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DESIGNING BETTER SEWER JUNCTION MANHOLES

by

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ABSTRACT

Head losses at sewer junction manholes are controlled by both the junction geometry and flow characteristics. Among geometrical parameters, junction benchings were found particularly important and their effects on junction head losses were therefore studied in scale models of selected manholes. The junction manholes studied included manholes with a 90^{o} bend, junctions of a main with a lateral, and junctions of two opposed laterals. Full-pipe depth benchings with U-shape cross-sections proved to be very effective in reducing junction head losses.

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L'OPTIMISATION DES REGARDS DE RACCORDEMENT

SOMMAIRE

Les pertes de pression dans les regards de raccordement dépendent de la configuration du regard et des caractéristiques de l'écoulement. Il s'avère que la forme des banquettes à l'intérieur des regards de raccordement a une influence énorme. Par conséquent, on a étudié leurs effets sur les pertes de pression au moyen de modèles réduits de regards de raccordement choisis. Les configurations retenues à cette fin sont les raccordements coudés à 90°, les raccordements d'une conduite principale avec une conduite latérale et ceux de deux conduites latérales diamétralement opposées. Les banquettes faisant toute la profondeur de la conduite et ayant une forme en U (vue en coupe) se sont révélées particulièrement efficaces pour réduire les pertes de pression dans les regards de raccordement.

DESIGNING BETTER SEWER JUNCTION MANHOLES

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Head losses at junction manholes can be significantly reduced by a proper arrangement of flow channels, also known as the benchings, inside the manhole. Four types of benchings were investigated in a laboratory study of manholes with 90^0 bend, junctions of a main with a lateral, and junctions of two opposed laterals. Full-pipe depth benchings with U-shape cross-sections proved to be very effective in reducing junction head losses.

HEAD LOSSES AT JUNCTION MANHOLES

Experience with operation of sewer systems indicates that many problems with sewer surcharging and the resulting basement flooding or sewage overflows are partly or fully caused by the flow conditions at sewer junction manholes. Indeed, in a properly designed and functioning sewer system, the flow must pass through the system comprising sewers, manholes and other appurtenances without an excessive rise in pressure and possible overflows caused by head losses at manholes. Thus, the design of junction manholes should focus on energy and pressure head considerations and, as a general rule, it should conserve energy by keeping its losses at junctions as low as practical. Without such considerations, poorly designed pipe junctions may act as bottlenecks which reduce the system capacity and collection efficiency.

Considering the importance of junction manholes and energy losses at these structures, a question may be asked why this problem has not received more attention . This can be largely explained by certain misconceptions about the design and operation of sewer junctions. In particular, junction head losses are sometimes considered to be negligible, or sufficiently small so that they can be accounted for by somewhat increasing the friction coefficient used for sizing sewer pipes. In another approach, it is suggested to estimate junction head losses from the momentum equation. While the above recommendations may be valid in specific cases, they should not be generalized. Indeed, Chow(1) noted in his discussion of channel junctions that the junction flow is a rather complicated phenomenon which does not lend itself to general analytical solutions and the best junction layouts would be found through experimental studies using scale models. Although the relatively low cost of individual junction manholes may not justify any research and development costs, the repetitive use of these structures in thousands of locations and their effects on the sewer system on the whole warrant further research on this subject. The selection of junction structures to be studied is made difficult by the lack of standardization in municipal engineering and large variations in design practices.

APWA STUDY OF SELECTED JUNCTION MANHOLES

Principal findings of a recent study of head losses at sewer junction manholes(2) are summarized below. This study which was sponsored by the American Public Works Association(APWA) dealt with three types of junction manholes - manholes with a 90° bend, junctions of a main with a lateral, and junctions of two opposed laterals. Considering the large number of experimental factors involved, it was necessary to focus on the most important factors and means of improving existing designs. Such considerations led to the selection of the arrangement of flow channels inside the junction manhole, commonly referred to as a benching, as a particularly important factor to be studied. This follows from the fact that the benching design, which is not generally subject to any restrictions, can be fully controlled and advantageously utilized by the hydraulic designer. Other important factors such as sewer sizes, flows, and alignments are to some extent given by the layout of the area to be serviced and can be less influenced by the hydraulic designer. Note also that even in an existing system ,where all basic parameters are fixed, the system capacity can be improved by redesigning junctions and retrofitting them with proper benchings. Details of individual junction designs studied follow.

