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THE SCREEN EFFICIENCY OF A NOVEL SELF-CLEANSING CSO

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ABSTRACT

The paper presents the results of testing of a novel self-cleaning CSO device at the UK National CSO Test Facility at Hoscar Wastewater Treatment Works, Wigan, when fitted with mesh screens of aperture sizes of 6 mm, 4 mm, 2 mm and 1 mm. The current standard in the UK for Combined Sewer Overflows (CSOs) and other intermittent discharges is based around the removal of aesthetic pollutants and the reduction of spill frequency. The most stringent consent standards (relating to discharges to high amenity waters) require a 'significant removal' of all gross solids, these being defined as particulate material, 6 mm in 2 directions or larger.

The results demonstrate that a significant performance gain can be achieved using a 4 mm aperture screen in place of a 6 mm screen but that the 2 mm screen does not offer a similar gain over the 4 mm screen. Initial testing with a 1mm screen indicates another significant gain in performance but with the penalty of a reduced hydraulic loading rate. It is concluded that CSO screening systems offering a 4 mm two directional screening standard can be significantly more efficient than 6 mm screens and may not entail any additional cost. The performance of a 4 mm screening system currently represents BATNEEC (Best Available Technology Not Entailing Excessive Cost) for a CSO screening device.

KEYWORDS

Combined sewer overflows; gross solids; self-cleansing mesh screens; syphon; field testing

INTRODUCTION

The focus of urban drainage in the 90's has shifted from the need to provide structurally sound drainage systems with adequate hydraulic carrying capacity to, water quality issues and the need to achieve use related water quality standards in receiving water bodies. In the UK, the emphasis for capital investment has shifted towards reducing the polluting impact of Combined Sewer Overflows (CSOs) and other intermittent wet-weather discharges from overloaded drainage systems. There is currently a requirement for the Water Service Companies to rectify two thirds of the identified 4000 unsatisfactory CSOs by the year 2005.

SCREENING OF COMBINED SEWER OVERFLOWS

The current standard in the UK (AMP2 Guidelines) for CSOs and other intermittent wet-weather discharges is based around the removal of aesthetic pollutants and the reduction of spill frequency (NRA, 1993). The most stringent consent standards (relating to discharges to high amenity waters) require “separation, from the effluent, of a significant quantity of persistent material and faecal / organic solids greater than 6 mm in any two dimensions.” Tests by the UK Water Industry CSO Research Group (CSORG), of the commonly used CSO chambers (i.e. Stilling Ponds and High Sided Weirs), found the performance of each of the chambers to be poor at their design flows. All chambers were observed to discharge a significant proportion of solids with dimensions greater than 6mm in two dimensions in the spill flow (UKWIR, 1997).

Given the range and characteristics of sewer solids in urban drainage systems, especially with aesthetic pollutants such as panty liners and condoms approaching neutral buoyancy, the above results are hardly surprising. It is generally recognised that the most effective way of achieving 100% compliance with the AMP2 requirements is with a screening system. When the AMP2 standards were produced, however, screening systems for use within the sewer network were poorly developed and at best unreliable.

Screens placed in combined sewer environments are subject to rapid blinding due to hair pining. Hair pining results from fine fibrous material becoming wrapped around the wires of bar screens and bridges the gap between the apertures of perforated (mesh) screens. This presents a major cleaning problem and to overcome this, conventional screening devices rely on electro-mechanical components to effect the cleansing of screens. Bar screens for example typically utilise raking mechanisms and are only effective in screening in one dimension. As such, they are not as efficient as perforated screens with defined aperture sizes. Reported results of tests to date at the UK National CSO Test Facility has highlighted that for screens with powered cleansing mechanisms, a 6mm mesh screen appears to be more effective at retaining 6mm solids than a 4mm raked bar screen (Saul, 1998).

