CFD Analysis on Flow Characteristics of WC Discharge in Horizontal Drain Using Particle Method.

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1.Introduction

Analysis by CFD (Computational Fluid Dynamics) makes it possible to reproduce the behaviours of fluid in a virtual space created by computer, and it helps assemble a drainage model and reduce time and construction cost required for installing measurement equipment. It is also promising as a new means of fluid measurement for it is suitable to check invisible fluid phenomena and measure forces applied to fluid.

The MPS method, which is one of the discretization methods of CFD analysis, has high accuracy in liquid analysis and is expected to be applied to water supply and sanitation facilities. Though its application to drainage systems has been tried, but the effectiveness of such systems has not been sufficiently verified.

In view of this situation, we examined characteristics of fixture discharge based on the measurement data obtained from horizontal branches of WC and compared them with analytical values, aiming to verify the adaptability of CFD analysis using the particle method to the drainage system.

In planning WC and fixture drain, it is essential that a drainage system be designed in such a way that waste material is transferred to drainage stack by fixture discharge without fail. In fixture discharge from WC, the capacity to convey fecal matter depends on average flow rate from a fixture (qd) and average flow rate from a fixture connected to the drain pipe (qd′) , and the performance evaluations of fixture discharge are described in SHASE-S220. CFD analysis may replace such evaluations if it can reproduce characteristics of fixture discharge. Therefore we compared the discharge characteristics of various fixtures by conducting experiments and analyses to verify the adaptability of CFD analysis using the particle method to fixture discharge from WC.

w	:	Flow rate from a fixture [L] The total amount of water discharged by one drainage
T_d'	:	Average drainage time [s] The time taken from discharging 20% of the discharge amount until 80% discharge
Q_{max}'	:	Peak drain flow rate from a fixture connected to the drain pipe [L/s] The maximum flow rate of the drainage flow rate
q_d'	:	Average flow rate from a fixture connected to the drain pipe [L/s]

$$qd' = \frac{0.6w}{td'}$$

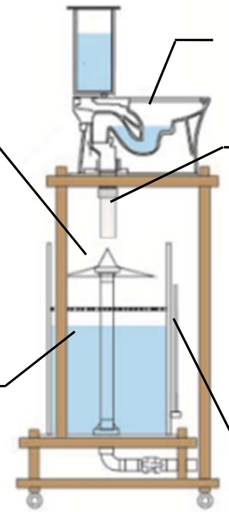
3.1.1 Purpose

Measurement of inflow conditions used for CFD analysis of wastewater characteristics in curved piping of appliance drainage needs to be measured by actual measurement. Therefore, it aims to obtain basic data for CFD analysis by measuring instrument drainage flow rate of the test equipment.

3.1.2 Method

We measured the water level of the drainage basin using the water level sensor and calculated the drainage flow rate.

Calculation item	Drainage flow rate
Tube material	U-PVC
Pipe diameter	φ75mm
measuring equipment	Throw-in water-level sensor
Measurement time	30sec
data output interval	0.02sec
Number of measurements	5times

