第6回衛生工学シンポジウム
1998.11 北海道大学学術交流会館

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SIMULATION ANALYSIS OF THE EFFECT OF PIPE CONNECTION STYLE ON IN-LINE STORAGE CAPACITY OF A STORM WATER DRAINAGE NETWORK

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INTRODUCTION

Although percents of sewered population in urban areas of many advanced countries are almost 100%, these areas are sometimes flooded. One of major reasons is that the practical conditions sometimes become tougher than those in design of urban storm water drainage pipe networks, for example rainfall intensity and the level of receiving water, by urban development. On one hand reinforce of drainage system is important in urban areas where these problems have already happened. On the other hand it's also need to improve the methods for primary design to avoid these problems in future. Selection of the pipe connection type used in urban storm water drainage pipe network is included in the latter one and possible to be improved. The aim of this study is to consider the differences between the types of pipe connection by peak water level and pipe storage with unsteady analysis in computer simulation.

METHODS

Two types of pipe connection

Two types of pipe connection are considered. One is pipe top connection (Fig. 1). The other is pipe bottom connection (Fig. 2). The pipes connected by former used in many cases have constant coverings (the differences of the levels between top of pipes and ground surface) if the slopes of pipes equal those of ground. The pipes connected by latter may have steeper slopes if the coverings are constant. The diameters of pipes are equal (designed by ground slope) in both types to make the differences of pipe connection type clear.

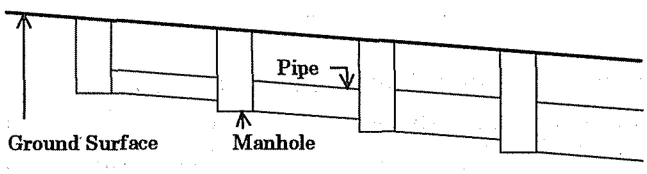

Fig. 1 Pipe top connection

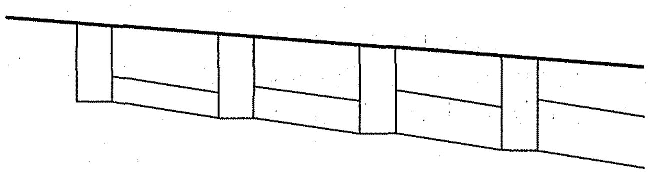

Fig. 2 Pipe bottom connection

Urban storm water drainage pipe networks

Two types of pipe networks are simulated by unsteady analysis. One consists of 10 pipes connected straight (Fig. 3). The simulations with this investigate the features of pipes connected straight by pipe top / bottom connection. The other consists of 100 pipes connected in tree-type (Fig. 4). The simulations with this investigate the features of tree-type networked pipes. The details of designed networks are given in Table 1. The terms "Main Pipes", "Sub Pipes", "Branch Pipes" are used in this study. The Branch Pipes are not drawn in Fig. 4 because they are so many and very small size. Rainfall in unit area flows into them. They are connected to sub pipes. The Sub Pipes are defined as nodes 11-100 in Fig. 4, which are connected from branch pipes and to main pipes. The Main Pipes are defined as nodes 1-9 in Fig. 4, which are connected from sub pipes and to receiving water.

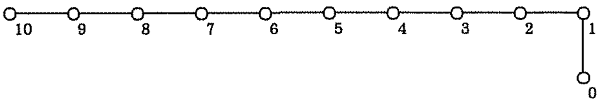

Fig. 3 Pipe network connected straight

Table 1 Details of designed pipe networks

Manholes	The joints of main /sub pipes: 4(m^2) The end of branch pipes: 2(m^2)
Main / Sub Pipes	Diameter: Designed by rational method Slope: 0.001(-)
Branch Pipes	Diameter: 0.3(m) Slope: 0.001(-)
Unit Areas	Area: 4(ha) Runoff Coefficient: 0.5
Ground	Slope:0.001(-)
Covering	2.5(m)
Rainfall Intensity Formula	$I = \frac{3200}{20 + t}$