CSOs in the main tend to be at remote sites and preferably, CSO screening devices should be self powered, self-cleansing and free from maintenance requirements. Conventional electro-mechanical screening devices require power, maintenance and are prone to failure due to seizure of moving parts after prolonged dry spells when the screens are not in service. The risks of failure of electro-mechanical devices are increased during rainfall events – the period when the screen is expected to operate in as reliable and fail safe mode as possible. Failure can arise when no electrical power is available due to lightning strike at sub-stations.

This paper describes a novel low maintenance self-cleansing CSO mesh screen requiring no external power source to operate - the Hydro-Jet™ Screen. Results of testing of the device at the UK National CSO Test Facility at Hoscar Wastewater Treatment Works, Wigan, when fitted with screens of aperture sizes of 6 mm, 4 mm, 2 mm and 1 mm are presented and discussed.

THE HYDRO-JET™ SCREEN

The Hydro-Jet Screen™ has been developed as an effective low cost, low maintenance, non-powered screening system for CSO application, and evolved from the Swirl-Cleanse™ screening system (Smith and Andoh, 1997). The system was developed specifically to meet the 6 mm in two directions aesthetic pollutant requirement outlined in AMP2 (former National Rivers Authority and Water Services Association 'Asset Management Plan'; NRA, 1993).

The configuration and operation of a single-sided Hydro-Jet Screen™ during a spill event is shown in Figures 1 - 3. The sectional view in Figure 1 shows a rectangular channel on the left-hand side. This is the dry weather flow channel and incorporates both an inlet and pass-on flow pipe to convey flows to treatment. When the inflow rate exceeds a predetermined pass on flow to treatment (i.e. during storm flow conditions), an overflow occurs. Under storm conditions, the flow weirs over and through a mesh screen on which the solids in the screened flow are deposited. The screened water is initially prevented from being discharged by a self-priming syphon with an air brake. The function of the syphon is to act as an open or closed valve and thus cause the water level to rise and fall in the chamber. Whilst the screened water level is rising towards the apex of the mesh screen panel, deposited material is removed by the following three mechanisms (see Figures 2 and 3):

1. The screened water rises in the chamber, displaces the trapped air and flows back up through the screen lifting material off the screen. The relatively low open area of the screen holes (22% for a 4 mm screen and 27% for a 6 mm screen) has the effect of increasing the pressure and thus velocity at which the back-flushing water and air passes through the screen.

