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► To cite this version:

D.I. Phillips, M. Simon. A sewage solids screening system for CSO chambers. NOVATECH 2007 - 6ème Conférence sur les techniques et stratégies durables pour la gestion des eaux urbaines par temps de pluie / 6th International Conference on sustainable techniques and strategies for urban water management, Jun 2007, Lyon, France. pp.697-704. <hal-03291449>

HAL Id: hal-03291449

<https://hal.science/hal-03291449v1>

Submitted on 19 Jul 2021

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A sewage solids screening system for CSO chambers

Un système de filtre pour les solides dans les chambres des déversoirs d'orage

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RESUME

Les déversés d'orages sortant des réseaux unitaires peuvent provoquer des problèmes écologiques, esthétiques et sanitaires sérieux dans les eaux réceptrices. Pour réduire ces effets, la quantité et la durée des déversés ont été réduites dans les dernières années ainsi que les éléments solides des eaux unitaires ont été retenus dans des bassins de rétention. La présente communication propose un nouveau dispositif pour retenir ces éléments dans le réseau. Ce dispositif a été sélectionné par la Emschergenossenschaft pour un site pilote au Vorthbach, proche de Essen en Allemagne. Il est un filtre qui utilise l'énergie de l'eau tombante pour maintenir l'appareil, qui fonctionne comme un tamis, libre de solides tout en laissant passer l'eau. Les solides retenus sont ensuite réexpédiés vers le réseau unitaire par une vanne uni-directionnelle.

ABSTRACT

Combined sewer overflows can cause serious environmental, aesthetic and public health problems in receiving waters. Increasingly the focus has been on reducing the frequency and duration of these spills together with retention of the entrained sewer solids within the CSO chamber. This paper reports on a new device for retaining these sewer solids that was selected over existing devices by the Emschergenossenschaft for a pilot study to be conducted on a CSO chamber discharging to the Vorthbach, a watercourse near Essen in Germany. The device, called the Mischwasser Siebsystem, utilizes the energy of falling water to maintain a specially shaped perforated screen free of sewer solids while allowing water to pass through. The retained sewer solids return to the sewer via a simple one-way valve.

KEYWORDS

CSO chambers, screening, sewer solids.

1 INTRODUCTION

Combined sewer overflows cause serious environmental, aesthetic and public health concerns in receiving water bodies. CSO events occur when the combined sewage and storm water flow exceeds the capacity of the sewer system.

Present measures to mitigate the impact of these events include temporary holding tanks at sewerage treatment plants, enlarged upstream sewers providing transient storage, real time control of sewer systems, separation of sewage and storm water flows and various types of overflow screening devices in CSO chambers.

In many situations screening is the only economically viable method and this paper reports on a new design approach to sewer overflow management currently being trialled by the Emschergerossenschaft at a CSO outlet discharging to the Vorthbach, a watercourse near Essen, Germany.

A consulting engineering company, Hydrotec GmbH had been retained by the Emschergerossenschaft in 2003 to investigate and to report on measures that might be implemented to reduce the impact on the Vorthbach of the frequent sewer overflows from this outlet.

After the company had examined all the available commercial devices it concluded that none would be entirely satisfactory at this outlet for a number of reasons including inadequate screening capacity, external power needs and high cost (Simon, 2003).

At about this time a new type of gross pollutant trap with a self-cleansing screen was being developed at Swinburne University of Technology in Melbourne, Australia. This was subsequently adapted to the Vorthbach CSO outlet as a screening device called the Mischwasser Siebssystem (MWSS).

In January 2006, Hydrotec presented a report to the Emschergerossenschaft (Simon, 2006) of a detailed design of the MWSS and eventually received final approval for a pilot installation on the 9th October 2006. To protect the intellectual property, patents were applied for in 2005.

This paper details the design criteria to be satisfied, the underlying hydraulic design theory and the mode of operation of the Vorthbach MWSS together with proposals for its future instrumentation and monitoring. The paper concludes that although the MWSS is a promising concept, a study program involving both field and laboratory testing is essential in order to confirm the veracity of the design assumptions and to improve the design methodology.

2 DESIGN CRITERIA

The following criteria were to be satisfied in the design of the MWSS:

- Installation within the CSO chamber.
- No requirement for an external power source.
- Able to treat all overflows up to the once in five-year ARI event by separating out sewer solids exceeding 10 mm from the overflow. The once in five-year ARI overflow was estimated to be 1.7 m³/s.
- The MWSS was to return these solids to the sewer on cessation of the overflow event.
- It was to be blockage-free and self-cleansing so as to need only minimal inspection and maintenance.
- Inspection and maintenance operations were to be conducted from aboveground.
- A surcharge overflow outlet was to be provided for rare overflow events or if the MWSS malfunctioned.

