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Operational Performance Boundaries in Drainage Systems

Dr Steve Cummings
Water efficiency drivers for further fixture water usage reductions are causing concerns that sanitary drainage systems are approaching operational limits.
Unique Industry collaboration – ASFlow committee research studies

1. Implications of flow reductions in sanitary plumbing and drainage systems
2. Reduction in flows impact on black water transportation.
3. To compare systems internationally.
4. Feasibility of ultra low WC discharge volumes

USA – Plumbing Efficiency Research Coalition (PERC)

GERMANY – Gelsenkirchen University of Applied Science

Waterless urinal research – Prof. Dr-Ing Mete Demiriz
ASFlow Committee – Research approach

Research approach:
• Investigate actual problem sites in the field
• Simulate the drainage configuration in the laboratory
• Evaluate the results and determine an appropriate solution
Research Studies – ASFlow Committee

Three major research studies conducted:

1. **Waterless urinals**
   - Study the implications of waterless urinals on the drainage systems.

2. **90° sweep junctions**
   - Study the implications on WC drainline performance of 90° sweep junctions installed onto a horizontal drainline.

3. **Horizontal sweep junctions**
   - Study the implications on WC drainline performance of sweep junctions installed onto a horizontal drainline.
**Study 1**

**Waterless Urinal Study** – Compatibility of Waterless Urinals and Drainline Systems

**Problem**

Urinal WITHOUT connection to basin

- 22,000 uses – 39 Months

**Solution**

Urinal WITH connection to basin

- 10,000 uses – 39 Months
Key Findings -

• Struvite build-up over time and use will occur in drainline systems connected to waterless urinals that can potentially cause complete blockage of the drainline.

• Struvite build-up in drainlines can be significantly reduced through the introduction of additional water using fixtures upstream of waterless urinals.

Plumbing and drainage Part 2: Sanitary plumbing and drainage – proposed amendment

11.24.2.3 Non-flushing (waterless) wall-hung urinals

Each waterless urinal shall be installed only where at least 2 fixture units, are connected upstream of the connection of the waterless urinal to the discharge pipe.
**90° Sweep Junction**

**Problem**

**45° Sweep Junction**

**Solution**
Key Findings -

• Transportation of waste significantly reduced by the 90° sweep junction configuration - hydraulic jump.

• The alternative 45º junction configuration provided satisfactory waste transportation.

Plumbing and drainage Part 2: Junctions installed on a vertical line – proposed amendment

4.9.3 Junction installed on a vertical line (part 2)

Junctions installed in a vertical plane shall not be used for connection of stacks. Sweep and 45º junctions may be laid in the vertical plane for the connection of a single discharge pipe or a drain, provided:

a) A 45º junction shall only be used for the connection of a water closet pan.
ASFlow – Domestic problem installation in Western Australia

31m drainline
Horizontal Sweep Junctions – CIT WC Drainline transportation performance testing

Study 3

4th Junction
Test Media / Paper
Waste Back Flow
### Study 3: Horizontal Sweep Junctions – Backflow evaluation on drainline transportation

<table>
<thead>
<tr>
<th>Flush Volume</th>
<th>Media</th>
<th>Ave. Backflow (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5L</td>
<td>250g Aus Media + paper</td>
<td>Total: 874ml</td>
</tr>
<tr>
<td></td>
<td>Junction 1</td>
<td>0ml</td>
</tr>
<tr>
<td></td>
<td>Junction 2</td>
<td>375ml</td>
</tr>
<tr>
<td></td>
<td>Junction 3</td>
<td>750ml</td>
</tr>
<tr>
<td></td>
<td>Junction 4</td>
<td>1125ml</td>
</tr>
<tr>
<td></td>
<td>Total: 1500ml</td>
<td>1500ml</td>
</tr>
</tbody>
</table>

874ml of a 4.5L flush volume was lost to junction backflow

Junction configuration resulting in a **19% loss** in full flush volume
### Horizontal Sweep Junctions – Alternative junction configurations – Drainline Test Results

