Preventive measures against water leakage in Tokyo Reducing number of water leakage repairs by 90% by the efforts of material quality improvement of service pipes

T. Okabe*, A. Tomaru**

* Bureau of Waterworks, Tokyo Metropolitan Government, 2-8-1 Nishi-Shinjuku, Shinjuku-Ku, Tokyo, okabe-takeshi@waterworks.metro.tokyo.jp

** Bureau of Waterworks, Tokyo Metropolitan Government, 2-8-1 Nishi-Shinjuku, Shinjuku-Ku, Tokyo, tomaru-atsushi@waterworks.metro.tokyo.jp

Abstract: In addition to promptly performing restoration work after an earthquake or other disaster, the Tokyo Metropolitan Government specifies materials for use in service pipes under roads (from water distribution pipe branches to on-premise water shut-off valves) for the purposes of preventive maintenance against water leakage as well as preventing road cave-ins and related secondary damage. Considering that over 90% of water leakages occur in service pipes in Tokyo, the Tokyo Metropolitan Government uses service pipes made with strong, highly earthquake-resistant materials, in addition to changing method of building branches in distribution pipes and working to gradually replace existing service pipes. These efforts contribute greatly to leakage prevention measures and the enhancement of the earthquake resistance of Tokyo water pipes. This paper reports on the Tokyo Metropolitan Government's initiatives to improve the quality of the materials used for Tokyo service pipes.

Keywords: water supply equipment; material for water supply equipment; number of water leakage repair

1. Introduction

In light of the fact that over 90% of water leakages in Tokyo occur in service pipes, the Tokyo Metropolitan Government has taken sweeping measures to use specific materials for service pipes located under roads (from water distribution pipe branches to on-premise water shut-off valves). Namely, we have used stainless steel pipes for pipes of diameters 50 mm or less since 1980, and ductile iron pipes for pipes of diameters 75mm or more since 1982. Later, we used corrugated stainless steel pipes with excellent workability and earthquake resistance for service pipes of diameters 50 mm or less. Finally, we replaced all water supply equipment under roadways with stainless steel items, including water distribution pipe branches. These preventive maintenance efforts in the form of the specification of materials used in water supply facilities ultimately reduced the number of water leakage repairs per year by around 59,000 cases (roughly 88%) over a span of 37 years.

2. Revising the materials used for service pipes: Background

Since 1889, when Tokyo's water utility service was first established, Tokyo had been employing lead pipes for service pipes of diameters 50 mm or less and cast-iron pipes for service pipes of diameters 75 mm or more. During Japan's period of high economic growth (1955 to 1973), water supplies were tight relative to demand due to urban population concentrations and the advancement of industrial activities. Consequently, we were in a crisis situation in which not even a drop of water could afford to be wasted, and countermeasures to water leakage from service pipes was an urgent issue. To address this, Tokyo decided to examine and revise the materials used for service pipes and their method of construction.

3. Using stainless steel pipes for service pipes of diameters 50 mm or less

3.1. Causes of water leakages in service pipes

In 1977, when lead pipes were used for service pipes of diameters 50 mm or less, the number of water leakage repairs performed per year in Tokyo was around 80,757 cases. Of these, 75,403 cases were repairs of water leaks in service pipes. The primary reasons for water leakage in service pipes were pipe cracks, corrosion, and other problems stemming from the materials used, as well as poor-quality pipe joints (Table 1).

	Service pipes		Snap tap	Poor-quality pipe joints	External damage	Other (Unauthorized pipes, etc.)	Total
	cracks	corrosion					
Repair cases (Percentage)	27,800 (36.9%)	10,002 (13.3%)	6,048 (8.0%)	18,466 (24.5%)	7,721 (10.2%)	5,366 (7.1%)	75,403 (100.0%)

Table1

The possible reasons for these kinds of damage are as follows:

・Lead pipes are susceptible to outer damage caused by vibrations or shocks from road excavation or similar.

・Because lead is a weak and plastic material, lead pipes are susceptible to cracks and fissures caused by vibrations and other external forces, by water hammer pressure, etc.

・Lead pipes are susceptible to soil corrosion, and the corrosion is especially pronounced in alkaline soils.

・The strength of lead pipe joints is heavily controlled by the technical workmanship of the joint.

Study began on measures to improve the pipes with the aim of preventing these issues from becoming factors in causing leakages in the future.

