4-1-1 Measures against Aging of Sewage Pipe

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Abstract
The 20th century was the age of construction in Japan. As time passes, sewage pipes are getting older and causing cave-ins. But, since huge amount of sewage pipes are buried underground, neither inspection to estimate the conditions nor renewal takes long time. So it is important to collect and integrate the information, make the comprehensive plans, then carry out the efficient measures. Tokyo Metropolitan Government Bureau of Sewerage has been executing measures against aging pipes, and occurrence of cave-ins has been reduced.

Keywords
Aging of Sewage Pipe; Reconstruction; Clay Pipe

INTRODUCTION
Sewage line network in Tokyo wards area, whose construction was originated in the construction of Kanda Sewage in 1884, has achieved 100% coverage of the area in FY1994, mainly by combined sewer system. Currently the bureau is managing over 16,000 km of sewage line, comparable to the roundtrip distance between Tokyo and Sidney. Because most of the sewage pipes were completed during the period of high economic growth around 1960s, total length of the sewage piping which has been used for more than 50 years has already reached 1,800 km in the FY2015. Without appropriate measures, the length is expected to reach about 8,900 km in the next 20 years. Therefore we are progressing measures against aging sewage pipes.

Aging of sewage pipes does not only disturb the original function of transporting sewage. It might also affect city activities such as traffic obstruction caused by cave-in of roads. There were over 1,200 road cave-ins in wards area in FY1995, one year after achieving 100% coverage of sewage line. Among major causes is that the connection pipes, which connect households and sewage main pipe, are made of clay, which are easily fractured by mechanical shock. Clay connection pipes are still remaining and therefore measures for connecting pipes together with the main pipes are going on.

MEASURES AGAINST AGING
Information utilization
In appropriately maintaining numerous sewage pipes in wards area and promoting measures against their aging, it is important to execute them according to the renewal plan based on the actual situation of the aging. For that purpose, it is necessary to collect and store the enormous data on
sewage piping, with the total length exceeding 16,000 km, and to keep them sorted out so that they can be conveniently utilized. These data are what would be called “big data of sewage pipes,” on which the state of sewage pipes, which are changing day by day, should be reflected. We are maintaining “SEwerage Mapping and Information System,” a.k.a. SEMIS, to enable all of the staffs to retrieve and utilize various data, and updating the data 6 times per year.

SEMIS contains the basic information about each sewage pipe such as location, depth, pipe type, date of constructed year, etc., and the maintenance information such as location where incidents of road cave-in and flooding occurred. Inspection of sewage pipes are planned and executed based on this information. Moreover, information about sewage piping is centrally managed by feeding back results of inspection such as damage degree to SEMIS. All information accumulated in this way is utilized for planning of countermeasures against disasters including flood and earthquake as well as aging and for implementation of the plans such as designing. Figure 1 shows the image of information utilization centered on SEMIS. Additionally, in order to improving convenience for users, part of basic information of SEMIS is published on the Web page of the office.

![Figure 1. Image of Information Utilization centered on SEMIS](image)

**Reconstruction**

*Outline of Reconstruction*

Projects aiming at extending the prescribed useful life, including improving the function such as capacity of draining rain water are defined as “Reconstruction” in Tokyo. While it has taken 110 years to build sewage piping in Tokyo wards area, urbanization has progressed during the period and the amount of rainwater flowing into sewage line has increased. Rainfall intensity and runoff coefficient had changed, so the capacity of draining rainwater is insufficient in some area. Therefore rainwater drainage capacity is going to be reinforced to the recent drainage level together with countermeasures against aging in the reconstruction works. Recent drainage level is 50mm/h for rainfall intensity and 80% for runoff coefficient, commonly called “50mm/h-80%”. Since reinforcement of drainage level should be considered in basins, all of the pipes is target of the reconstruction.

There are 4 types of reconstruction, utilizing existing (RA), rehabilitation (RB), constructing another pipe (RC) and replacing (RD). RA is adopted when existing pipes are not damaged at all
and satisfies the recent drainage level. RB is a method to rehabilitate the existing pipe by coating vinyl chloride internally such as spiral liner method or slip-line method. RC is adopted when existing pipe have insufficient capacity of drainage and need to construct another new pipe to fill in the gap. RD is adopted when existing pipe is difficult to utilize as RA or RB, and replace the existing pipe to new pipe by open cut method. The flow chart to determine the reconstruction type is shown in Figure 2. Since numerous infrastructures are congested in urban area, rehabilitation method, in which existing sewage pipe can be reconstructed without excavating roads, is mainly utilized in Tokyo. Rehabilitation method does not only reduce cost and work period compared to open cut method but also suppresses noise and vibration to contribute to reduce influence to resident life.

Utilization of methodologies of asset management

In order to advance the reconstruction of sewage pipes systematically and efficiently, methodology of asset management considering life cycle costs and leveling the reconstruction projects in mid- to long-term is utilized.

Based on the past record of construction and maintenance cost, the economical useful life, which gives lowest annual average of the lifecycle cost, was calculated to be about 80 years, from the correlation with the lapse of years. Therefore, although useful life of pipe designated by law is 50 years, it was extended with appropriate maintenance by 30 years. And it was decided that the reconstruction of sewage piping of the whole area was promoted with the economical useful life of 80 years, as shown in Figure 3.
Additionally, in order to level the amount of works in mid- to long-term, the wards area was divided into 3 areas according to the period of construction, as shown in Figure 4. The 163 km² of the urban area, where the sewage piping is the most aged, is defined as the first period area and prioritized in the reconstruction work. The full-fledged reconstruction work has been continued since FY1995, with the first period area planned to complete until 2029, as shown in Figure 5. So far the reconstruction of 73 km², or 45%, of the first period area was completed as of the end of FY2016.

