Study of Water Surface Control as a Debris Reduction Measure for the Improvement of the Combined Sewer System

Le contrôle de la surface de l'eau comme méthode pour réduire les déchets dans le but d'améliorer le réseau d'assainissement

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RÉSUMÉ

Les villes qui très tôt se sont engagées dans la construction et la gestion de systèmes d'assainissement utilisent généralement des systèmes unitaires. Toutefois, lors d'évènements pluvieux intenses, le débit d'eau qui s'écoule dans les réseaux de ces villes augmente et des flux non traités – eaux usées et eaux pluviales – sont rejetés dans les milieux récepteurs publics, induisant contamination et odeurs. Dans les villes qui utilisent des systèmes unitaires, il est donc urgent de mettre en œuvre des mesures d'amélioration à des fins de santé publique. Les objectifs d'amélioration sont : 1) la réduction de la charge polluante, 2) la santé et la sécurité publique, 3) la réduction des débris.

Cette étude traite de l'un des objectifs d'amélioration immédiate, à savoir le contrôle de la surface de l'eau, développé à l'aide d'un dispositif de réduction des débris, composé d'une plaque de contrôle et d'un déflecteur. Le CSE (contrôle de la surface de l'eau) a été installé dans des chambres de partage existantes afin de réduire la quantité de débris contenus dans les eaux d'assainissement non traitées et rejetées dans le milieu aquatique public. L'effet de la réduction de la quantité de débris et la durabilité des équipements ont été évalués, et l'efficacité du CSE a été démontrée.

MOTS CLÉS

Système d'assainissement unitaire, amélioration du système unitaire, mesures de réduction des débris, surverse de réseau d'assainissement unitaire, eaux usées non traitées

ABSTRACT

In cities where the combined sewer system is employed, there is a need for urgent and intensive performance of measures for improvement. For the combined sewer system, immediate improvement goals are: 1) reducing the contamination load, 2) ensuring public health and safety, and 3) reducing debris

This study deals with one of these immediate improvement goals, that is, with Water Surface Control, which was developed as a debris reduction measure and consists of a control plate and baffle. Water Surface Control (WSC) is a mechanism designed to guide debris towards an interceptor by means of the baffle, and to draw the debris into the interceptor sewer with a vortex produced by the control plate. WSC was installed in existing diversion chambers in order to reduce the outflow of debris contained in untreated sewage discharged from the diversion chamber into the body of public water. The debris outflow reduction effect and equipment durability were evaluated, and the effectiveness of WSC was demonstrated.

KEYWORDS

Combined sewer system, combined sewer improvement, debris reduction measures, combined sewer overflow, untreated sewage

1 INTRODUCTION

In Japan, the combined sewer system in which both foul water and storm water are treated using the same sewer is employed in cities which have, from early on, been engaged in the creation and management of sewage works. However, when there is heavy rainfall in such cities, the water flowing into the combined sewer pipes increases and untreated combined sewage, i.e. a mixture of foul water and storm water, flows out as a combined sewer overflow and is discharged into the body of public water. As a result, water contamination or foul odors occur in the public water body, so that combined sewer system improvements are required from the viewpoint of public health.

In cities where the combined sewer system is employed, there is a need for urgent and intensive performance of combined sewer improvements. As immediate improvement goals for the combined sewer system, it is necessary to: 1) reduce the contamination load, 2) ensure public health and safety, and 3) reduce debris. As an improvement measure for debris reduction, it is stipulated in technical standards that a mechanical screen be installed or other measures taken to minimize the outflow from the diversion chamber of debris contained in the combined sewer overflow occurring during rainfall. Against this background, Water Surface Control (WSC), a device that has low initial costs because it has a simple structure, operates without electricity, and is easy to maintain, has been under development since 2000.

This study deals with WSC which consists of a control plate and baffle. For WSC employed as a debris reduction measure, we examined its debris outflow suppression effect for the debris contained in combined sewer overflow discharged from the diversion chamber, and its durability in order to investigate the effectiveness of installing it in a diversion chamber.

