New rainwater discharge chamber which can control intercepting flow rate

Une nouvelle chambre d'écoulement des eaux pluviales pour contrôler l'interception du débit

Shinji Arao*, Shuhei Oda**, Kohei Oda**

* Dept. of Civil and Environmental Eng., National Institute of Technology, Matsue College, 14-4 Nishi-ikuma, Matsue, 690-8518, Japan (arao@matsue-ct.jp)
** Waken Design Office Inc., 34-11 Shinjuku 1-chome, Shinjuku-ku Tokyo 160-0022, Japan (s-oda@wsnet.co.jp), (kh-oda@wsnet.co.jp)

RÉSUMÉ

Récemment au Japon, des projets d'amélioration du système d'assainissement unitaire ont été mis en place pour atteindre les objectifs en matière de réduction de la pollution et des impuretés, ainsi qu'en matière de sécurité d'hygiène publique. Toutefois, il est difficile de contrôler l'interception du débit d'une installation de partage au moment d'une forte chute de pluie, même dans le contexte actuel des projets d'amélioration du réseau d'assainissement unitaire. Afin de résoudre ce problème, les auteurs ont développé une nouvelle chambre d'écoulement des eaux de pluie qui peut contrôler l'interception du débit à une valeur constante. L'utilité du mécanisme a été démontrée par des calculs numériques et des expériences sur un modèle (Shuhei ODA *et al.*, 2014). Dans cette étude, l'utilité de ce nouveau mécanisme est démontrée par l'amélioration de la précision de la mesure du débit d'un modèle de partage qui est à une échelle 2,5 fois plus grande que celle utilisée dans les précédentes études (Shuhei ODA *et al.*, 2014). Le résultat expérimental obtenu avec le nouveau modèle de partage indique qu'une erreur d'interception (un débit excessif d'égout intercepté/débit prévu d'égout intercepté) se situe dans la plage de 1 % à 2 %.

ABSTRACT

Recently in Japan, improvement projects of combined sewer system have been implemented to achieve the goals for reductions of pollution load and impurities and for security of public sanitation. However, it is difficult to control the intercepting flow of a diversion facility at the time of heavy rain even in the current combined sewer improvement projects. In order to solve this problem, the authors have developed a new rainwater discharge chamber which can control the intercepting flow rate at a constant value. Usefulness of the facility has been demonstrated by numerical calculations and model experiments (Shuhei ODA *et al.*, 2014). In this study, utility of a new facility is demonstrated by improving flow measurement precision of a diversion model which is 2.5 times in scale as large as that used in previous study (Shuhei ODA *et al.*, 2014). Experimental result with the new diversion model shows that an interception error (excessive flow rate of intercepted sewage/planned flow rate of intercepted sewage) is in the range of 1 % to 2 %.

KEYWORDS

Combined sewer, diversion chamber, interception accuracy, sewer management

1 INTRODUCTION

Sewer sideweir with a throttling pipe is a simpe device to limit the discharge to treatment facilities (Giudice *et al*.,1999).In the conventional combined sewer system where intercepting and overflow of sewage are incorporated in a diversion chamber, the interception accuracy in an intercepting pipe is low during periods of heavy rainfall, and so it is difficult to achieve reliable sewage management around the world. In Japan, with the revisions of Enforcement Order of the Sewage Water Law in fiscal year 2003, the combined sewer emergency improvement projects were required as measures for reducing the pollution load on public water areas. The confluence improvement projects have been completed in fiscal year 2013 in small and medium cities, and the projects are carried on aiming for completion by fiscal year 2023 also in large cities. With the confluence improvement projects, in the diversion facility (JIWET, 2003, see Figure1) normally installed in the rainwater discharge chamber, the height of the overflow weir is made larger to increase the intercepting flow rate to the sewage treatment plant to be twice that of the conventional one to thereby reduce the pollution load on public water areas so as to achieve the goals for reducing by half the number of times of releasing the untreated released water from the overflow weir. Such an improved diversion facility still has a problem of increase in the ratio of the excessive interception ((intercepting flow rate - planned intercepting flow rate)/planned intercepting flow rate) with an increase in rainfall intensity, failing to control the flow rate of intercepted sewage to the sewage treatment plant, and is therefore still in a situation of having to release a part of the sewage untreated to the public water areas. To overcome the issue, it is necessary to introduce the diversion facility that can surely control the flow rate.