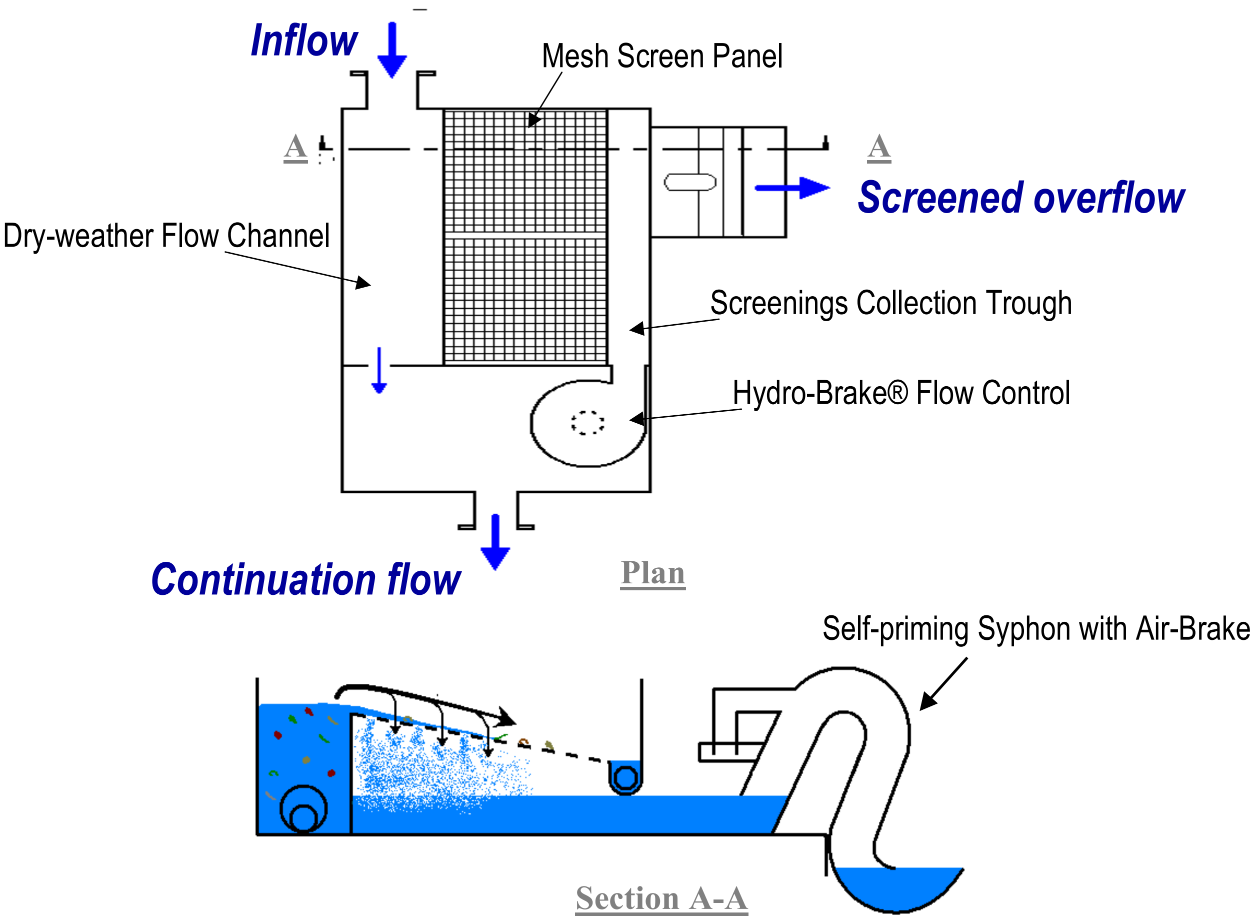
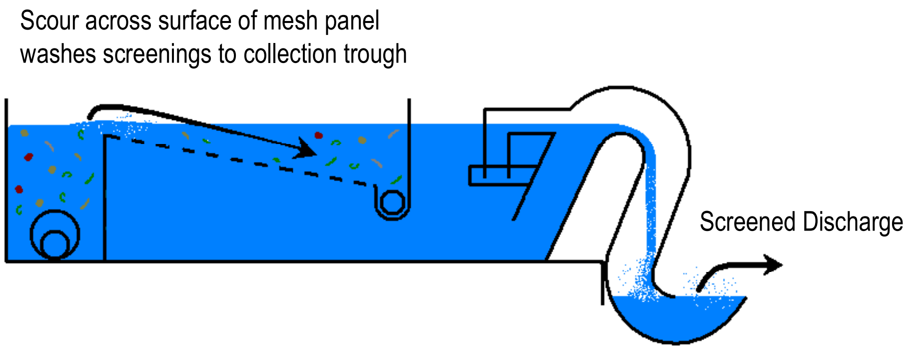


Figure 1

2. The rise in water level increases the air pressure under the screen "blowing" air through the screen holes. This effect becomes more pronounced as the water level rises and air is forced out from beneath a curtain of water. This mechanism is particularly useful for cleaning the top portion of the screen. During overflow, this portion is continually covered in water and would otherwise blind.

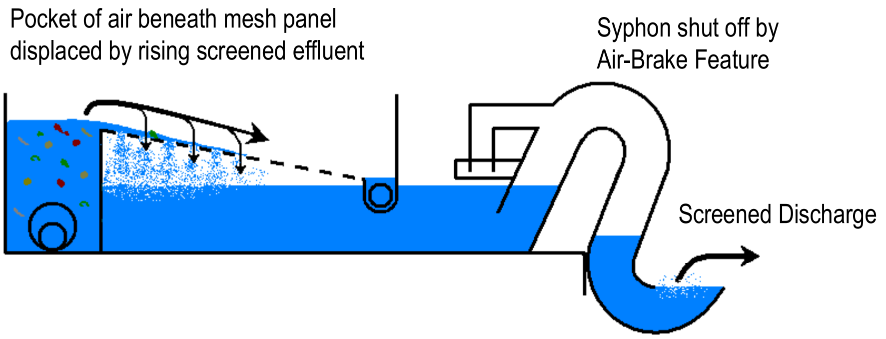
3. The scouring action of the water flowing across the surface of the mesh has the effect of transporting the screenings towards the screenings collection trough for ultimate disposal, via a vortex flow control, with the continuation flow to treatment.