2 OUTLINE OF WATER SURFACE CONTROL

2.1 Outline of Water Surface Control

WSC is installed in the diversion chamber of a combined sewer system for the purpose of suppressing the amount of debris contained in the untreated sewage discharged as an overflow during rainfall which flows out into the public water body.

WSC is a debris outflow suppression mechanism consisting of a device called a baffle, which guides debris towards and above the interceptor sewer, and a device called a control plate, which produces a vortex to draw the debris into the interceptor sewer and flush it downstream (treatment plant) together with intercepted untreated sewage.

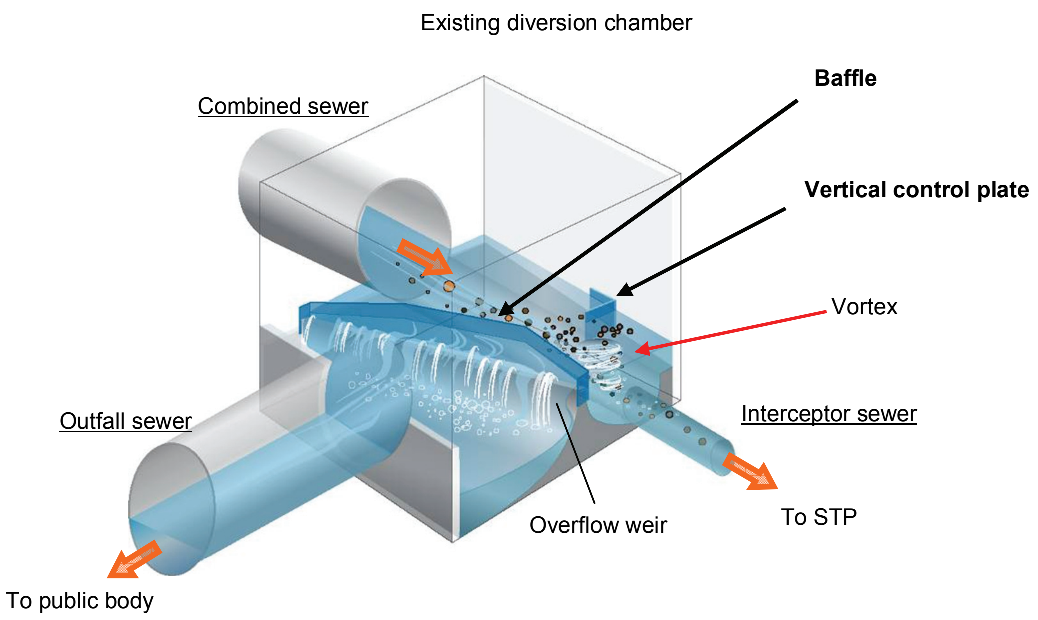

Fig.1 Outline of Water Surface Control (WSC)

(Baffle and vertical control plate type)

2.2 Principle and structure

WSC is a device that uses the flow energy of water to make it easier for the debris floating in the existing diversion chamber to flow into the interceptor sewer.

2.2.1 Description of devices making up WSC

(1) Baffle

The purpose of the baffle is to prevent floating debris from flowing out together with untreated sewage overflowing from the overflow weir and to guide the debris toward near the mouth of the interceptor sewer.

The baffle is installed in the existing diversion chamber with a clearance of 150 mm or more upstream of the overflow weir which releases combined sewer overflow during heavy rain. Its height is set so as to be higher than the overflow weir at the top and lower than the overflow weir at the bottom.

A baffle is made by forming stainless steel into a shape as shown in Fig. 1, and this is then installed in the existing diversion chamber with anchor bolts.