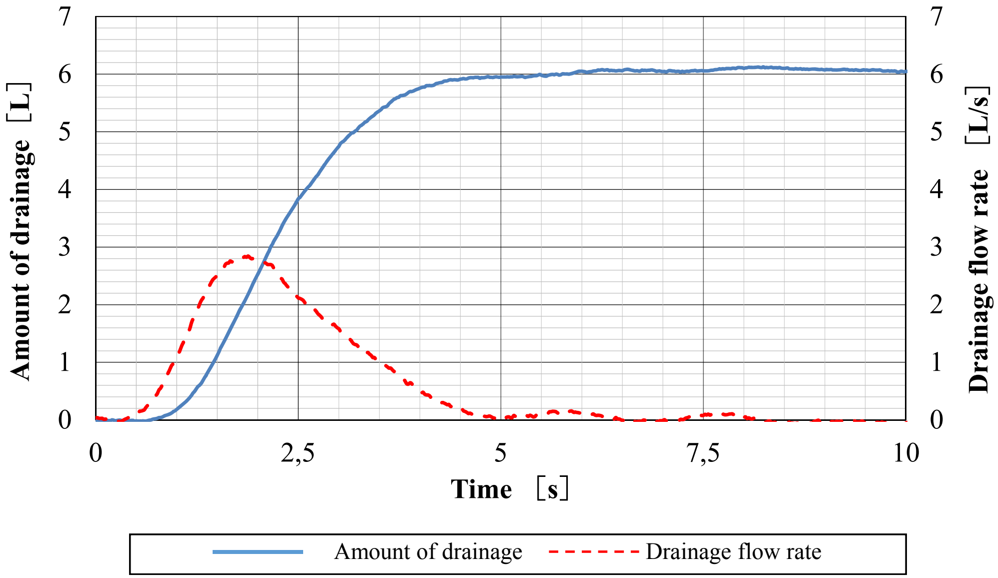


3.1.3 Results

Actual measurement values are listed in Table . The average of average flow rates from a fixture was 2.37 L/s. The first flow rate data most approximate to that value was used for analysis.

	w[L]	td[s]	qd[L/s]	qmax[L/s]
1st time	6.06	1.54	2.36	2.84
2nd time	5.89	1.46	2.42	2.91
3rd time	6.32	1.64	2.31	3.00
4th time	6.07	1.50	2.43	2.92
5th time	6.01	1.54	2.34	2.93
Average	5.99	1.53	2.37	2.89

w : Flow rate from a fixture [L]
The total amount of water discharged by one drainage
t_d : Average drainage time [s]
The time taken from discharging 20% of the discharge amount until 80% discharge
q_{max}': Peak drain flow rate from a fixture connected to the drain pipe [L/s]
The maximum flow rate of the drainage flow rate
q_d' : Average flow rate from a fixture connected to the drain pipe [L/s]



1st time

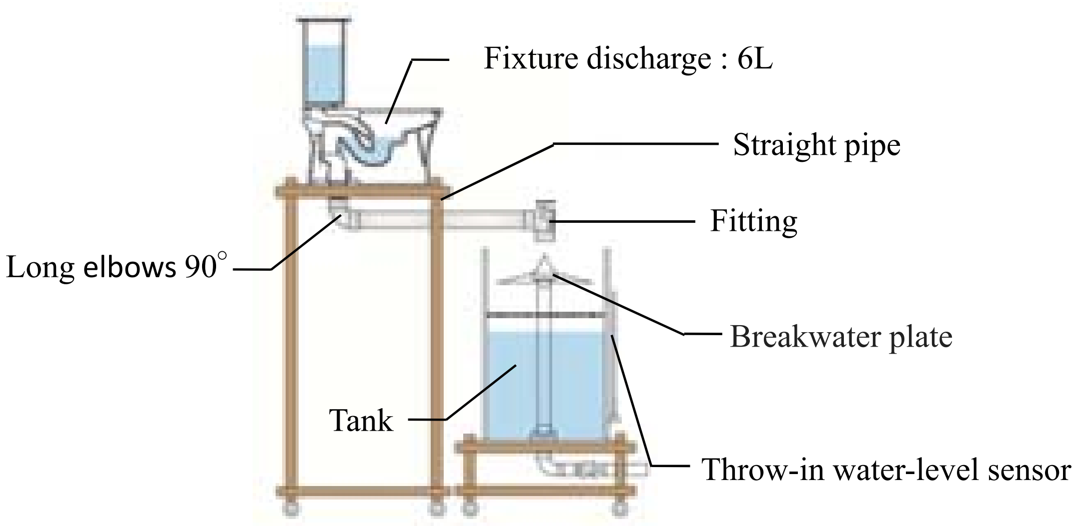
3.2.1 Purpose

Fixture discharge characteristics were measured in fixture drains of 1 m, 4 m, and 8 m to elucidate the effects of horizontal pipe length on fixture discharge.

3.2.2 Method

We measured the water level of the drainage basin using the water level sensor, and calculated the amount of drainage and the drainage flow rate and peak drain flow rate from a fixture and average flow rate from a fixture.