MANHOLES WITH 90^o BEND

The basic manhole design without any benching is shown as design M1 in Fig.1. This design is characterized by large flow turbulence at the junction and concomitant high head losses described by the head loss coefficient K varying from 1.5 to 1.9. The corresponding head loss ΔE would be expressed as $\Delta E = K\ v^2/2g$ where v is the mean outfall velocity and g is the acceleration due to gravity. In design M2(Fig.1), it was attempted to reduce junction head losses by inserting a semicircular channel, which in the plan follows a circle segment connecting the inlet with the outfall, into the manhole. Such an arrangement barely reduced junction head losses as indicated by the observed K's in the range from 1.5 to 1.7. This lack of improvement was caused by a secondary circulation in the manhole caused by the deflection of the incoming flow by the benching upward. A significant reduction in head losses was achieved by inserting a U-shape channel, design M3 in Fig.1, which reduced K's to the range from 0.9 to 1.3. Even more dramatic reduction was achieved by using a special design shown as M4 in Fig.1. In this design, the pipe diameter is expanded by one third immediately upstream of the junction, a curved channel with a U-shape cross-section is provided at the junction, and the pipe diameter is reduced to the original size immediately downstream of the junction. For this design, the head loss coefficient was only 0.5. The geometric design of the eccentric pipe reducers/expanders employed in design M4 may seem to be rather crude, but is reflects the technology currently used for manufacturing such products. In fact, the costs of these expanders/reducers would have to be weighted against the benefits resulting from reduction of head losses.

JUNCTIONS OF MAIN WITH PERPENDICULAR LATERAL

The use of benchings at junctions of a main with a lateral is again beneficial for reducing junction head losses. To characterize junction head losses, which in this case depend on losses and discharges in the main and lateral, by a single number, the total junction power losses were calculated for lateral inflows varying from 0 to 100% of the outflow and averaged. Such mean power losses for benching designs M2-M4(see Fig.2) were then expressed as percentages of the reference loss corresponding to the junction without benching (M1). The results of these calculations are presented in the table below.

	Benching Design			
	M1	M2	M3	M4
Relative Power Loss	100%	91%	72%	47%

It is obvious from the above table that in order to reduce junction head losses significantly, it would be necessary to use benching designs M3 or M4.

JUNCTION OF TWO OPPOSED LATERALS

This type of junctions produces the highest head losses among the junctions discussed here. The head losses are again controlled by the junction geometry and the relative lateral size and inflow. Using the procedures described in the preceding section, the relative mean power losses for benching designs M1-M4 (see Fig.3) are listed in the table below.

	Benching Design			
	M1	M2	M3	M4
Relative Power Loss	100%	93%	75%	51%

Significant reductions in junction head losses can be achieved only when using benchings M3 and M4.

SUMMARY

Head and pressure losses at sewer junction manholes are controlled by both the junction geometry and flow characteristics. Since the flow characteristics are more or less given, the designer should concentrate on junction geometry and particularly on junction benching. As demonstrated for three junction types, junction head losses can be reduced by using proper benchings. If the mean power losses at junctions without benching are taken as a reference (100%), designs with a semicircular benching (M2) reduce this loss by slightly less than 10%. A full pipe depth, U-shape benching (M3) is much more effective, because it reduces power losses by 25% to 40%. The greatest reduction can be achieved by using a special design with a U-shape benching and an expanded pipe diameter at the junction(M4) - by 50% to 70%. Full-pipe depth benchings(M3, M4) also reduce flow turbulence and junction susceptibility to sulphide gas releases. In new designs, proper junction benchings can be easily implemented in prefabrication or in-situ construction. If a comprehensive analysis of an existing system indicates a need for reduction of junction head losses, this can be achieved by retrofitting junctions with benchings made of poured concrete or other materials.

ACKNOWLEDGEMENT

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2. Marsalek, J. Head Losses at Selected Sewer Manholes. Special report No.52, American Public Works Association, Chicago, Ill., 1986.