![Figure 4. Reconstruction Areas and Average Age](image)

Measures are taken on connection pipes as well as main pipes in reconstruction works. Connection pipes have been also inspected inside together with the main pipe during the inspection of piping. Basically if the connection pipe is made of clay, it is changed to a polyvinyl chloride pipe. If it is not, measures are taken by pipe replacement or rehabilitation method, as necessary. Besides, because reconstruction work is not executed in the second and third period area for the time being, piping is kept in good condition by maintaining partially as necessary.

![Figure 5. Image of Asset Management](image)
**Accelerating the Reconstruction Project**

As mentioned above, rainwater drainage capacity is going to be reinforced together with countermeasures against aging in the reconstruction works. However, reinforcement of drainage capacity requires constructing new sewage pipes or pipe replacement and additional pumping stations, therefore they caused the reconstruction work to take time since its launch. Moreover, drainage capacity should be reinforced from downstream, which is usually main facilities such as trunk sewer and pumping station. Hence we have adopted “Method of Preceding Measures against Aging” since 2001, defining conventional method as “Normal Method”. Method of preceding measures against aging secures existing draining capacity and takes measures against aging in advance, promoting reconstruction in phases. Additionally, owing to the adoption of “Method of Preceding Measures against Aging in Stages” since 2012, reconstruction operation was accelerated to about twice as fast, achieving reconstruction rate of about 7 km² per year, which is necessary to complete reconstruction of the whole wards area in about 80 years, as shown in Figure 6.

![Figure 6. Past Efforts of Reconstruction](image)

In principle, design of reconstruction work of branch sewer is proceeding with normal method. But method of preceding measures against aging is carried out in areas where the dynamic water level is computed to be GL-1.0m or lower in the simulation, which is thought equivalent for 50mm/h-80%, in order to advance the reconstruction as a measure against aging.

Nevertheless, simulation showed that there were only a limited number of basins where the dynamic water level was GL-1.0m or lower and therefore countermeasures against aging did not proceed in majority of basins, where the dynamic water level was above GL-1.0m, until the completion of reinforcement of main facilities. So “Method of Preceding Measures against Aging in Stages” was newly added as a methodology of executing measures against aging ahead of the reinforcement of main facilities to promote reconstruction. Figure 7 shows the flow chart to determine the reconstruction methods.

If it is discovered that the rainwater draining capacity is equivalent for 50mm/h-80% (dynamic water level is GL-1.0 or lower) by simulation, the area is specified “Area of Preceding Measures against Aging” and start reconstruction work, that should not be less than current draining capacity. In This area, reinforcement for 50mm/h-80% by rational method is postponed. Besides, since the plan is basically prepared by rational method also in these areas, the rainwater draining plan have to be formulated.
Main facilities are developed and ready for draining, or to become ready in recent years

Existing pipe is significantly aging and needs urgent reconstruction, but it takes time to reinforce main facilities

As a result of confirming the past record of flood disasters, a risk of flooding is identified

"Method of Preceding Measures against Aging" or "Method of Preceding Measures against Aging in Stages"

Dynamic water level is lower than GL-1.0m

Capacity of existing pipe and dynamic water level are confirmed by simulation

First Stage of "Method of Preceding Measures against Aging in Stages"

Second Stage of "Method of Preceding Measures against Aging in Stages" (Develop major branch lines, etc. so that dynamic water level may be GL-1.0m or less)

Develop major branch lines (in the future)

"Normal Method" (in the future)

Figure 7. Flow Chart to Determine the Reconstruction Methods

Rainwater drainage level of the first stage of “Method of Preceding Aging Measures in Stages” shall not be less than current draining capacity. Additionally, reconstruction work can be done without simulation. In the second stage, dynamic water level shall be GL-1.0m or lower by simulation.

In the Area where “Method of Preceding Aging Measures” or “Method of Preceding Aging Measures in Stages” have adopted, the rainwater drainage level shall be the level of “Normal Method” in the future.

While pipes aged longer than its legal useful life are increasing, it is necessary to perform reconstructing works more efficiently in order to prevent road cave-ins caused by fracture of pipes and to maintain the function sufficiently. Therefore selection of appropriate method is important.
CONCLUSIONS

We have continued collecting and utilizing big data of sewage pipes and consequently the number of incidents of road cave-in, which is regarded as one of index of measures against aging of pipes, has decreased to about half of 1995, when the restructuring project was launched, although the average age of piping became older, as shown in Figure 8.

![Figure 8. Number of Cave-ins in Tokyo wards area](image)

Aging of infrastructure is the issue which we face without fail as time passes. Especially, sewage pipes buried underground, through which sewage is continuously flowing, is not only in the environment where concrete is corroded but also difficult to inspect and can hardly stop the flow. They are the infrastructures of which measures against aging is difficult to take.

We are going to devise method, develop and implement new technologies flexibly and actively, and continue to make effort toward realization of “Safe City,” which Tokyo aims at, and continuity of the capital function.