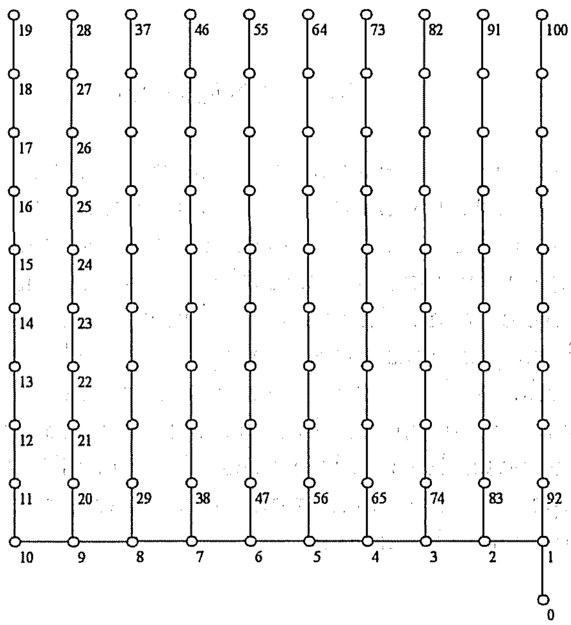

Fig. 4 Pipe network connected in tree-type

Conditions for simulations

Hyetograph showed by Fig. 5 is made from the rainfall intensity formula used in design. The rainfall intensity formula is integrated by time, and then made discrete. Runoff coefficient is 0.65 in simulations, where it's 0.5 in design, considering increase with urban development. Inflow hydrographs for each unit area are made based on this. The level of receiving water varies by time (Fig. 5). At the simulation the program package for the numerical unsteady analysis of urban storm water collection systems suggested by Takakuwa and Funamizu (1994) is used. It is based on the equations of continuity and motion.

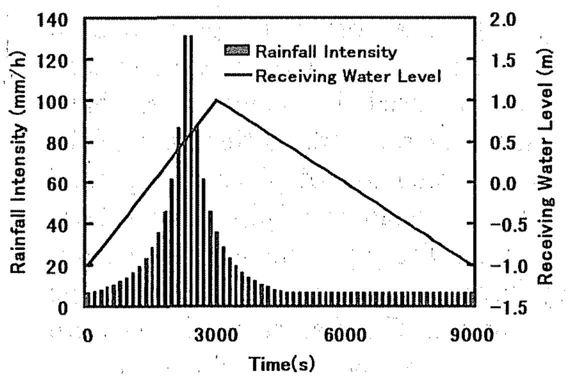

Fig. 5 Hyetograph and Receiving Water Level

RESULTS AND DISCUSSION

Features of pipe networks connected straight

Fig.6 shows the peak water levels and flow rates at each node in Fig. 3. The pipe network with pipe bottom connection has lower peak water level than that with pipe top connection. At the peak time, hydraulic gradient can be less with less friction loss by less flow rate. In this case pipe storage seems to make the peak flow rate less and the peak water level lower. Fig. 7 shows the variance of flow rate at node 1 by time. In early time flow rate in the case of pipe bottom connection is more than that in the case of pipe top connection, because the former case has the steeper slopes than the latter case. Thus the former case can have the larger capacity for pipe storage by larger removal of the rainfall in early time. At the peak time, the former case has the enough capacity but the latter case doesn't. Then the difference of the peak water levels showed by Fig. 6 appears. The difference is larger in tough conditions: harder rainfall, higher receiving water level. Fig. 8 shows the variance of flow rate difference between the pipe network with pipe top connection and that with pipe bottom connection at each node by time. Fig. 9 shows the variance of water level difference.