DRAFT FIGURES

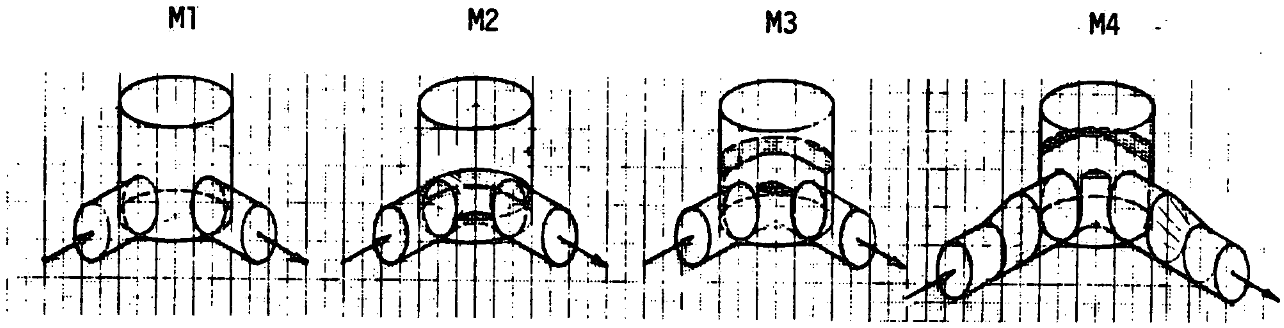

Fig.1. Manhole With 90° Bend: Designs Tested

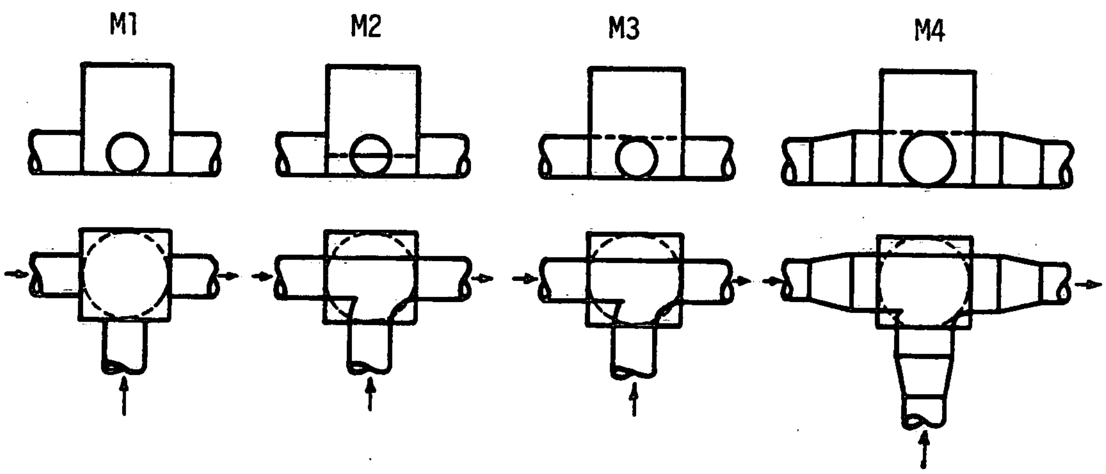

Fig.2. Junctions of Main With Perpendicular Lateral: Designs Tested

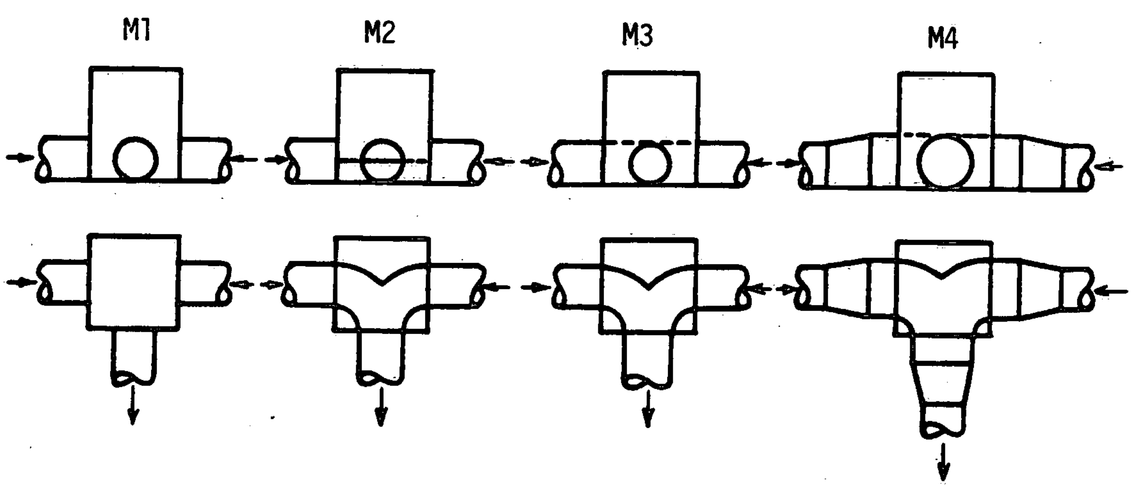

Fig.3. Junctions of Two Opposed Laterals: Designs Tested