

Monitoring and Analysis of the Current Situation of the Drainage Network in a City of Northern China

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Abstract. The urban drainage network is the most important part of the urban drainage facilities. The current situation monitoring of the drainage pipe network is carried out, the existing problems are found, the causes of the problems are analyzed and the pertinent suggestions are proposed. A sustained, stable and safe operation of drainage network can effective and efficient to prevent water environment from increasing deterioration, help to control black and odorous water, and improve the water environment. Based on the monitoring work of drainage network in a city of northern China, this paper discusses the monitoring and vulnerability analysis of pipeline network.

1. Introduction

With the development of social economy and the rise of people's living standard, their request of the environment quality is higher than before ^[1]. The drainage network, as the municipal infrastructure, is the most important part of the urban drainage facilities. Its main function is to collect, discharge sewage and rain water, and play a great role in the protection of the urban water environment and the management of the ecological environment.

Monitoring of drainage network is very necessary ^[2]. It is the demand of government supervision ^[3]. Monitoring of drainage pipe network is the need to improve the quality of maintenance, evaluate operation status, realize early warning and prediction, reduce urban waterlogging and prevent water pollution.

This work briefly introduces the monitoring results about the basic situation of the drainage network in a City of Northern China, and calculates the vulnerability of the drainage pipeline by network analysis^[4-5]. It provides a new method for drainage pipeline and a new idea for pipeline evaluation.

2. Monitoring of drainage pipe network

Drainage network monitoring is mainly depending on a equipment which called Pipe Quick View Inspection (QV). Practice shows that QV is currently the most rapid monitoring device for pipe network endoscope, which not only can discover functional defects, but also find structural defects. From May 2016 to April 2017, the author completed the monitoring work of 803 drainage network, 320 kilometers, as shown in Table 1.



Table 1. Completion of drainage network monitoring

Serial number	Category	Monitoring completion length (km)
1	Rain pipe	59
2	Sewage pipe	158
3	Confluence tube	103
Total	--	320

From May 2016 to April 2017, the author completed the monitoring task of 320 km drainage network, the post maintenance pipeline and the random sampling pipeline are 160 km. A total of 2656 defects were found, including 1860 functional defects and 796 structural defects. Functional defects are mainly deposition and obstacles, which are 57% and 29% of the total number of functional defects. The structural defects are mainly corrosion and dislocation, which are 51% and 21% of the total structural defects respectively, as shown in Table 2.

Table 2. Defects of drainage pipe network

Serial number	Category	Defect name	Number	Subtotal
		Deposition	1062	
1	Functional defects	Obstacle	541	1860
		Others	257	
		Corrosion	407	
2	Structural defects	The staggered	171	796
		Others	218	
Total	--	--	2656	2656

2.1. Comparison of the post maintenance pipeline and the random sampling pipeline

Through the comparison of the functional defects of the post maintenance pipeline and the random sampling pipeline, it is found that the deposits and obstacles in the post maintenance pipeline are obviously lower than those of the random sampling pipeline, indicating that the maintenance effect is remarkable, as shown in Table 3.

Table 3. Comparison of the functional defects of the post maintenance pipeline and the random sampling pipeline

Category	Defect name	The post maintenance pipeline	The random sampling pipeline
	Deposition	149	913
Functional defects	Obstacle	123	418
	others	69	188
Total	--	341	1519

Through comparing with the functional defects of the post maintenance pipeline and the random sampling pipeline, the corrosion of pipelines is serious in the post maintenance pipeline, the main

reason is that most of the pipelines are sewage pipes and confluence pipes. H_2S gas is produced by anaerobic fermentation of sewage in such pipelines, resulting in pipeline corrosion, the staggered joint is serious in the random sampling pipeline, the main reason is that the random sampling pipeline is mostly urban trunk road and secondary road which the pressure of the urban traffic is higher, and the pipeline is buried deeper and the ground load is larger, which causes the relatively serious fault of the random sampling pipeline, as shown in Table 4.

Table 4. Comparison of the structural defects of the post maintenance pipeline and the random sampling pipeline

Category	Defect name	The post maintenance pipeline	The random sampling pipeline
Structural defects	Corrosion	276	131
	The staggered joint	43	128
	other	102	116
Total	--	421	375

2.2. Comparison of pipelines with different attributes

By comparing the functional defects of the 3 types of pipeline, it is found that the deposition and obstacles in the rainwater pipe are most, and most of them are concentrated in the rainwater pipe (the connection pipe between the rainwater inlet and gully), the main reason is that wind and rain carry road dust, gravel and garbage into the rainwater inlet, and concentrated in the connecting pipe, which need to intensify maintenance. Other types of defects in sewage pipes are relatively serious. They are mainly fouling which attached to the wall of pollutants carried by sewage and accumulated for a long time, as shown in Table 5.

Table 5. Comparison of pipelines with different attributes

Category	Deposition	Obstacle	Others	Subtotal
Confluence pipe	178	116	32	326
Sewage pipe	227	197	157	581
Rainwater pipe	657	228	68	953
Total	1062	541	421	1860

On the other hand, the sewage pipe has the most serious structural defects in the 3 kinds of pipeline, the main reason is that H_2S gas is produced by the anaerobic fermentation of sewage, that causing pipeline corrosion. The staggered joint of the rain pipe is relatively serious, the main reason is that the rainwater pipe is shallower than the sewage pipe and the confluence pipe, which is easier influenced by the pavement pressure, as shown in Table 6.