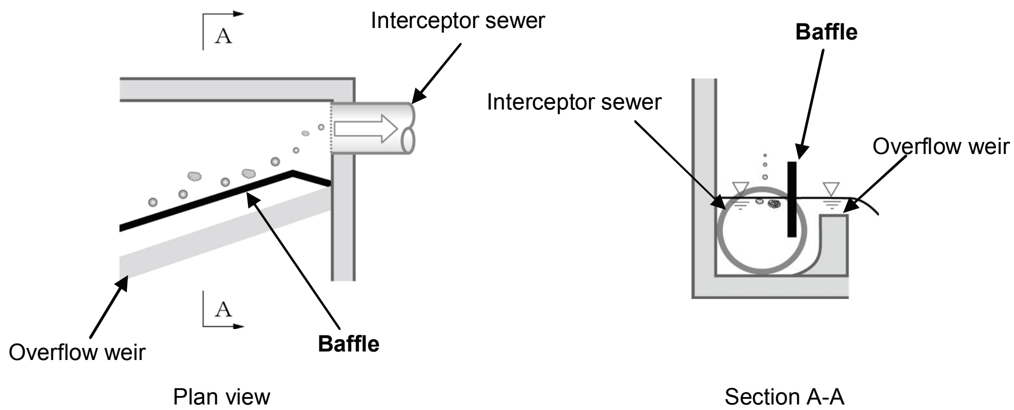

Fig.2 Baffle

(2) Control plate

1) Vertical control plate

The vertical control plate produces a vortex near the mouth of the interceptor sewer in the existing diversion chamber in order to draw the floating debris in the existing diversion chamber into the interceptor sewer.

The vertical control plate is installed upstream of the interceptor sewer in the existing diversion chamber and its height is set so as to be higher than the overflow weir at the top and lower than the overflow weir at the bottom.

A vertical control plate is made by forming stainless steel into a shape as shown in Fig. 3, and this is then installed in the existing diversion chamber with anchor bolts.

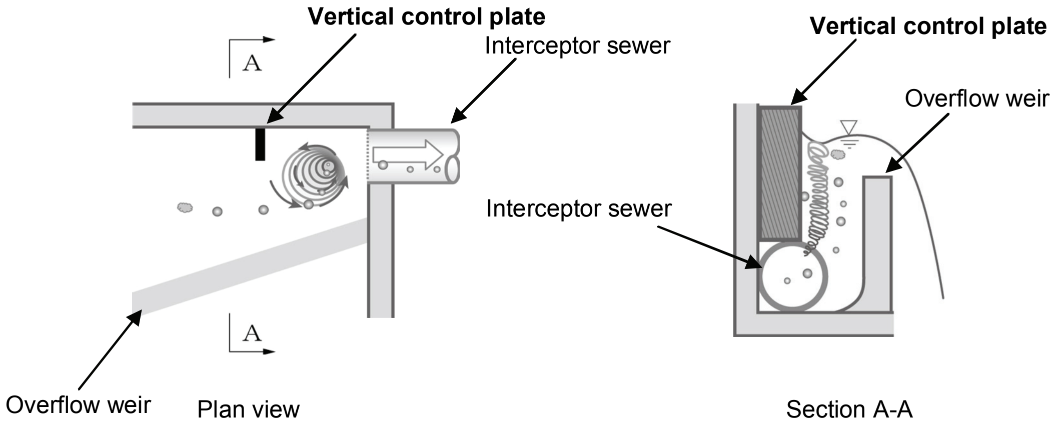

Fig.3 Vertical control plate

2) Horizontal control plate

The horizontal control plate controls the water surface or flow velocity distribution in the existing diversion chamber in order to form an open channel flow near the mouth of the interceptor sewer, thereby drawing the floating debris near the water surface into the interceptor sewer.

The horizontal control plate is installed upstream of the interceptor sewer in the existing diversion chamber and its height is set so as to be lower than the overflow weir at the top.

A horizontal control plate is made by forming stainless steel into a shape as shown in Fig. 4, and this is then installed in the existing diversion chamber with anchor bolts.