3 DESIGN THEORY

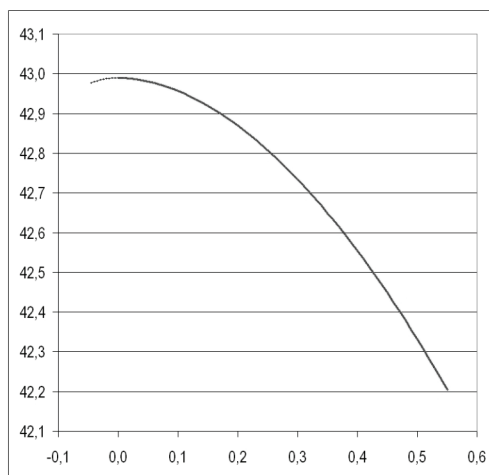
A major problem with side overflow weirs in sewer overflow chambers is that they are subject to highly turbulent inflows causing an uneven distribution of overflows. In this design an immersed baffle wall was employed that not only precluded large solids from entering the MWSS device but also effectively throttled the overflow thus smoothing out fluctuations along the weir crest.

From the hydraulic theory of orifice slots (Daugherty & Ingersoll, 1954) it can be shown that the influence of a 200 mm high surge in a CSO chamber on weir overflows during the once in 5 year ARI overflow of 1.70 m³/s can be suppressed by 95 per cent if the baffle is positioned 200 mm in front of the weir with its lower edge extended by 300 mm below the weir crest.

Water flowing over a weir accelerates as its potential energy converts into kinetic energy. Laboratory studies showed that on impacting on a lower water surface a hydraulic jump was created that dissipated the kinetic energy in a violent rotating action. For the design once in two-year ARI overflow event of 0.7 m³/s it was calculated that in falling the design 0.54 m, the water would attain an impact velocity of 3.2 m/s.

Now if the weir face is curved so as to match that of the under-side of the falling jet at the maximum design overflow of 1.7 m³/s, then the jet will also remain in contact with the weir face at all lesser flows ensuring that it will always impact on the lower water surface immediately adjacent to the screen.

This weir shape, as shown in figure 1 below, is commonly known as an ogee profile and prevents sub-atmospheric pressures forming between the weir face and the flow nappe at high flows leading to flow instability and cavitation. The subsequent implosions can damage the weir and make flow measurement difficult. The equation to the ogee profile is given in hydraulic texts (Featherstone & Nalluri, 1995), but can also be calculated using Newton's laws of motion.

Figure1. Ogee weir profile for a 1.7 m³/s overflow

The curved screen is perforated by rows of 10 mm diameter holes. The rows are spaced 15 mm centre to centre apart while the holes total 40 per cent of the screen face area. The holes permit water to pass through but screen out larger sewer solids. The violent turbulence within the hydraulic jump maintains the holes free of the solids.

The through-flow capacity of a given perforated screen can be determined from a consideration of the water depth differential between the separation chamber and the flush-water chamber for various overflow events and the application of the orifice equation with appropriate coefficients for both the drowned and free hole sections of the screen. See figure 2 below.

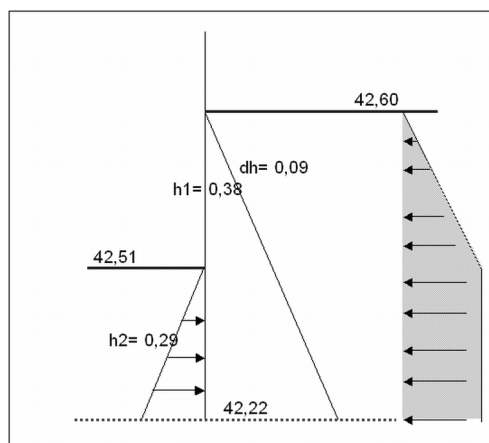


Figure 2. Water surfaces in the separation and flush water chambers for the once in 2-year ARI event

After the flow has passed through the screen into the flush water chamber, it flows over the back weir located behind the ogee weir as shown in figure 3 below. In the pilot MWSS design, the water falls 0.34 m to the floor of the MWSS, dissipating its remaining velocity energy before flowing to the receiving water body via 1200 mm pipes. The design water levels in the various chambers are indicated for both the once in 2 and once in 5 year ARI overflow events.