The authors have developed, in previous studies (Shuhei ODA *et al.,* 2014), a diversion device (in which three side overflow weirs and three orifices are combined, called a three regulating tanks model hereinafter) which can substantially fix the intercepting flow rate even if the inflow flow rate into the rainwater discharge chamber increases, and have verified its utility by numerical calculations and hydraulic model experiments. In this treatise, a model which is 2.5 times in scale as large as the experimental open channel used in the previous study (Shuhei ODA *et al.,* 2014) is created and the measurement precision of the flow rate is improved, to reconfirm the utility of the three regulating tanks model. Further, intercepting characteristics of a two regulating tanks model (in which two side overflow weirs and two orifices are combined) are revealed to show that the two regulating tanks model is excellent as compared with the one regulating tank model in the conventional technology (see Figure1).

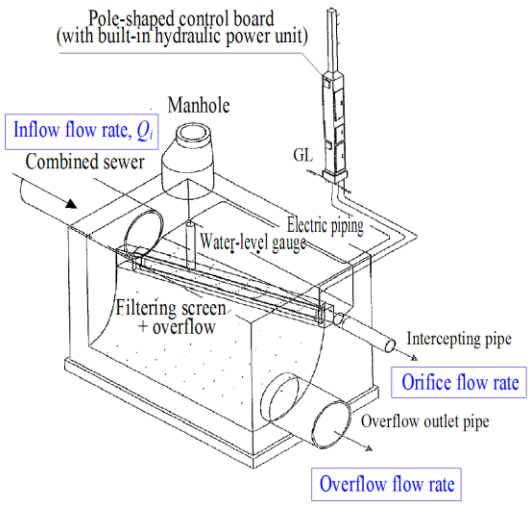


Figure1 Standard rainwater discharge chamber

2 EXPERIMENTAL DEVICE

Figure2 and Photograph1 show the outline of the experimental device (the model in a scale of 1/13 of the assumed original size). As a conventional type (one regulating tank model) in which a open channel (open channel gradient is horizontal) made of an acrylic resin having a length of 2.625 m and a width of 0.500 m is combined with the side overflow weir for diversion and the orifice for interception, a side overflow weir having a weir length of 1.000 m and a weir height of 0.150 m was installed and one orifice (three kinds of diameter Φ = 0.0269 m, 0.0197 m and 0.0150 m) was installed slightly downstream of the overflow weir. Note that the vertical distance from the weir top portion to the orifice center was set to 0.0505 m. Further, as shown in Figure2, in a three regulating tanks model of a new diversion device, the total length 1.000 m of the overflow weir was trisected so that each weir length was 0.333 m, and the orifices having almost the same diameter as that of the orifice used in the one regulating tank model were installed at three points slightly downstream of the trisected overflow weirs, respectively. Note that the vertical distance from the open channel bottom surface to each orifice center was set to 0.0995 m. Further, in a two regulating tanks model, the total length 1.000 m of the overflow weir was divided so that the upstream weir length was 0.667 m and the downstream weir length was 0.333 m. Table1 lists the dimensions relating to the side overflow weir and the orifice used in the one regulating tank model, the two regulating tanks model, and the three regulating tanks model.

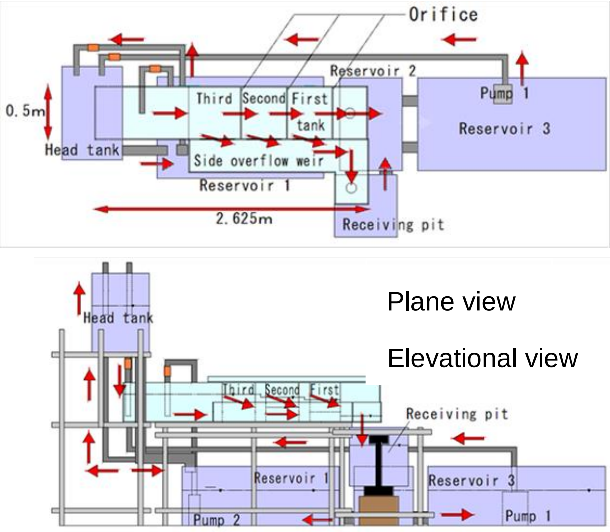
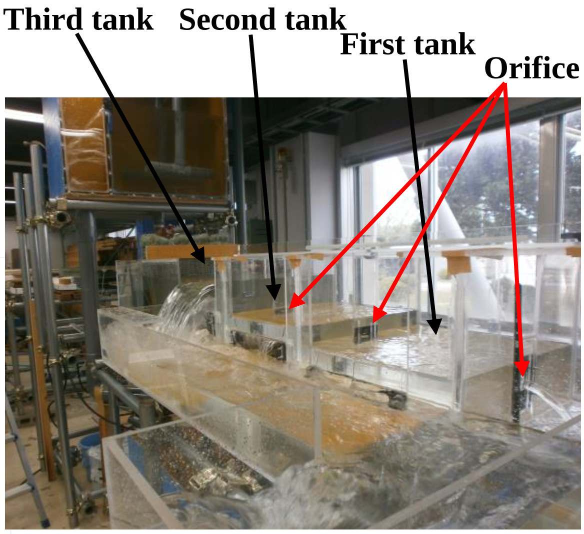