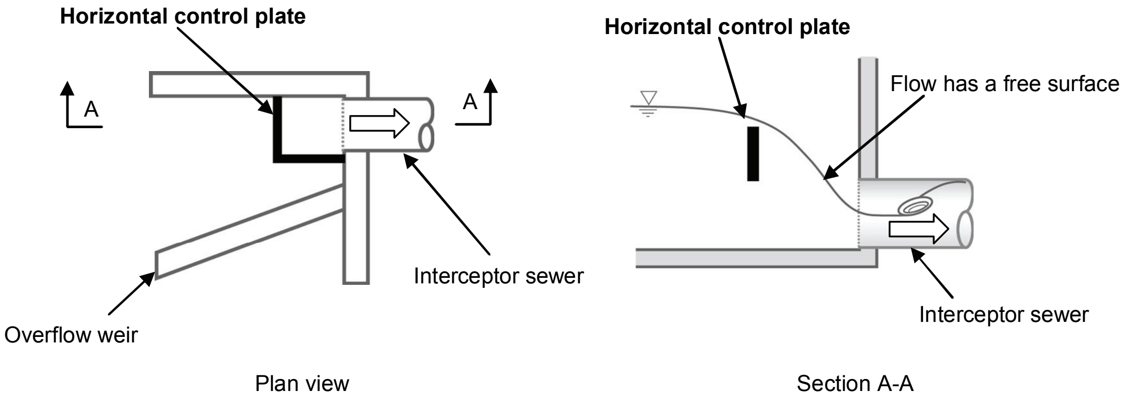

Fig.4 Horizontal control plate

2.2.2 Device configurations

There are five different device configurations of WSC depending on the combination of baffle and control plate. Before installing WSC, a preliminary survey of the existing diversion chamber is conducted to observe the flow conditions and water level. Then, a configuration appropriate for the existing diversion chamber in question is selected based on the observation results and the design specifications set by the relevant local authority, paying attention to the design water level, the heights of the overflow weir and interceptor sewer and the amount of available space near the interceptor sewer.