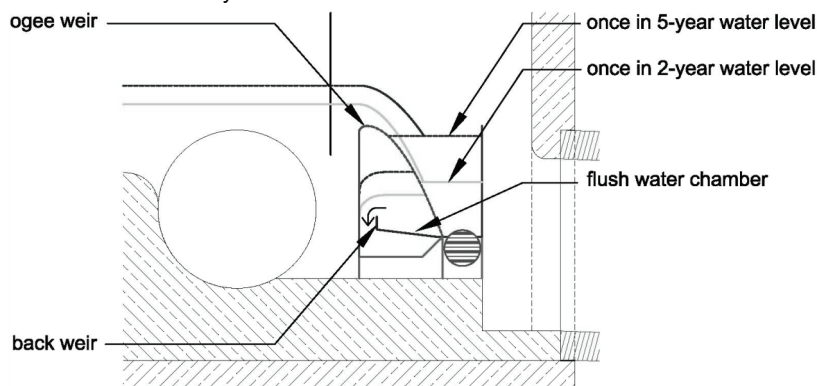


Figure 3. Water levels in the CSO, separation and flush water chambers for the once in 2 and 5 year ARI overflow events

The primary purposes of the back weir are to maintain a pool of water in the separation chamber for the formation of the hydraulic jump, to ensure even flow through the perforated weir and to retain a pool of screened water in the flush chamber for sewer solids flushing purposes.

Also shown in figure 3 is a simple one-way ball valve that closes off the return outlet to the sewer chamber during high sewer flows. This prevents short-circuiting of the device during such flows, so preventing unacceptable frequencies of discharge.

Figure 4 below shows a plan view of the MWSS without the screen, revealing transverse dividing walls spaced along the flush chamber. These compartmentalise the flush water to improve the flushing of solids from the separation chamber during separation chamber emptying.

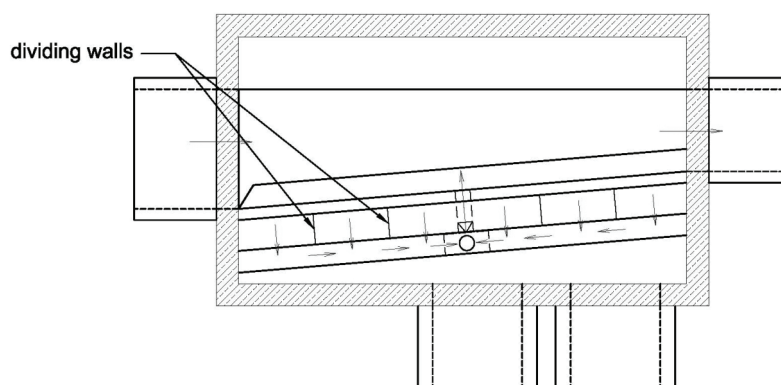


Figure 4. Plan view showing dividing walls in flush water chamber

4 MWSS IN OPERATION

The different modes of operation of the Vorthbach MWSS will now be described with reference to figures 5 to 8 below.

Figure 5 is a cross-section through the valve housing during dry weather flow and shows the ball resting on the floor of the housing. Note the baffle wall in front of the weir extending below the weir crest.

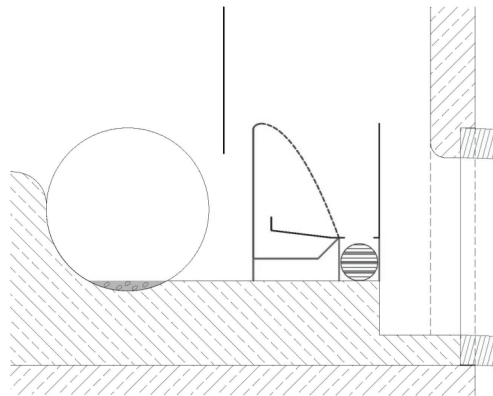


Figure 5. Cross-section through valve housing during dry weather flow

Figure 6 below illustrates a wet weather flow event in the sewer that is not severe enough to overtop the weir. As the 250 mm diameter 4.9 kg ball has an SG of only 0.60, it floats upwards to close off the circular 200 mm diameter valve opening to the separation chamber to prevent flows short-circuiting the MWSS.

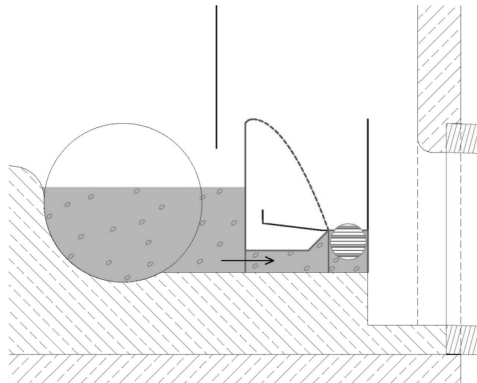


Figure 6. Cross-section through valve housing during a non-overflow wet weather event

The circular valve opening is lined with a neoprene-like material that can distort to accommodate matter that might lodge between it and the ball and so prevents serious leakage occurring.