Figure2 Outline of experimental device (three regulating tanks model)



Photograph1 Experimental device with three regulating tanks (viewed from downstream)

Table1 Dimensional data regarding side overflow weir and orifice

	Type of model	Weir length	Orifice diameter φ	Weir height
Type A	One regulating tank model	1m	0.0269m	0.15m
Type B			0.0197m	0.15m
Type C			0.0150m	0.15m
Type D	Three regulating tanks model	0.333m×3	From the downstream 0.0269m, 0.0268m, 0.0268m	From the downstream 0.15m, 0.196m, 0.252m
Type E			0.0197m, 0.0198m, 0.0198m	0.15m, 0.202m, 0.258m
Type F			0.0150m, 0.0150m, 0.0150m	0.15m, 0.207m, 0.265m
Type G	Two regulating tanks model	Upstream 0.667m, Downstream 0.333m	From the downstream 0.0269m, 0.0268m	From the downstream 0.15m, 0.207m
Type H			0.0197m, 0.0198m	0.15m, 0.207m
Type I			0.0150m, 0.0150m	0.15m, 0.207m

3 EXPERIMENTAL RESULT

Figure3 shows the experimental results in the one regulating tank model (conventional technology), the two regulating tanks model (new technology), and the three regulating tanks model (new technology). The vertical axis in Figure3 represents the magnification of the inflow flow rate (Q_i) into the rainwater discharge chamber with respect to the planned intercepting flow rate (Q_0) and is given in Equation (1). The horizontal axis represents the excessive ratio (%) of the intercepting flow rate (Q_2) with respect to the planned intercepting flow rate (Q_0) and is given in Equation (2).

Sewage flow rate ratio (inflow magnification) $= \frac{Q_i}{Q_0}$ (1)

Interception error (%) $= \frac{Q_2 - Q_0}{Q_0} \times 100$ (2)

As illustrated in Figure3, in the one regulating tank model (conventional technology) in which the orifice diameter is varied into three kinds, the interception error increases with an increase in sewage flow rate ratio in any of the cases. At a sewage flow rate ratio of 30, the interception error drastically decreases from 29% to 1% in Type D (an orifice diameter of 0.0269 m) of the three regulating tanks model as compared with Type A of the one regulating tank model. Further, at a sewage flow rate ratio of 80, the interception error decreases from 25% to 2% in Type F (an orifice diameter of 0.0150 m) of the three regulating tanks model as compared with Type C of the one regulating tank model. From these facts, it has been reconfirmed that the three regulating tanks model has extremely excellent functions capable of controlling the intercepting flow rate as substantially achieving the target. On the other hand, regarding Type G of the two regulating tanks model in which the orifice diameter is set to

0.0269 m, the interception error is about 6% at a sewage flow rate ratio of 30, which is larger than that of the three regulating tanks model. However, that is quite smaller than the interception error of 29% of the one regulating tank model.