The screened overflow, free from aesthetic pollutants, is discharged to the receiving watercourse. The mechanism by which the screen back washes is essentially a cyclic process. The key element responsible for this is the novel, patented discharge syphon, shown on the right hand side in the sectional view. When the water level has risen to the crest of the syphon, the syphon primes, discharging the screened effluent to the watercourse. This lowers the water level and the air brake pipe causes the syphon to shut-off before the cycle repeats.



Syphon primed and beginning to lower water level

Figure 2



Air-brake pipe causes syphon to stop and cycle repeats

Figure 3

The Hydro-Jet Screen™ system has been subject to an extensive development, testing and evaluation programme. The application of computational fluid dynamics to optimise its hydraulic characteristics are described elsewhere (Faram and Andoh, 1999, *submitted*). The device has also been independently tested at the UK National CSO Test Facility at Hoscar Wastewater Treatment Works, Wigan. Its performance, assessed in terms of gross soids removal efficiencies when using crude sewage, has been shown to be superior to that of other CSO systems (Saul, 1998).

In an effort to evaluate the scope for providing CSO screening performance better than the AMP2 regulatory requirements, the Hydro-Jet Screen™ system was tested with screens of 6 mm, 4mm, 2 mm and 1mm. This enabled an assessment to be made of the performance gains that can be achieved by using a finer mesh size and also established the hydraulic penalty incurred in terms of reduced screen loading rate for finer mesh sizes.

EFFICIENCY TESTING OF THE HYDRO-JET™ SCREEN

A single sided Hydro-Jet Screen™ unit with a maximum hydraulic flow capacity of 120 l/s was set up such that the inflow, screened flow and continuation flow could all be measured separately. The screened discharge from the unit and continuation flow containing the screenings were passed into separate channels each containing a series of 6mm mesh sacks to collect solids. Crude sewage that had not received any prior treatment was used as the test effluent.

The decision to assess the efficiency of the finer aperture (i.e. 4mm, 2mm and 1mm) mesh screens using a series of 6 mm mesh sacks was taken so that comparative results between different devices could still be made. The UKWIR CSORG test program at the National CSO Test Facility, Wigan, has used 6 mm sacks throughout and this has been broadly adopted as the current standard test protocol (UKWIR, 1997). The mesh sacks themselves rapidly become coated with a paper-mâché type material, which traps material far smaller than the mesh size. The test therefore provides some objective assessment of the removal of gross solids and provides scope for a comparative assessment. It must be borne in mind however that this test protocol may have a bearing regarding observed results and their subsequent interpretation and in this regard the results should be interpreted in relation to gross solids captured in mesh sacks subject to progressive blinding.

Tests were carried out at a series of steady state flow conditions, each for a 20-minute period. At the end of which, the mesh sacks were removed and hung for 30 minutes to allow water to drain out before weighing. The efficiencies of the screens were assessed by comparing the mass of material collected from the screened effluent with that from the continuation flow in accordance with the protocols developed by the UKWIR CSORG (UKWIR, 1997).

