Discussion of "Design Considerations for High-Speed Flow in Sewer Systems"

Gaetano Crispino

Research Associate, Dept. of Engineering, Università degli Studi della Campania "L. Vanvitelli," Aversa 81031, Italy (corresponding author). ORCID: https://orcid.org/0000-0002-3889-1115. Email: gaetano.crispino@unicampania.it

Michael Pfister

Professor, Dept. of Civil Engineering, Haute Ecole d'Ingénierie et d'Architecture de Fribourg (HES-SO), Fribourg CH-1705, Switzerland. Email: michael.pfister@hefr.ch

Corrado Gisonni

Full Professor, Dept. of Engineering, Università degli Studi della Campania "L. Vanvitelli," Aversa 81031, Italy. Email: corrado.gisonni@unicampania.it

Willi H. Hager, M.ASCE

Emeritus Professor, Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie (VAW), Eidgenössische Technische Hochschule Zürich (ETH Zurich), Zürich CH-8093, Switzerland. Email: hager@vaw.baug.ethz.ch

This paper presents a discussion of "Design Considerations for High-Speed Flow in Sewer Systems" by Yu Qian, David Z. Zhu, and Bert van Duin, https://doi.org/10.1061/(ASCE)HY.1943-7900.0002004.

Introduction

The discussers are happy to see that sewer hydraulics merits a state-of-the-art review in the *Journal of Hydraulic Engineering*; the discussers thank the authors for their initiative. Troubling phenomena, such as air pulsation, abrasion, abrupt pressurization, and even geyser flow, may characterize the operation of sewer structures with fast flows. The authors proposed a summary of the design criteria to prevent the occurrence of such incidents. Structural solutions, including the realization of specific manholes as a drop structure, were also reviewed.

Among other issues, flow choking should be avoided in sewer conduits and manholes because it can strongly reduce their discharge capacity. Choking more likely occurs for supercritical flows in manholes than across sewer conduits because geometric and hydraulic changes provoke flow surface singularities (shock waves).

Before focusing on the bend and junction manholes with supercritical approach flow, the discussers briefly recall the development conducted by Hager (2010) regarding the Froude number F for partially filled sewers. Differentiating the specific energy with respect to the flow depth h at a generic cross section

$$\mathsf{F}^2 = \frac{Q^2}{gA^3}\frac{\mathrm{d}A}{\mathrm{d}h} \tag{1}$$

a substitution of $A = \mathrm{f}(y)$ as well as its derivate was inserted into Eq. (1), with $y = h/D$ as the partial filling ratio. The following term results:

$$\mathsf{F}^2 = \frac{Q^2}{gD^5}\frac{1}{y^4}\cdot \mathrm{p}(y) \tag{2}$$

The analysis of the function $\mathrm{p}(y)$ indicates that it is approximately equal to unity (less than 3.4% difference) for common values of $0.30 < y < 0.95$; it is therefore neglected to yield

$$\mathsf{F} = \frac{Q}{\sqrt{gDh^4}} \tag{3}$$

Eq. (3) of the original paper empirically fitted by the authors is close to the physically based solution of Hager (2010).

Bend Manholes

For a specific geometry, the choking condition can be derived from the choking (subscript c) number $\mathsf{F}_c = Q/(gD^5)^{0.5}$, which was fitted by Eq. (4) of the original paper. The latter was further transformed into Eq. (5) of the original paper, where the discussers noted that the coefficient 2.85 should read 2.085. The combination of Eq. (3), instead of Eq. (2) of the original paper, and Eq. (4) of the original paper yields an equation slightly simpler than Eq. (5) of the original paper

$$1 = 2.12(1.25\cdot y^5 - 1.53\cdot y^6)^{0.4}\frac{D^{1.8}R^{0.2}}{A} \tag{4}$$

The state-of-the-art review can be completed by mentioning an approach for a wider geometrical spectrum recently published by Crispino et al. (2023) to predict the normalized discharge capacity (subscript C) as $Q_C^* = Q_C/(gy^3D^5)^{0.5}$ of bend manholes at the choking onset, based on

$$Q_C^* = ky^{(\alpha-1.5)} \tag{5}$$

Here $k = 0.1(R/D + L/D + 5)$ as well as $\alpha = 0.7 - \sin(\theta/8)$ are two geometrical parameters. The length L is the straight extension as suggested by Gisonni and Hager (2002a), R is the axial curvature radius, and θ is the bend deflection angle. The equation proposed by the authors ignores their effects.

Eq. (5) of the discussion applies within $0.30 \le y \le 0.70$, $45° \le \theta \le 90°$, $1 \le R/D \le 3$, and $0 \le L/D \le 2$. Fig. 1 illustrates that Eq. (5) represents well the experimental observations of Del Giudice et al. (2000), Gisonni and Hager (2002a), and Crispino et al. (2023). The data of Kolarevic et al. (2015) are not retained because they refer to circular conduit bends, and not to U-shaped bend manholes. Indeed, the hydraulic features of these two structures are quite different.

The authors noted, from their Eq. (5), that a maximum (subscript M) filling ratio of $y_M = 0.80$ avoids flow choking. The experimental and numerical observations of Gisonni and Hager (2002a) and Crispino et al. (2023) indicate smaller values of roughly $y_M = 0.65$ for supercritical flow in bend manholes.