3.2. Study of improvement measures

In studying materials for use in service pipes with diameters of 50 mm or less, we considered the impact of earthquakes as well as resilience to pipe corrosion and outer damage that had been causing water leakage in the past. Specifically, we selected a suitable type of pipe from nine types used in waterworks, after first considering all aspects of water supply facilities including the qualities of materials, joining methods, branching methods, and piping structures, in addition to performing physicochemical tests.

(1) Study of the qualities of pipe materials

The type of pipe (pipe material) to be used was selected through a process of elimination. After physical testing, pipe types were judged unsuitable if any factors were discovered that constituted a “fatal flaw” in terms of the pipe’s functionality as a service pipe in waterworks services.

In physical testing, pipe performance was assessed in tensile tests, bending tests, and pressure resistance tests after applying an impact load under the hypothetical assumption that the pipe had experienced a shock from outer damage caused (for example) during another company's installation of equipment in the pipe's underground environment. To further assess pipes' corrosion resistance, pipe type selection was conducted under the hypothetical assumption of a flaw created in an outer surface. These results are compiled below (Table 2).

	①	②	③	④	⑤	⑥	⑦	⑧	⑨
	Hard-type polyvinyl chloride lined steel pipe	Powdered polyethylene lined steel pipe	Stainless steel pipe	Hard-type polyvinyl chloride pipe	Impact-resistant hard vinyl chloride pipe	Heat-resistant hard vinyl chloride pipe	Polyethylene pipe (pipe D1)	Polyethylene pipe (pipe D2)	Lead pipe
Visual check	Moderate	Moderate	Good	Bad	Bad	Bad	Bad	Bad	Bad
Tensile test	Good	Good	Good	Moderate	Moderate	Bad	Bad	Bad	Bad
Bending test	Good	Good	Good	Moderate	Moderate	Bad	Good	Good	Bad
Water pressure resistance	Good	Good	Good	Good	Good	Bad	Moderate	Moderate	Moderate
Material deterioration (external surface)	Bad	Moderate	Good	Good	Good	Good	Good	Good	Bad

Table 2

Selection based on physical testing

Physical testing found that, although pipe types (1) and (2) suffered cracks to the pipe exterior with interior bulging and plastic alterations, there were no apparent problems during performance testing. Additionally, pipe types (4) through (9) suffered damage that lowered their water tightness, and in some cases internal bulges and plastic alterations caused a degradation of the pipe material. In performance testing, these pipe types had poor results relative to pipe types (1) through (3). Therefore, pipe types (4) though (9) were judged to be unacceptable for use in Tokyo with its many road excavations.

Selection based on corrosion resistance

Because steel pipes have low corrosion resistance, they were banned from use in areas of Tokyo prone to soil corrosion.

Pipe type (1) was judged to be unsuitable for use due to concerns that construction by another company may damage the outer surface of the pipe and cause the lining to peel, which if left ignored for many years may result in worsening corrosion. Additionally, (2) was found unsuitable due to concerns about the ability to prevent corrosion at the ends of pipes.

It was concluded that pipe type (3), stainless steel pipes, performed better than any of the other materials in impact tests and when considering the risk of corrosion after installation. Although there were no domestic Japanese resources at the time on soil corrosion in stainless steel pipes, soil in Tokyo was compared and contrasted with soil used in a burial testing by the American NBS (National Bureau of Standards), with the aim of estimating corrosion resistance in the long run. At the very least, it was found that over the fourteen years of NBS's test, the buried stainless steel pipes had not reached their corrosion resistance limit. The decision was therefore made to use stainless steel pipes (SUS316) as service pipes.

(2) Study of pipe joint shapes

Pipe connection methods can be broadly separated into the “rigid structure” and the “flexible structure” of joints. The rigid structure handles external force using the strength and toughness of the pipe, whereas the flexible structure uses a specific part to absorb displacement caused by an external force.

For pipes installed underneath roadways, we felt it was preferable to use a flexible joint structure that could absorb forced deformations in the ground, so as to lessen the impact of earthquakes and also due to the fact that such pipes are under constant external pressure from vehicle weight and ground displacement. Therefore, we selected an expansion flexible joint to be used with service pipes and snap taps due to that joint’s earthquake resistance and ability to adapt to ground deformations. The expansion flexible joint has a mechanical structure that crimps the joint by fastening a nut.

(3) Study of branch drilling methods

Snap taps in use at the time involved drilling a hole into a water distribution pipe and screwing the snap tap into it. This method required a certain level of technical skill to perform. Moreover, it often resulted in water leakage due to its structure in which a load from above or axial force resulted in a concentration of pressure on the snap taps or the joint parts of water distribution pipes.