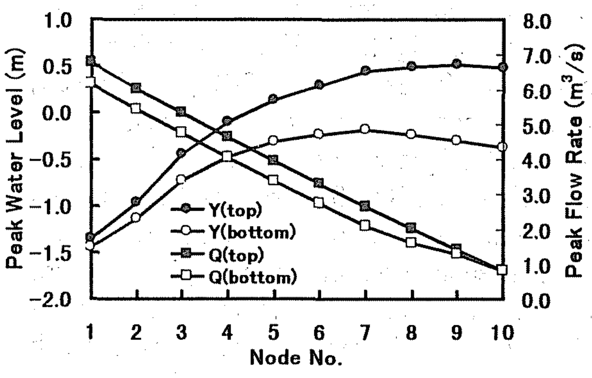

Fig. 6 Water Level and Flow Rate at Peak Time

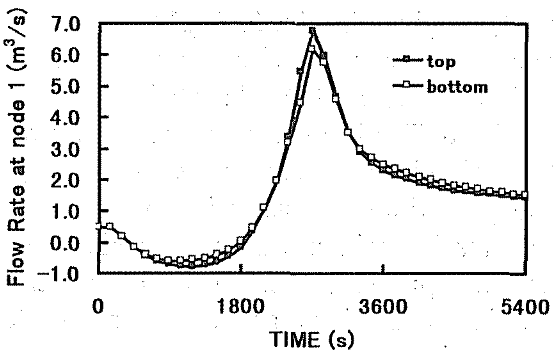

Fig. 7 Variance of Flow Rate difference at node 1 by time

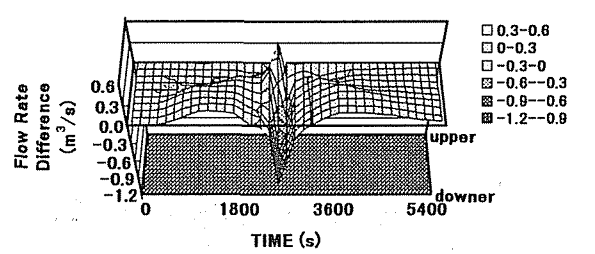

Fig. 8 Variance of Flow Rate difference

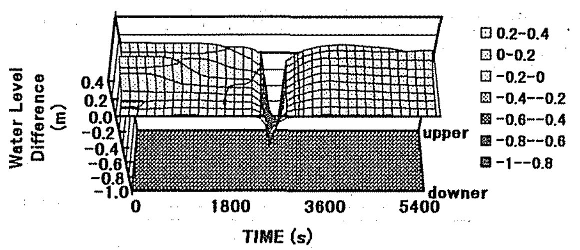

Fig. 9 Variance of Water Level difference

Features of pipe networks connected in tree-type

Features of pipe networks connected in tree-type are integrals of those of straight typed, because they consist of some pipes connected straight. In Fig. 4, the details of each route (node 11-19, 20-28, ···, 92-100) are same each other and they also same to the detail of pipes node 2-10 in Fig. 3. But the variances of the flow rate and water level are not same each other because the water levels at each node on the main pipes are not same each other. Fig.10 shows the variance of flow rate difference of the downer sub pipes (node 92-100). It seems almost same as Fig. 8. That's because the water level at node 1 varies almost same as the receiving water level given in Fig. 5. Fig.11 shows the variance of flow rate difference of the upper sub pipes (node 11-19). It's totally different from Fig. 8. The inflows from each sub pipe to the main pipes are less by the pipe storage at the peak time especially in downer. The flow rates in main pipes are less also by their own pipe storage. Then the water levels in main pipes are much lower. It makes the inflow from upper sub pipes more in early times, and the upper sub pipes have large capacity for pipe storage at the peak time or later. Fig. 12 shows the variance of inflow difference from each sub pipe. The flow rate differences in main pipes are integrals of the differences of inflows from each sub pipe (Fig. 13). These make the differences of water level at main pipes (Fig. 14), downer sub pipes (Fig. 15), and upper sub pipes (Fig. 16).

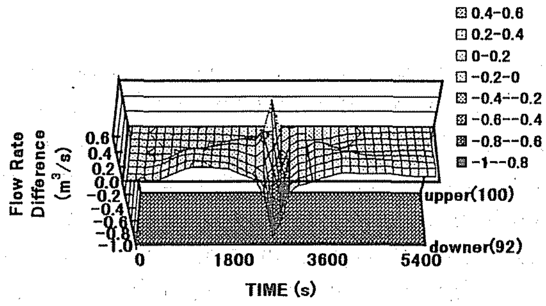

Fig. 10 Variance of Flow Rate difference (92-100)