Calculation item	amount of drainage drainage flow rate qmax , qd`
Tube material	U-PVC
Pipe diameter	φ75mm
pipe gradient	1/100
measuring equipment	Throw-in water-level sensor
Measurement time	1m,4m : 20sec 8m : 60sec
data output interval	0.02sec
Number of measurements	5times



3.2.3 Results

Actual data for each horizontal pipe length are shown in Table. Average flow rates from a fixture connected to the horizontal pipe at 1 m, 4 m, and 8 m were 2.43 L/s, 1.61 L/s, and 0.50 L/s respectively.

Horizontal pipe length	w [L]	td [s]	qd' [L/s]	qmax ［L/s］
1m	6.05	1.49	2.43	2.88
4m	6.09	2.29	1.61	2.42
8m	5.99	7.13	0.50	1.26

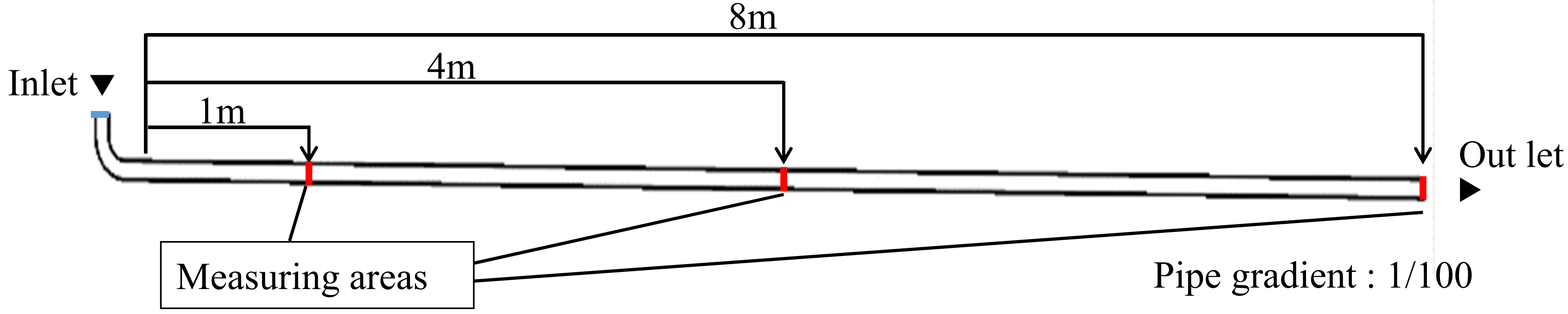
w : Flow rate from a fixture[L] t_d : Average drainage time[s]
q_d’ : Average flow rate from a fixture connected to the drain pipe [L/s]
q_{max}’ : Peak drain flow rate from a fixture connected to the drain pipe [L/s]

4.1 Purpose

Fixture drainage characteristics measured at 1 m, 4 m, and 8 m from the long elbows were numerically analyzed to see if CFD analysis based on the particle method is suitable for examining characteristics of drainage in horizontal branches from a WC.