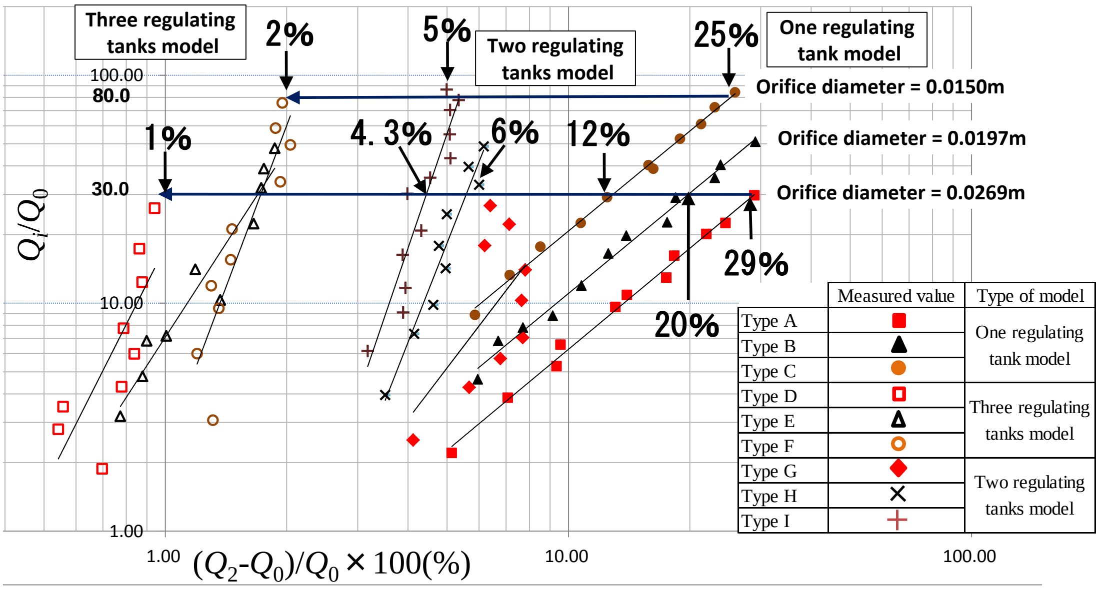


Figure3 Relationship between sewage flow rate ratio and interception error

Figure4 illustrates the relationship between the flow rate of inflow water and the overflow water depth at the upstream end of each weir in the three regulating tanks model. When the flow rate of inflow water was 0.00934 m^3/s, the overflow water depth was 0.060 m at the weir of the third tank, 0.0045 m at the second tank, and 0.0012 m at the first tank. As described above, the water depth only slightly increases at the first tank, so that the water level in the regulating tank at the most downstream can be fixed to almost a constant value. Further, as illustrated in Figure4, the increase in water level in the second tank is considerably suppressed.

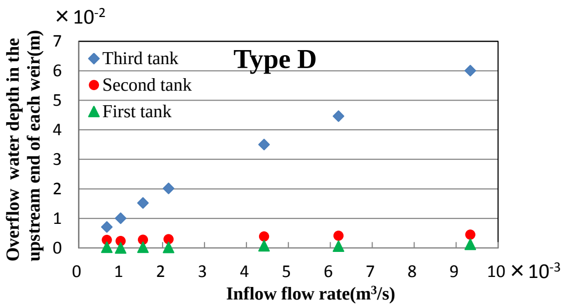


Figure4 Relationship between flow rate of inflow water and overflow water depth

4 CONCLUSIONS

In the three regulating tanks model (new technology) in which three sets of the side overflow weirs and the orifices are installed, the interception error (the excessive ratio of the intercepting flow rate with respect to the planned intercepting flow rate) falls within a range of 0.5% to 2%. In the two regulating tanks model in which two sets of the side overflow weirs and the orifices are installed, the interception error falls within a range of 3% to 8%, though the interception error is larger than the interception error of the three regulating tanks model.

LIST OF REFERENCES

Giudice, G. D. and Hager, W. H. : Sewer Sideweir with Throttling Pipe, Journal of Irrigation and Drainage Engineering, Vol.125, No.5, pp.298-306, September, 1999.

Japan Institute of Wastewater Engineering and Technology: Combined Sewer Improvement Measure Filtering Screen Technical Manual, pp.7-13, 2003 (in Japanese).

Shuhei Oda, Kohei Oda and Shinji Arao: Technical Theory and Verification of Flowing Water Diversion in New Rainwater Discharge Chamber, Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering), Vol.70, No. 2, pp. 49-59, 2014 (in Japanese).

Shuhei Oda, Kohei Oda and Shinji Arao: Study on Optimization of Combined Sewer System with New Diversion Chamber, 13th ICUD, Kuching, Sarawak, Malaysia, 2014.