As can be seen below in figure 7, as the water level in the sewer rises above the weir crest, water overflows the weir crest and cascades down the screen and into the separation chamber pool to form a hydraulic jump before passing through the screen and exiting the MWSS via the back weir and outlet pipes.

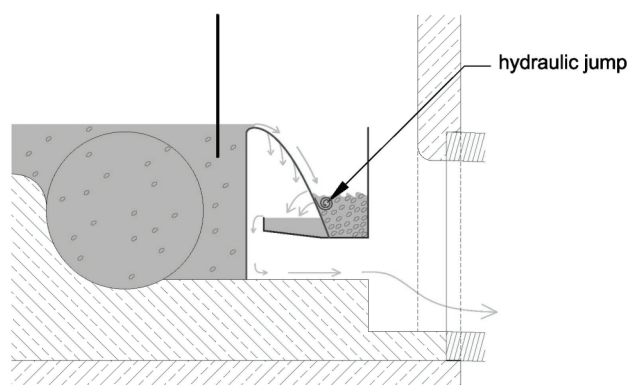


Figure 7. Cross-section through MWSS during an overflow wet weather event

As the screened water flows through the flush chamber it also flushes out any fine settled solid matter and so maintains the flush chamber free of solids accumulations.

When overflow ceases and the flow in the sewer falls towards the dry weather flow rate, the floating ball moves to one side of the valve housing to allow the pool of retained water and sewer solids in the separation chamber to return to the sewer via the valve and return conduit, as shown in figure 8 below.

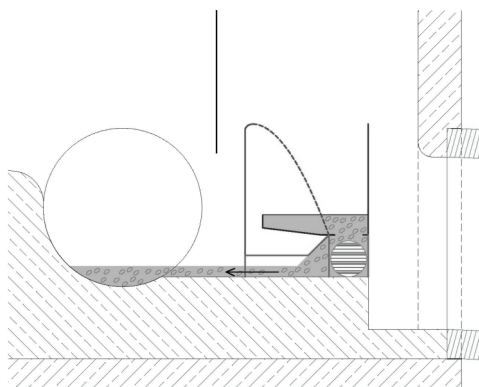


Figure 8. Cross-section through valve housing following an overflow wet weather event

As the water level in the separation chamber falls, the water stored in the flush water chamber flows through the adjacent screen holes into the separation chamber to assist in flushing the sewer solids to the central valve opening and back to the sewer.

In rare events when the weir overflow exceeds the screen capacity the excess flow passes over a further weir at the rear of the MWSS to discharge directly to the outlet pipes as shown in figure 9 below. This weir is topped with a grate to retain large sewer solids.

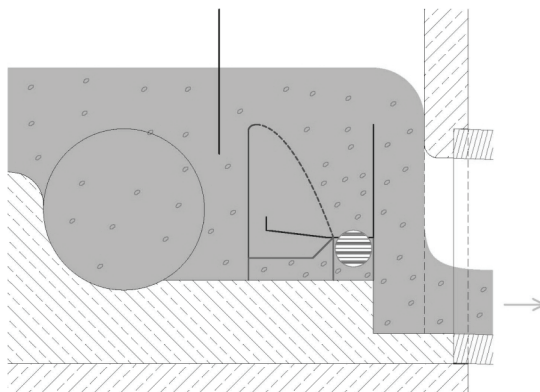


Figure 9. Cross-section through valve housing during an excess overflow wet weather event

5 FURTHER STUDIES

Although the design methodology for the pilot MWSS was based on hydraulic theory supported by laboratory studies, further laboratory and field studies are needed to verify the veracity of the methodology. Consequently it is planned to conduct additional laboratory tests and in order to evaluate the performance of the MWSS during overflow events, to instrument the Vorthbach CSO chamber.

6 CONCLUSIONS

- While the concept of the MWSS shows considerable promise as an effective approach to sewer solids screening during CSO events, additional laboratory and field studies are necessary in order to determine the veracity of the design assumptions.
- The pilot MWSS installed by the Emschergerossenschaft and its subsequent instrumentation and monitoring will assist in the evaluation of the concept.
- The outcomes of the studies to be reported at a future Novatech conference.

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