<table>
<thead>
<tr>
<th>Flush V.</th>
<th>Junction Configuration</th>
<th>Test Media</th>
<th>Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5L</td>
<td>4 Standard Sweep Junctions</td>
<td>Aus 250g</td>
<td>5m</td>
</tr>
<tr>
<td>4.5L</td>
<td>4 Sweep Junctions UPWARDS 90º</td>
<td>Aus 250g</td>
<td>8m</td>
</tr>
<tr>
<td>4.5L</td>
<td>4 Alternative Sweep Junction Design</td>
<td>Aus 250g</td>
<td>8.6m</td>
</tr>
<tr>
<td>4.5L</td>
<td>4 Sweep Junction - DIN 1986 Standard</td>
<td>Aus 250g</td>
<td>8.6m</td>
</tr>
</tbody>
</table>

Ave 1st Flush

Ave 2nd Flush
Study 3

Horizontal Sweep Junctions – CIT WC Drainline transportation performance testing

Sweep Junctions

Waste Back Flow

Problem

Alternate Sweep Junctions

Solution 1

DIN 1986 Standard

Solution 2
Key Findings -

• Waste transportation performance of horizontal sweep junctions is **adversely affected** by waste water back flow.

• Horizontal sweep junctions configurations – **probable cause** of drainline blockage in Western Australia.

• Alternative junction design provided a **significant improvement** in drainline transportation.

• **German DIN standard 1986** requirements should to be considered for adoption into AS/NZS 3500.2.
Investigation is continuing

More problem installations are become known to the committee

Installation in WA: System not operating effectively, 9 horizontal junctions on main branch
Representative WC test media criteria
Test Solid Media Study – WC drainline transportation testing

Comprehensive drainline testing conducted on 60m drainline testing rig

Gearing up to commence US PERC study work
**Test Solid Media Study** – Performance variation between test solid media

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Media</th>
<th>MaP Uncased - Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L (0.8gal)</td>
<td>Uncased MaP</td>
<td>![Graph]</td>
</tr>
<tr>
<td>4.8L (1.3gal)</td>
<td>Uncased MaP</td>
<td>![Graph]</td>
</tr>
<tr>
<td>6L (1.6gal)</td>
<td>Uncased MaP</td>
<td>![Graph]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Media</th>
<th>AUS/DIN - Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L (0.8gal)</td>
<td>Aus/DIN</td>
<td>![Graph]</td>
</tr>
<tr>
<td>4.8L (1.3gal)</td>
<td>Aus/DIN</td>
<td>![Graph]</td>
</tr>
<tr>
<td>6L (1.6gal)</td>
<td>Aus/DIN</td>
<td>![Graph]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Media</th>
<th>MaP (Latex) - Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L (0.8gal)</td>
<td>MaP (Latex)</td>
<td>![Graph]</td>
</tr>
<tr>
<td>4.8L (1.3gal)</td>
<td>MaP (Latex)</td>
<td>![Graph]</td>
</tr>
<tr>
<td>6L (1.6gal)</td>
<td>MaP (Latex)</td>
<td>![Graph]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Media</th>
<th>Polypropylene Balls - Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3L (0.8gal)</td>
<td>Polypropylene Balls</td>
<td>![Graph]</td>
</tr>
<tr>
<td>4.8L (1.3gal)</td>
<td>Polypropylene Balls</td>
<td>![Graph]</td>
</tr>
<tr>
<td>6L (1.6gal)</td>
<td>Polypropylene Balls</td>
<td>![Graph]</td>
</tr>
</tbody>
</table>

Results show significant difference in drainline transportation between types of test media.
### Test Solid Media Study – WC drainline transportation test results

**Reductions in flush volume** – *exponential reduction* in solid waste drainline transportation performance

<table>
<thead>
<tr>
<th>Vol.</th>
<th>Media</th>
<th>Ave. Drainline Carry (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6L (1.6gal)</td>
<td>250g AUS/DIN Media</td>
<td>[Graph showing carry distances for 250g AUS/DIN Media]</td>
</tr>
<tr>
<td></td>
<td>250g MaP (latex) Media</td>
<td>[Graph showing carry distances for 250g MaP (latex) Media]</td>
</tr>
<tr>
<td>4.5L (1.2gal)</td>
<td>250g AUS/DIN Media</td>
<td>[Graph showing carry distances for 250g AUS/DIN Media]</td>
</tr>
<tr>
<td></td>
<td>250g MaP (latex) Media</td>
<td>[Graph showing carry distances for 250g MaP (latex) Media]</td>
</tr>
<tr>
<td>3L (0.8gal)</td>
<td>250g AUS/DIN Media</td>
<td>[Graph showing carry distances for 250g AUS/DIN Media]</td>
</tr>
<tr>
<td></td>
<td>250g MaP (latex) Media</td>
<td>[Graph showing carry distances for 250g MaP (latex) Media]</td>
</tr>
</tbody>
</table>