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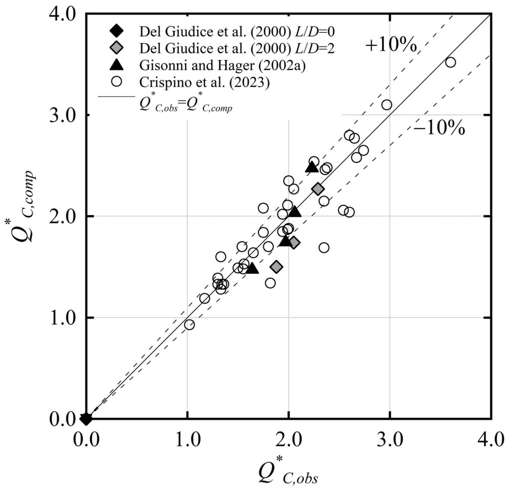

Fig. 1. Comparison between observed (subscript *obs*) and computed through Eq. (5) of the discussion (subscript *comp*) normalized discharge capacity for 45° and 90° supercritical bend manholes.

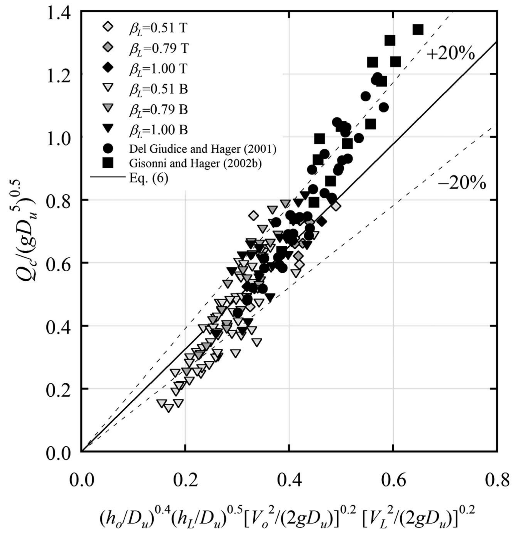

Fig. 2. Capacity of 45° and 90° junction manholes with aligned sewer pipe bottoms (B) or tops (T) against the nondimensional group of Eq. (6) of the discussion.

Junction Manholes

The authors proposed an interesting approach based on the Eqs. (7) and (8) of the original paper to predict the capacity of supercritical junction manholes. Their equations fitted the experimental data of Del Giudice and Hager (2001) and Gisonni and Hager (2002b), involving 45° and 90° junctions of U-shaped section, with a constant diameter D of all pipe branches. Usually, the upstream pipes are often of smaller diameters D_o and D_L than the downstream pipe with D_u. Further, a junction manhole can be aligned by the pipe bottoms (B) or tops (T) (Pfister and Gisonni 2014; Crispino et al. 2019; Crispino and Gisonni 2020). Then the reference diameter D of Eqs. (7) and (8) of the original paper needs to be specified as

$$Q_c/(gD_u^5)^{0.5} = 1.63(h_o/D_u)^{0.4}(h_L/D_u)^{0.5} \times [V_o^2/(2gD_u)]^{0.2}[V_L^2/(2gD_u)]^{0.2} \qquad (6)$$

$$\mathsf{F}_{rc} = 1.64(h_o/D_u)^{-0.45}[V_o^2/(2gD_u)]^{0.5} \qquad (7)$$

$$\mathsf{F}_{rc} = 1.64[h_L/D_u\cos(45°)]^{-0.45}[V_L^2/(2gD_u)]^{0.5} \qquad (8)$$

Eq. (6) of the discussion applies for both upstream operating branches, whereas Eqs. (7) and (8) of the discussion refer to the cases in which the straight or the lateral branch are operating, respectively. Fig. 2 shows that Eq. (6) of the discussion loses accuracy as compared with Eq. (7) of the original paper, which is however not directly applicable for variable branch diameters. It is remarkable that Q_c decreases by reducing $\beta_L = D_L/D_u$. For small D_L, the manhole capacity reduces because the lateral flow is blocked by the straight approach flow for $\mathsf{F}_o > \mathsf{F}_L$, leading to a similar choking flow affecting the lateral branch of smaller pipe diameters.

Cavitation in Sewers

The discussion of cavitation in the context of sewer flows is interesting. Is this a recurring issue? Cavitation is probable within high-speed flows of low-level outlets or spillways (Coleman et al. 1999), but less in fast sewers' flows.

The authors mentioned in their introduction that most codes limit the sewer flow velocity or recommend measures above 3 to 6 m/s [Directive 11633 (Italian Ministry of Public Works 1973) in Italy, and SIA (2017) in Switzerland]. Higher velocities represent a risk for wastewater outflow if chocked. Yet, even then, cavitation is absent because incipient velocities ($\sigma < 0.2$ as accurate criterion) hardly occur. Pronounced surface irregularities, sensitive to cavitation damage, are avoided in sewers with supercritical flows because they would initiate distinct shock waves (chocking).

Inception of flow self-aeration within sewers (Volkart 1978; Hager 2010) is reported for velocities only marginally exceeding the preceding limits, so cavitation would be limited due to the presence of entrained air almost parallel to its occurrence. A technical aeration seems challenging because it requires fast flows [$\mathsf{F}>6$ for step aerator (Pfister and Hager 2010a, b)] and the air supply duct, reaching also below the flow, could be blocked by deposits.

Data Availability Statement

All data that support the findings of this study are available in the cited references.

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