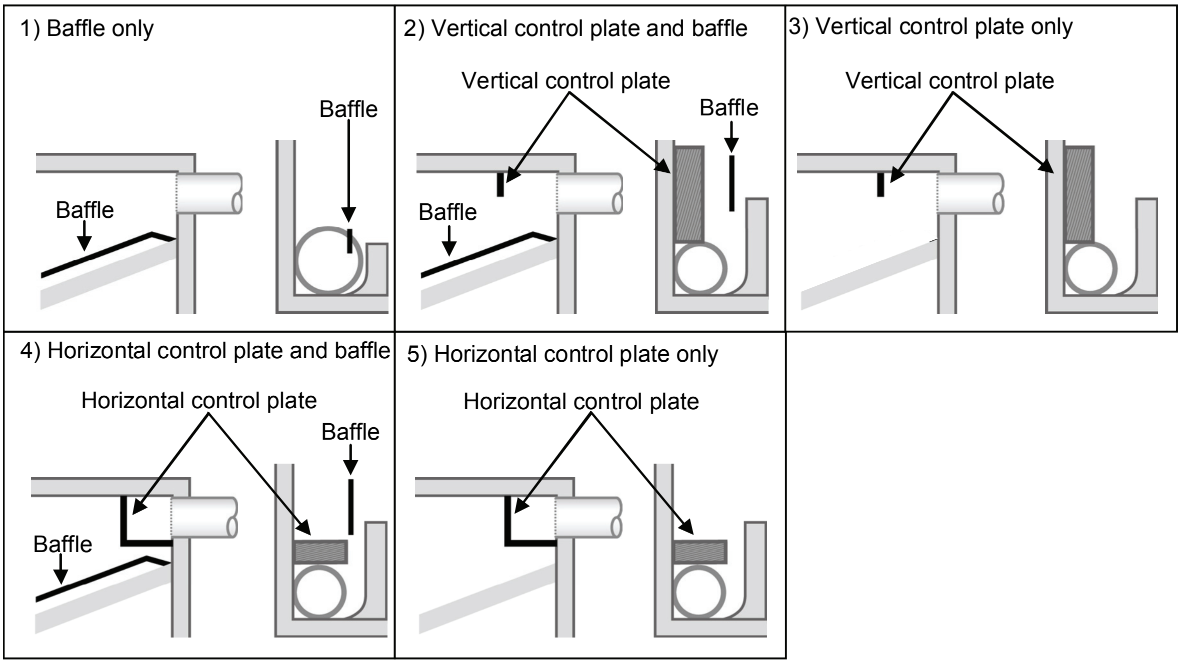

Fig.5. Five configurations of device

2.2.3 Scope of Application for WSC

WSC can be applied to diversion chambers that meet conditions 1) to 4) described below. However, WSC can also be applied to diversion chambers that do not meet these conditions if structural changes are made or a detailed study is conducted.

1) The distance between the baffle and the overflow weir is at least 150 mm.

2) The interceptor sewer is connected to a sidewall of the diversion chamber.

3) The interceptor sewer and the combined sewer are not connected or in close proximity to one another.

4) The bottom of the combined sewer is lower than the top of the overflow weir.

2.2.4 Preparation for the installation of WSC

To install WSC, it is necessary to determine the basic conditions, conduct a preliminary survey, design and plan the layout, produce and install the devices, and then conduct a follow-up survey. A preliminary survey and follow-up survey, characteristic of the provision of WSC, are outlined below.

(1) Preliminary survey

WSC is a device used to help guide debris to the interceptor sewer by means of the water flow energy in the diversion chamber. It is difficult to accurately ascertain the water flow conditions if only a theoretical study is conducted. A preliminary survey is intended to ascertain the water flow conditions in the diversion chamber while it is raining by using a water gauge and a CCD camera. A plan for the optimal layout for the baffle and control plate in the diversion chamber is developed based on the information obtained then.

(2) Follow-up survey

It is necessary to confirm that the vortex produced after the devices for WSC have been installed draws debris into the interceptor sewer. The follow-up survey is conducted to confirm that debris is drawn into the interceptor sewer after the baffle and control plate have been installed in the diversion chamber. If the planned effects cannot be attained, a plan to make improvements to the devices should be developed.

3 PERFORMANCE EVALUATION METHOD

For performance evaluation, we examined the ability of the device to suppress the debris contained in combined sewer overflow discharged from the existing diversion chamber from flowing out into the public body of water, and examined the device's durability.

3.1 Debris outflow suppression ability

3.1.1 Evaluation method

Debris outflow suppression ability was evaluated using the screening retention value (SRV), which serves as an index indicating the improvement rate for debris outflow suppression through installation of WSC.

In the calculation formula, $TSRE_{with}$ denotes the rate of debris intercepted in the existing diversion chamber and flushed into the interceptor sewer in the case where WSC is installed. $TSRE_{without}$ in the calculation formula denotes the debris interception rate by the overflow weir alone in the case where WSC is not installed.

$$SRV(\%) = \frac{TSRE_{with} - TSRE_{without}}{1 - TSRE_{without}} \times 100$$

$$TSRE_{with} = \frac{\text{Amount of debris in interceptor sewage}_{with} + \text{Amount of captured debris when WSC is installed}}{\text{Amount of debris in interceptor sewage}_{with} + \text{Amount of debris in overflow}_{with} + \text{Amount of captured debris when WSC is installed}}$$

$$TSRE_{without} = \frac{\text{Amount of debris in intercepted sewage}_{without}}{\text{Amount of debris in intercepted sewage}_{without} + \text{Amount of debris in overflow}_{without}}$$