Therefore, we employed a snap tap with a branch saddle in which the pipe branches after the snap tap is affixed to the water distribution pipe. To prevent corrosion to the drilled surfaces of distribution pipes, an anti-corrosion core was inserted into the snap taps. To prevent corrosion to the snap tap with branch saddle, these fixtures were covered with polyethylene sleeves.

In 1980, after these studies were completed, we specified the use of stainless steel pipes, expansion flexible joints, and snap taps with saddles (made of bronze) for use as materials for water supply facilities installed underneath roads. These materials were selected due to their corrosion and earthquake resistance strength as well as their workability, among other factors.

Later, in 1998, we specified the corrugated stainless steel pipe for use due to its superior workability and fewer joints in comparison with the conventional stainless steel pipe. In 2006, to stop water leaks caused by macrocell corrosion resulting from dissimilar metals, we changed snap taps with saddles and their sockets, as well as gate valve B, to items made of stainless steel. Due to this, all water supply equipment of diameter 50 mm or less installed underneath roads in Tokyo were subsequently made of stainless steel (Figure 1).

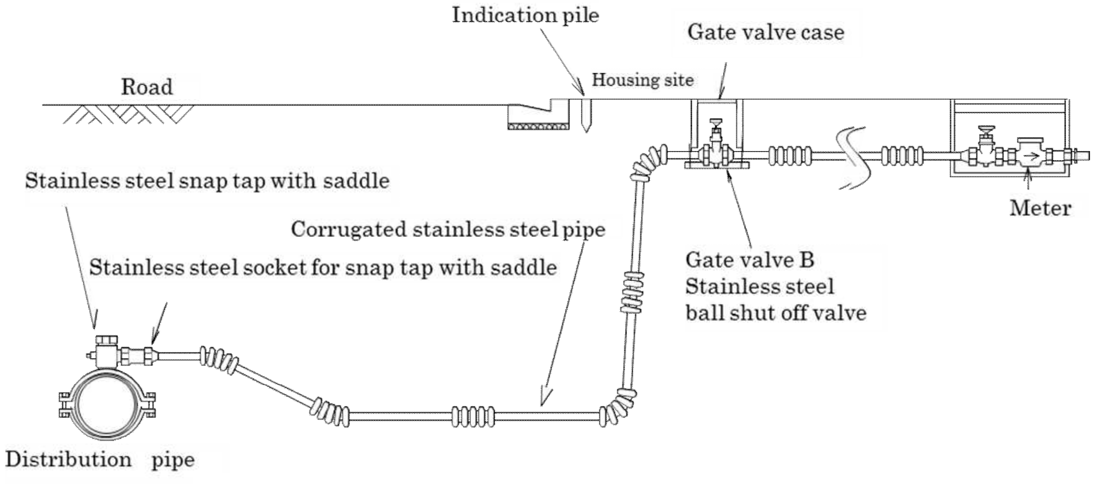


Figure 1　Water supply equipment to be buried beneath the roads

3.3. Initiatives to improve service pipe materials

Initially, stainless steel pipes were used only for new service pipes, when changing pipe diameters, or when performing other modification work. However, to reduce the frequency of water leakage in service pipes, which accounted for most such leaks, work began in 1982 to systematically replace all service pipes with stainless steel pipes to coincide with replacements of distribution pipes, leak repairs, and other initiatives. By 2006, after around 25 years of work, we had successfully replaced all service pipes located under roads with stainless steel pipes.

These initiatives ultimately reduced the number of water leakage repairs per year in Tokyo by roughly 88% (67,361 cases to 8,287 cases) relative to 1979, the period before stainless steel pipes were introduced (Figure 2).