Table 6. Comparison of pipelines with different attributes

Category	Corrosion	The staggered joint	Others	Subtotal
Confluence pipe	52	55	81	188
Sewage pipe	326	27	50	403

Rainwater pipe	29	89	87	205
Total	407	171	218	796

3. Vulnerability analysis

3.1. Pipeline degradation model

The commonly used model of pipeline degradation is the Markov model. It is a change process based on time and state. It is described that the deterioration of the pipeline is divided into stages. It is the result of multiple factors, and the structural vulnerability changes are divided into 3 stages.

Stage 1: the fragility of pipeline is high because of the improper laying of pipeline and imperfect construction. With the increase of time, the vulnerability of pipeline construction to normal operation, the vulnerability is reduced to the lowest.

Stage 2: as pipeline aging and laying age increase, pipeline vulnerability increases steadily.

Stage 3: when pipeline deterioration has reached a dangerous level, the pipeline has the highest vulnerability. When the pipeline is considered to be in the third stage, the repair and replacement of the pipeline should be carried out in time.

3.2. Factors affecting the vulnerability of pipelines

Pipe diameter (B1): the smaller the pipe diameter, the smaller the moment of inertia, the worse the bending resistance, and the worse the structure.

Pipeline Embedment (B2): in a certain depth, the earth pressure of the rigid pipe increases with the burying depth, but it is smaller than that of the shallow buried pipeline.

Pipeline age (B3): as the pipeline age increases, the pipeline is corroded and the thickness of the pipe wall decreases.

Piping materials (B4): pipes need a certain strength to withstand external loads and internal water pressure, and pipes react with water bodies, and the wall thickness decreases.

3.3. Network analysis

The network analysis method can solve the characteristics of the interaction of elements, scientifically and rationally determine the weight of the evaluation index of the vulnerability of the drainage pipeline structure, so that the analysis is more rational and hierarchical.

Taking B1, B2, B3 and B4 as criteria, building a judgment matrix for the comparison of each element, calculating conformance ratio, and construction of limit super matrix.

Table 7. Construction of judgment matrix

B1	B1	B2	B3	B4	Wi	conformance ratio	B2	B1	B2	B3	B4	Wi	conformance ratio
B1	1	4	3	2	0.48	0.083<0.1	B1	1	4	3	5	0.51	0.096<0.1
B2	0.25	1	2	2	0.22		B2	0.25	1	0.25	3	0.13	
B3	1/3	0.5	1	2	0.17		B3	1/4	4	1	4	0.29	
B4	0.5	1/3	0.5	1	0.13		B4	0.2	1/3	0.25	1	0.07	
B3	B1	B2	B3	B4	Wi	conformance ratio	B4	B1	B2	B3	B4	Wi	conformance ratio
B1	1	2	1	0.25	0.19	0.036<0.1	B1	1	4	3	2	0.50	0.083<0.1
B2	0.5	1	0.5	1/3	0.12		B2	0.25	1	2	2	0.22	
B3	1	2	1	0.5	0.22		B3	1/4	0.5	1	2	0.15	
B4	4	3	2	1	0.48		B4	0.5	1/3	0.5	1	0.13	

$$W = \begin{bmatrix} 0.48 & 0.51 & 0.19 & 0.48 \\ 0.22 & 0.13 & 0.12 & 0.22 \\ 0.17 & 0.29 & 0.22 & 0.17 \\ 0.13 & 0.07 & 0.48 & 0.13 \end{bmatrix}$$

The values of every row of the limit super matrix are consistent. The first column is taken as the index weight. $W_i = [0.48, 0.22, 0.17, 0.13]$

pipeline age and pipe diameter are taken as positive indicators.

$$p_i = X_i / X_{\max}$$

buried depth and material quality of pipeline are treated as reverse indicators.

$$p_i = X_{\min} / X_i$$

Taking 8 pipelines randomly as an example, we use the comprehensive rating method to calculate the vulnerability of pipelines. $V = \sum_{i=1}^n W_i P_i$

Serial number	Line name	pipeline age	buried depth of pipeline(m)	pipe diameter (mm)	Pipe material	V
1	Line 1	36	6.9	300	Concrete	0.502
2	Line 2	25	3.8	500	Concrete	0.467
3	Line 3	15	7	1050	Concrete	0.41
4	Line 4	58	1.3	300	Concrete	0.863
5	Line 5	27	4.1	1550	Concrete	0.594
6	Line 6	36	2	400	Concrete	0.613

7	Line 7	58	1.6	400	Concrete	0.834
8	Line 8	18	5.6	500	Concrete	0.385

Only 1 pipelines have a vulnerability value of less than 0.4. Indicating that the pipeline has a smaller degree of damage, and the overall structure of the pipeline is better.

The vulnerability of 2 pipelines is between 0.4 and 0.5. Indicating that the pipeline is generally damaged, and the pipeline basically meets the requirements of operation.

The vulnerability of 2 pipelines is between 0.5 and 0.6, indicating that the pipeline is seriously damaged.

The vulnerability of the 3 pipelines is greater than 0.6, indicating that the pipeline is seriously damaged and needs to be repaired in time.

4. Concluding remarks

This paper briefly introduces the monitoring results of drainage pipe network, compares and analyses the defects of pipeline with different maintenance and different properties, and uses the network analysis method to calculate the vulnerability of drainage pipeline, which provides a new method and new idea for the evaluation of pipe.

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