Amount of debris in interceptor sewage_{with}	: Dry weight of debris intercepted when WSC is installed
Amount of captured debris when WSC is installed	: Dry weight of debris captured when WSC is installed (increase in amount of intercepted debris)
Amount of debris in overflow_{with}	: Dry weight of debris flowing out to discharge side when WSC is installed
Amount of debris in intercepted $\text{sewage}_{without}$	: Dry weight of debris intercepted when WSC is not installed
Amount of debris in $\text{overflow}_{without}$	: Dry weight of debris flowing out to discharge side when WSC is not installed

SRV does not denote the debris interception rate, but the rate of improvement. Thus, even if the rate of TSREwith remains the same, SRV varies when the rate of $TSRE_{without}$ changes.

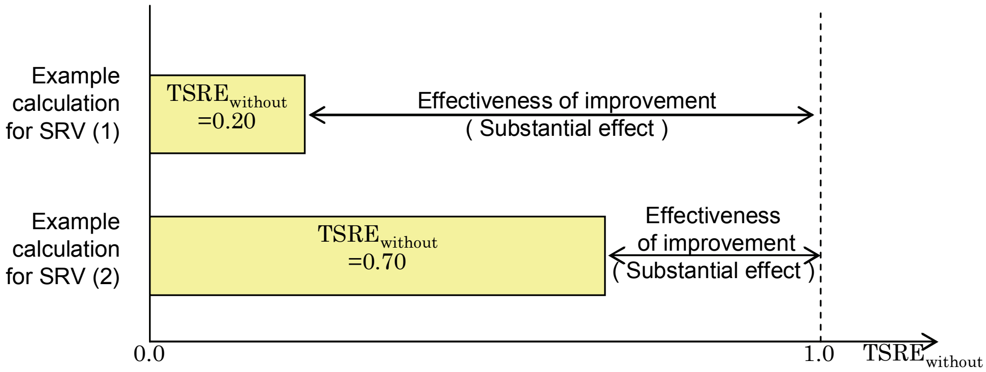

Fig.6 Relationship between $TSRE_{without}$ and the effectiveness of the improvement

3.1.2 Investigation method

(1) Outline of investigation method

The investigation was conducted in the 36 existing diversion chambers of combined sewers that were in service. The investigation was performed using two patterns, that is, by the artificial sewage method in which water trucks are used on a clear day to simulate the swelling of water quantity on a rainy day and in which artificial debris is dropped into the system, and by the natural rainfall method in which natural rainfall and real debris are used. The dry weight of the debris flowing through the interceptor sewer and the outfall sewer in each existing diversion chamber was measured before and after the installation of WSC in order to calculate $TSRE_{with}$, $TSRE_{without}$, and SRV.

(2) Debris investigated

Debris is generally referred to as solid matter contained in sewage and forming a deposit in the sewer.

In the artificial sewage method, a preliminary examination was performed to monitor the debris contained in the combined sewer overflow in the diversion chamber under investigation and, based on these examination results, artificial debris made of deficient components, i.e. about 50 percent dead leaves, 40 percent paper and 10 percent polystyrene foam was dropped from an upstream manhole to reproduce the debris during natural rainfall.

In the natural rainfall method, we performed investigations using real debris.

Photo 1. Added artificial debris

(3) Debris collection method

In the artificial sewage method, nets were installed to collect debris on the interceptor sewer side and outfall sewer side. The nets were set up at the beginning of overflow and removed on its completion. In this method, debris was collected in order to examine the amount of outflow of debris contained in the combined sewer overflow and the amount of intercepted debris flowing into the interceptor sewer.

In the natural rainfall method, water was collected in the diversion chamber at positions as close as possible to the combined sewer and just before the outfall sewer to in order to examine the amount of inflow of debris into the diversion chamber and the amount of outflow of debris contained in the combined sewer outflow.