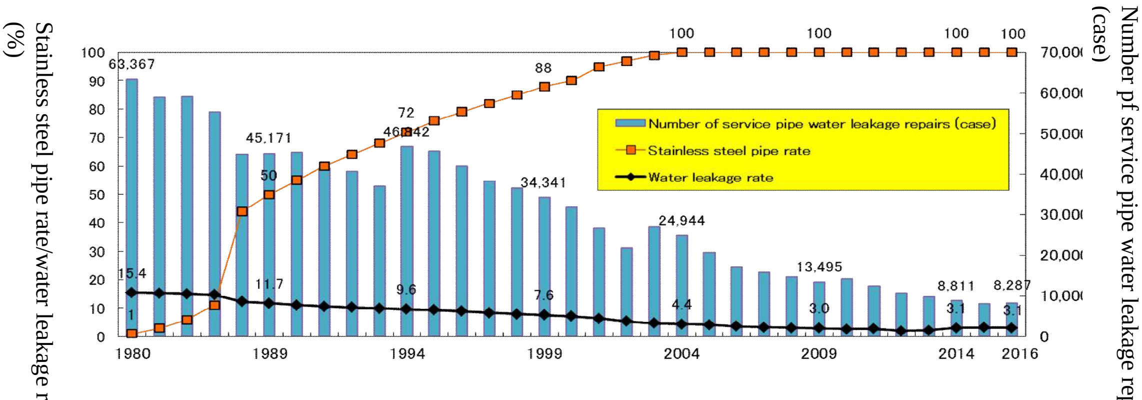
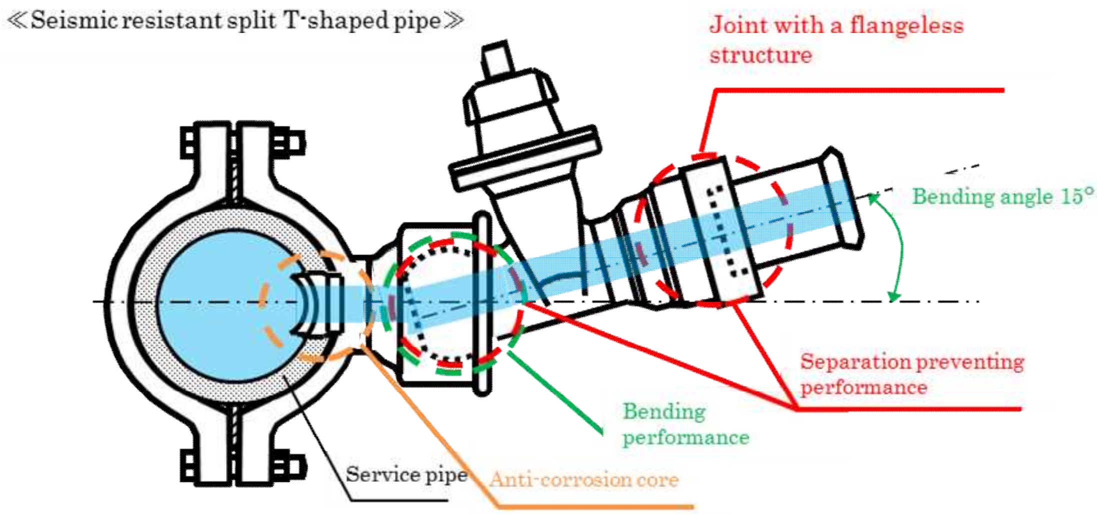


Figure 2　Changes in umber of service pipe water leakage repairs, water leakage rate, stainless steel pipe rate

For service pipes of diameters 75 mm or more, we have been employing ductile iron pipes since 1982 and earthquake-resistant joint pipes since 1998.

On the other hand, in the event that large water consumers start to use service pipes with diameters 75 mm or more, there will generally be a need to cut off the water supply during branching from water distribution pipes. For this reason, the Tokyo Metropolitan Government had traditionally been employing split T-shaped pipes, but there were problems ensuring their earthquake resistance performance.

Thus in 2005-06, we engaged in joint research with a private company to develop an earthquake-resistant split T-shaped pipe and designated it a specified material for water supply equipment in 2006. The earthquake resistance performance of the earthquake-resistant split T-shaped pipe is of the highest rank of bending performance and separation-prevention performance in the “Technical Standards for Underground Earthquake-Resistant Joint Pipes (draft)” (Japan Institute of Country-ology and Engineering).



4. Conclusion

The Tokyo Metropolitan Government has engaged in initiatives to improve service pipe materials by using pipes made of strong, earthquake-resistant materials for service pipes installed underneath roads, and by replacing service pipes in work coinciding with water distribution pipe replacements and other opportunities. This combination of material improvements and pipe replacements has contributed tremendously to maintaining Tokyo’s low rate of water leakages.

Tokyo’s average daily water distribution volume was around 4.20 million m^3 in FY 2017. Even if 1% of this were to leak, that would be 40,000 m^3 of non-revenue-earning water per day.

These leakage prevention measures can prevent water leakage volumes on par with the amount of water generated by the development of a new dam or other water resource. In this sense, efforts to improve the materials used for service pipes are extremely useful as water leakage prevention measures.