4.2 Outline of analysis

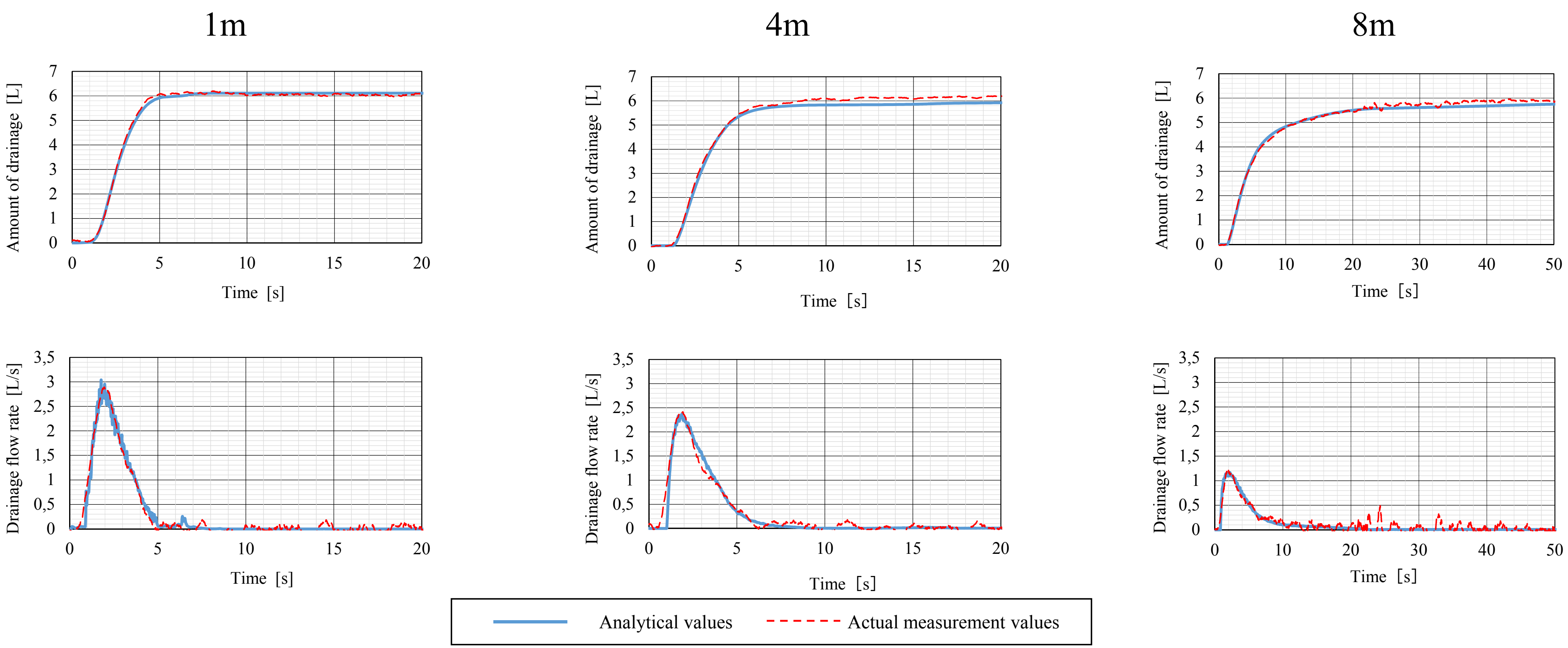
Conditions were set so that the drainage system used in the analysis was the same system as the one used in the experiment. An inlet opening was made at the upper part of the fixture drain, and inlet flow rates were determined based on inflow data measured in 3.1. The experimental model was designed in such a way that fluid could be freely discharged from horizontal branches. Measuring areas were set at points of 1 m, 4 m, and 8 m from the connection with the fixture drain and measurements were made.