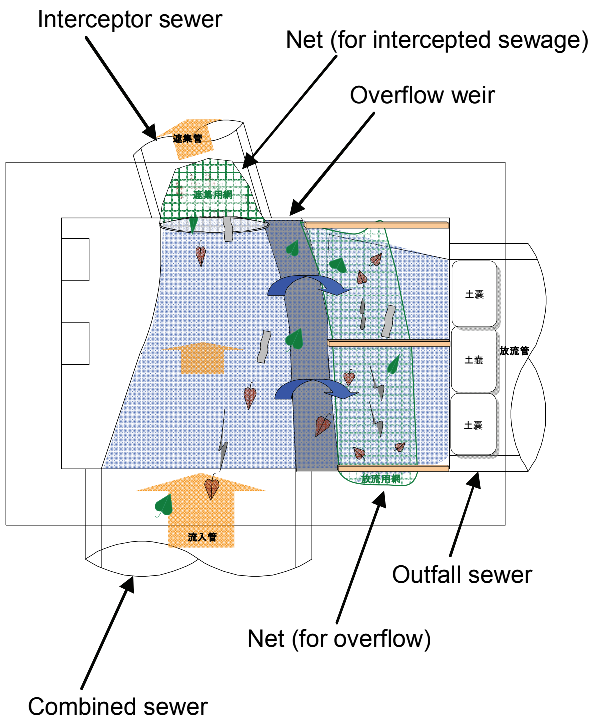

Fig.7 Schematic of debris collection method (Collection method using artificial sewage)

(4) Measurement of amount of debris

The debris collected in the net was classified into 1) paper, 2) feces, 3) kitchen waste, 4) grass and wood, 5) hair, 6) plastics, 7) metals, 8) oil balls, and 9) other, and the dry weight of each was measured.

(5) Number of times survey was performed

Survey data collection was performed three times for each diversion chamber.

3.2 Durability

To examine durability, a follow-up survey was performed for 2 months after installing WSC in 36 diversion chambers. The survey items performed include checking: 1) the anchors, nuts and bolts for looseness, 2) the baffle and control plate for deformation, 3) entwining of waste around the device, and 4) device components for corrosion.

4 SURVEY RESULTS

4.1 Debris outflow suppression capability

The survey results from the 36 diversion chambers are shown in Table 1.

Table 1 Survey results of debris outflow suppression capability

Chamber Number	$TSRE_{without}$	$TSRE_{with}$	SRV (%)	Combination of system			Chamber Number	$TSRE_{without}$	$TSRE_{with}$	SRV (%)	Combination of system		
				Baffle	Vertical control plate	Horizontal control plate					Baffle	Vertical control plate	Horizontal control plate
1	0.665	0.776	33.1	レ	レ		19	0.766	0.966	85.5	レ	レ	
2	0.445	0.669	40.4	レ	レ		20	0.000	0.880	88.0	レ		
3	0.316	0.634	46.5	レ	レ		21	0.000	0.893	89.3	レ		
4	0.089	0.683	65.2	レ	レ		22	0.000	0.920	92.0	レ		
5	0.000	0.668	66.8	レ			23	0.000	0.932	93.2	レ	レ	
6	0.225	0.756	68.5	レ	レ		24	0.000	0.937	93.7	レ		レ
7	0.627	0.892	71.0	レ			25	0.000	0.938	93.8	レ		
8	0.685	0.911	71.7	レ	レ		26	0.423	0.971	95.0	レ		
9	0.460	0.850	72.2	レ			27	0.351	0.977	96.5	レ		
10	0.000	0.738	73.8	レ	レ		28	0.122	0.972	96.8		レ	
11	0.616	0.911	76.8	レ			29	0.295	0.978	96.9	レ	レ	
12	0.119	0.812	78.7	レ			30	0.000	0.974	97.4	レ		レ
13	0.000	0.794	79.4	レ	レ		31	0.582	0.990	97.6	レ	レ	
14	0.109	0.830	80.9	レ	レ		32	0.340	0.992	98.8	レ	レ	
15	0.452	0.908	83.2	レ	レ		33	0.000	0.988	98.8	レ	レ	
16	0.000	0.836	83.6	レ	レ		34	0.000	0.990	99.0	レ	レ	
17	0.316	0.893	84.4	レ	レ		35	0.000	0.991	99.1	レ		
18	0.336	0.897	84.5	レ	レ		36	0.302	0.995	99.3	レ		

An example of some survey data (Chamber Numbers 26 and 36) is shown in Table 2.