Highlights the need for representative drainline transportation testing at ultra-low flush volumes
Toilet Paper Media Study – German study into female toilet usage

Preferred methods and positions during female urination in public restrooms

- Floating: 79.3%
- Nest making: 16.7%
- Standing: 3.3%
- Others: 0.7%

Figure 2 – Preferred methods and positions
Toilet Paper Media Study – Nesting

Nest Making – potentially 30 sheets used
Usage Total – 45 sheets
Toilet drainline transportation evaluation of 22 commercially available toilet paper brands

The ASFlow Committee is conducting research into the performance of toilet paper and the identification of appropriate test media.
Toilet paper characteristics varied by;

- Number of ply
- Weight
- Material
Toilet Paper Media Study – WC drainline transportation test results

Average Drainline Transportation Performance (m) of Test Toilet Paper using 4.5L and 3L Flush Discharge
Toilet Paper Test Media – WC drainline transportation test results

Average Drainline Transportation Performance (m) of Test Toilet Paper using 4.5L and 3L Flush Discharge

30 Sheets @ Full Flush 4.5L
15 Sheets @ Half Flush 3L
## Toilet Paper Media Study – Determination of performance characteristics

<table>
<thead>
<tr>
<th>No.</th>
<th>Test Paper Characteristics</th>
<th>Sheet Size: 11x10cm</th>
<th>Ply:</th>
<th>Weight (g) of 10 sheets:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.5</td>
<td>Best Performing</td>
<td></td>
<td>2</td>
<td>3.8g</td>
</tr>
<tr>
<td>No.8</td>
<td>Poorest Performing</td>
<td></td>
<td>1</td>
<td>3.6g</td>
</tr>
<tr>
<td>No.12</td>
<td>Nearest the Average</td>
<td></td>
<td>2</td>
<td>5.1g</td>
</tr>
</tbody>
</table>

Size, Ply and Weight
Testing was carried on using 30 sheets of crumpled toilet paper. Each test paper produced varying diameters of bulk.
Toilet Paper Media Study – Realistic testing

Chaotic path through and into the drainline

Simulated Flush rig with 1 metre drainline carry
Toilet Paper Media Study – Realistic testing

Breakdown of 30 sheets of paper after a 4.5L full flush with 1 metre drainline carry
### Toilet Paper Media Study – Realistic testing

<table>
<thead>
<tr>
<th>Test Paper Characteristics</th>
<th>Best Performing</th>
<th>Poorest Performing</th>
<th>Nearest the Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.5</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>No.8</td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>No.12</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
</tr>
</tbody>
</table>

Breakdown of 30 sheets of paper after a 4.5L full flush with 1 metre drainline carry.
Toilet Paper Media Study – Results

Comparison of Average Drainline Transportation Performance (m) of Test Toilet Paper and Test Media using 4.5L and 3L Flush Discharge

Combination of solids and paper reduce drainline performance
Toilet Paper Media Study – Results

Comparison of Average Drainline Transportation Performance (m) of Test Toilet Paper and Test Media using 4.5L and 3L Flush Discharge

**No.8 Poorest Performing**

![Bar chart showing comparison of average drainline distance for No.8 Paper, No.8 Paper + MaP Media, and No.8 Paper + AS1172.1 Media.]

**Solids Media Only**

![Bar chart showing comparison of average drainline distance for MaP Media Only and AS1172.1 Media Only.]

Average Drainline Distance (m)
**Test Solid and Paper Media** – Transportation behavior

<table>
<thead>
<tr>
<th>Behavior of Solids and Paper during transportation testing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direction of flow</strong></td>
</tr>
<tr>
<td>Solids</td>
</tr>
</tbody>
</table>

**Typical Separation of Solids and Paper**

Observation that generally solids accelerate away from paper
**ASFlow Research Approach** – Real life building study

24 level building in Western Australia -

- Major blockages occurring in the WC drainline connecting the female toilets
- Video footage showed large toilets paper deposits within drainline
- Changed type of toilet paper – with the characteristics of the Best Performance Paper
- Since September 2010 ‘**no blockages have been reported**’
ASFlow research outcomes are showing the way in the creation of a sustainable sanitation system with improved low flow performance.