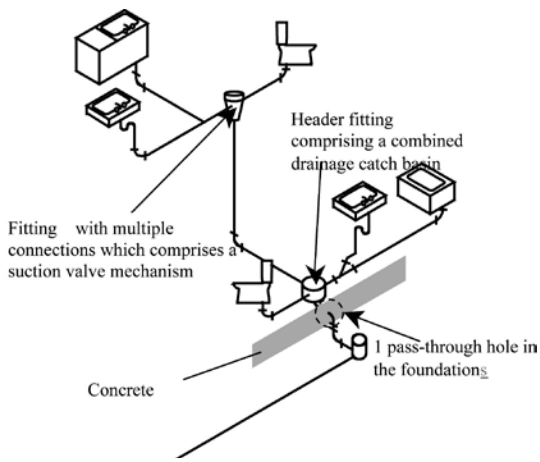

Fig. 9 – Image of a drainage system for low-rise houses

6 Conclusion

This paper has acquired the following knowledge with regard to the design and construction of the drainage system currently used for low-rise houses in Japan, and has subsequently indicated further issues.

(1) The influence of the configuration of the vent pipe used for the single stack vent system

With 2-storey houses, even if ventilation is not provided by the vent pipe, it does not actually affect the drainage performance of the drainage system. Meanwhile, with 3-storey houses, when the pipe diameter is 75[mm], the diameter of the opening of the vent pipe needs to be 25[mm] for providing sufficient ventilation.

(2) The influence of the configuration of the house drain on the drainage stack

With single drainage applied from the 2nd or 3rd floor, the diameter of the house drain does not affect the drainage performance of the drainage system. However, with simultaneous drainage, installing two toilets to one drainage stack with a diameter of 75[mm] creates risks in the actual use of the drainage system, regardless of the diameter of the house drain.

(3) Further issues and suggestions concerning the development of materials for low-rise houses
There is a need for the development of an improved drainage system with combined drainage performance, for example, by securing sufficient ventilation in the combined drainage fitting part of the horizontal fixture drain branch and in the house drain.

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8 Reference
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9 Presentation of author

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