Table 2 Survey data

Chamber Number	Test number	WSC not installed			WSC installed			$TSRE_{without}$ (Average)	$TSRE_{with}$ (Average)	SRV (%)
		*1 (mg)	*2 (mg)	$TSRE_{without}$	*3 (mg)	*4 (mg)	$TSRE_{with}$			
26	1)	3,825	3,311	0.536	36,736	81	0.998	0.423	0.971	95.0
	2)	6,621	6,024	0.524	10,410	725	0.935			
	3)	8,162	30,618	0.210	45,918	884	0.981			
36	1)	11,650	41,637	0.219	42,146	27	0.999	0.302	0.995	99.3
	2)	18,886	51,417	0.269	2,611	23	0.991			
	3)	46,247	64,567	0.417	24,456	125	0.995			

*1 : Amount of debris in intercepted $sewage_{without}$

*2 : Amount of debris in $overflow_{without}$

*3 : Amount of debris in intercepted $sewage_{with}$ + Amount of captured debris when WSC is installed

*4 : Amount of debris in $overflow_{with}$

SRV is used for evaluation in this study, which is the evaluation index chosen at the SPIRIT21 Committee to evaluate debris removal technology with respect to improvement of the combined sewer system. The SPIRIT21 Committee set the development target (required performance) at an SRV of 30 percent or more.

SPIRIT21 is a new technology development project utilizing strong industrial-academic-government collaboration. It addresses various subjects relating to sewage works especially in the areas where promotion of technological development needs to be a priority. Its purpose is to guide and promote private-sector-driven technology development as well as the rapid and varied practical application of developed technology.

According to the results of the current survey, SRV was between 33.1 and 99.3 percent after installing WSC in the existing diversion chamber. Thus, the effectiveness of installing WSC was demonstrated. The interception rate when WSC was installed was between 63.4 and 99.5 percent, and this also demonstrated that it is a good device for debris outflow suppression.

Table 3 shows the WSC configurations and their mean capabilities. High values resulted in the case of all configurations, that is, the mean SRV was 78 percent or more and the mean interception rate was 85 percent or more. Capability showed little dependency on the combination of baffle and control plate.

Table 3 Capability by configuration

Combination	Locations applied	Average		
		$TSRE_{without}$	$TSRE_{with}$	SRV
Vertical control plate only	1	0.122	0.972	96.8%
Vertical control plate＋Baffle	20	0.281	0.858	78.3%
Horizontal control plate＋Baffle	2	0.000	0.956	95.6%
Horizontal control plate only	0	—	—	—
Baffle only	13	0.223	0.900	86.0%

4.2 Durability

In the follow-up survey of durability, each of the survey items was checked and the results were that no problem was found in the 36 existing diversion chambers. Some entwining with debris was seen, however, its extent was too small to impair WSC functioning, and at present there is no effect on durability. The WSC has no moving parts and the device itself has no failure-prone elements, so the risk of failure is judged to be very low.

Making a comprehensive judgment from the follow-up survey results and WSC structure, the durability of WSC can be evaluated as excellent.

5 CONCLUSIONS

WSC can be evaluated as having excellent performance with regard to 1) and 2) below. As a debris reduction measure for use in improving the combined sewer system, installation of WSC in the existing diversion chamber was found to be effective.

1) Investigation of WSC with regard to SRV found that it has performance higher than the development goal set up at the SPIRIT21 Committee.

2) Investigation of the durability of WSC found this to be excellent.

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