RESULTS AND DISCUSSION

Total solids retention efficiency (TE) as defined below, was used to assess the performance of the different aperture mesh panels.

$$\text{Total Efficiency (T.E)} = \frac{\text{Total Mass of Solids Retained}}{\text{Total Mass of Solids in Inflow}} \times 100$$

A series of 20minute tests over a range of flows were undertaken for each of the mesh panels. The results obtained for the series of tests up to a flow rate of 60 l/s are summarised in Table 1. Table 2 shows the results for tests for the 6mm and 4mm aperture mesh panels at flows between 90 –120 l/s. Student t-tests indicated that the differences in efficiency between the 6mm and 4mm screen results were significant but that the differences between the 4mm and 2 mm screen were not. Only two tests were conducted for the 1mm aperture mesh screen at a flow rate of 45 l/s. It was not possible to carry out tests at flows above 45 l/s for the 2mm and 1mm aperture screens because of the restricted hydraulic capacity of these finer aperture mesh panels.

Table 1: Screen Efficiency for the Hydro-Jet™ Screen with mesh panels – up to 60 l/s

	Screen Mesh Aperture Size (mm)			
Statistic	6	4	2	1
Average Total Efficiency (%)	51	67	69	90
Number of Observations	17	20	12	2
Standard Deviation	9	8	10	1
Flow Range (l/s)	17 – 60	18 - 60	17 – 45	45
Average Flow	45	43	33	45
Average Mass of Screen Solids (g)	988	1821	1530	1473
Average Mass of Discharge Solids (g)	956	776	613	90

Table 2: Screen Efficiency for the Hydro-Jet™ Screen with mesh panels – : 90 - 120 l/s

	Screen Mesh Aperture Size (mm)	
Statistic	6	4
Average Total Efficiency (%)	48	60
Number of Observations	3	3
Standard Deviation	9	8
Flow Range (l/s)	90 – 120	90 –120
Average Flow	100	100
Average Mass of Screen Solids (g)	2558	3468
Average Mass of Discharge Solids (g)	3118	2143

In all tests, no solids greater than 6mm in two dimensions was observed in the spill flows showing complete compliance with the AMP2 requirements. The results presented in Tables 1 and 2 show a general trend of increasing Total Efficiency with decreasing mesh aperture size and also a decreasing average mass of discharged solids in the spill flows with decreasing mesh aperture size as would be expected.

An assessment of the relative improvement in Total Efficiency with decreasing mesh aperture size shows a significant difference between the 6mm and 4mm but not between the 4mm and the 2mm (ie. in terms of the removal of gross solids as measured by the adopted test protocol). Given the hydraulic restrictions observed for the mesh panels with apertures of 2mm or less, it is deemed that the optimum aperture size for the CSO application of the Hydro-Jet™ Screen is with a 4mm aperture mesh.

These results are significant as they indicate that from a performance perspective, in a CSO application, a 4 mm mesh screen will offer distinct performance advantages over a 6 mm mesh screen without incurring a penalty of reduced hydraulic loading capacity. In practice this means that a 4 mm mesh screen can be provided at the same relative costs as the 6 mm mesh screen with no financial or cost penalty whilst potentially giving some 25% - 30% relative gain in gross solids removal.

CONCLUSIONS

Fine screening of sewage presents many technical problems. For CSOs these problems are exacerbated by their often remote location or difficult access coupled with the intermittent nature of operation. Electro-mechanical

Screens with their moving mechanical parts are often more prone to failure when not operating continually because of the harsh environment in combined sewer systems. Most CSOs typically operate for less than 100 hours a year (ETRAC, 1998). In addition, level or flow sensors and switch-gear is required to start and stop the raking systems of electro-mechanical screens. This provides another potential point of failure within the system.

The Hydro-Jet Screen™ provides the ideal characteristics of a CSO screening device. The screen operates reliably in the sewer environment, is hydraulically fail-safe, has no moving parts and requires no external sources of power. The device overcomes many of the concerns about screens raised in the UK guidance document for the design of CSO structures (Balmforth et al., 1994). Field tests carried out to date show complete compliance with the UK national consent standards for the discharge of CSOs to high amenity waters.

The results of the work presented in this paper show that significant performance gains are obtained with a 4mm aperture mesh screen in comparison with a 6mm aperture mesh screen with relative performance gains of the order of 25 %– 30%. The Hydro-Jet Screen™ utilising a 4mm mesh panel, represents one of the Best Available Technology Not Entailing Excessive Cost for a CSO screening device.

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