4.3 Analysis method

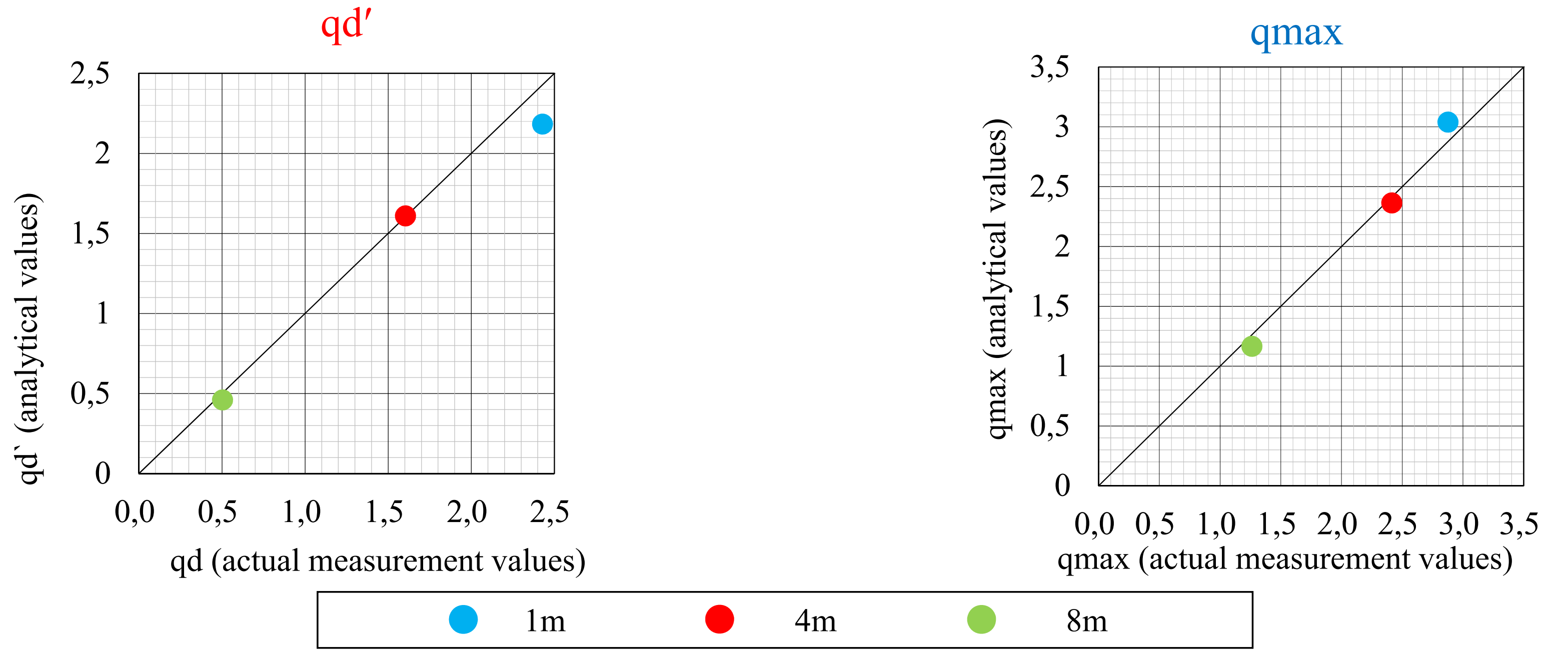
Type	Analysis conditions
Calculation method	MPS method
Solution (Pressure condition)	Implicit method
Pressure gradient blend ratio	0.9
β	1
γ	1
Solution (Viscous condition)	Implicit method
Solution (surface tension)	Potential method
Physical properties	Fluid : water（Fluid） Individual : Wall surface（Polygon）
Slip condition	4
Contact angle	90°
particle diameter	2.0mm
primary particle distance	2.0mm
primary time step size	0.5ms（2,000Hz）
Courant number	0.2
coefficient of surface stabilization	0.97
collision distance	0.9
Collision coefficient	0.2
influence radius	3.1
data output interval	20ms（50Hz）

4.4 Results of analysis and discussion



Comparing the drainage flow rate and the drainage volume of the analysis value and the measured value for each length of the drain pipe, the respective values were approximately approximated.

4.4 Results of analysis and discussion



Classification	Horizontal pipe length	w [L]	td [s]	qd' [L/s]	qmax ［L/s］
Actual measurement values	1m	6.05	1.49	2.43	2.88
	4m	6.09	2.29	1.61	2.42
	8m	5.99	7.13	0.50	1.26
Analytical values	1m	6.11	1.68	2.18	3.04
	4m	6.11	2.28	1.61	2.36
	8m	6.11	7.98	0.46	1.16

-0.25

+0.16

5.Conclusion

In this study we analysed and compared actual measurement values and analytical values of discharge flow rates from a fixture connected to the drain pipe based on the particle method of CFC analysis. The findings can be summarized as follows

1) Actual measurement values and analytical values of average flow rates from a fixture connected to the drain pipe and peak drain flow rates from a fixture connected to the drain pipe with each horizontal pipe length were found to be similar.

2) Actual measurement values and analytical values of discharge flow rates were also found to be similar.Though CFD analysis based on the particle method proved to be applicable to straight piping, its performance with fixture discharge with curved piping has not been confirmed. Therefore, it remains to be examined in the future studies.