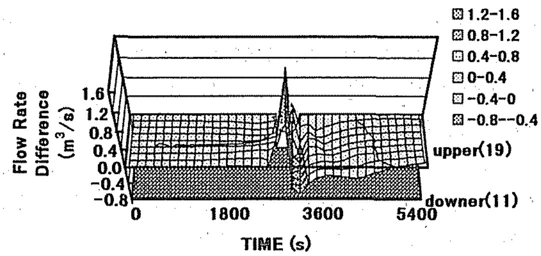

Fig. 11 Variance of Flow Rate difference (11-19)

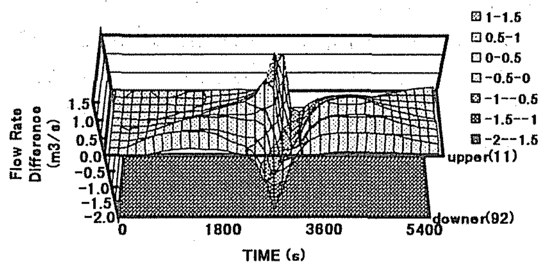

Fig. 12 Variance of Inflow difference from each sub pipe

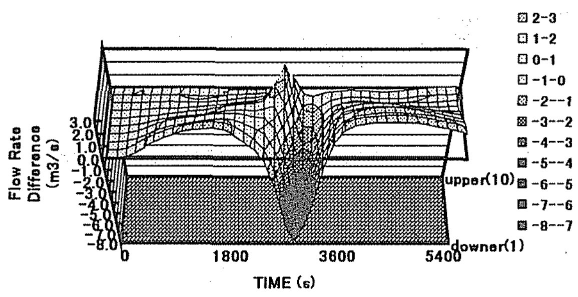

Fig. 13 Variance of Flow Rate difference (node 1-10)

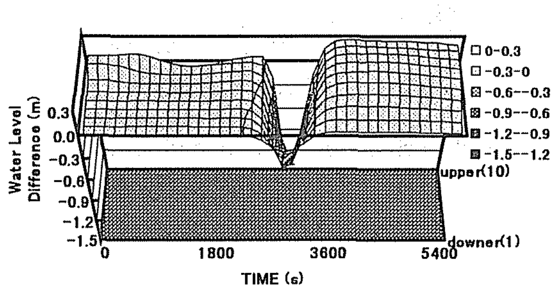

Fig. 14 Variance of Water Level difference (node 1-10)

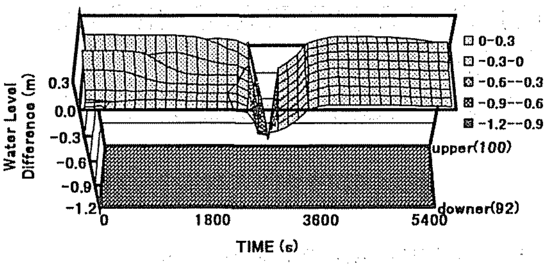

Fig. 15 Variance of Water Level difference (node 92-100)

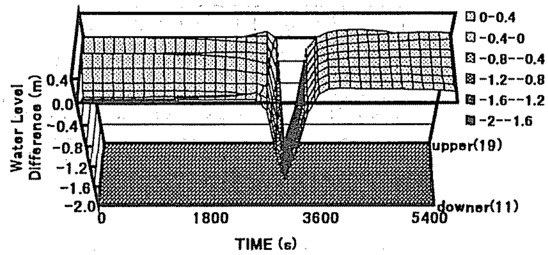

Fig. 16 Variance of Water Level difference (node 11-19)

CONCLUSIONS

The conclusions made by this study are following:

1) The pipe networks connected straight by pipe bottom connection have larger flow rate in early time because of their steeper slopes.
2) They can have larger capacity for pipe storage at the peak time by 1).
3) They can have lower water level because they have less flow rate by 2).
4) In the pipe networks connected in tree-type by pipe bottom connection, downer sub pipes' behaviors are almost same as those of the pipe connected straight because the water levels of nodes connected to the main pipes vary as the receiving water level.
5) In that case, the main pipes' water levels are lower at the peak time by their own pipe storage and by the delay of the inflows from each sub pipe, especially in the upper part.
6) In that case, upper sub pipes have much lower water levels at the peak time by pipe storage and by 5).