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Development of the "Gray-Buster-Advance Lining" method for Renovation of Gray Cast-iron Pipes

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1. ABSTRACT

The Gray-Buster-Advance Lining (GBA) method for the renovation of gray cast-iron pipes has been developed. In general, gray cast-iron pipes installed in the past are prone to be broken by ground subsidence. The breakage of these pipes must be prevented in order to reduce the risk of gas leak accidents. This GBA method can form a thick synthetic resin membrane inside the pipes without the need for excavation, and can make the pipes as robust as new pipes.

In addition, a remarkable feature of this method is that re-connection work of branching lateral pipes is not needed because blocking of branch points by the resin membrane can be avoided by blowing air from the end of the service lateral pipe during the resin lining process. Therefore, the construction cost for digging, filling and re-paving can be reduced compared with conventional methods such as the pipe-in-pipe method.

In this paper, the characteristics and procedure of the GBA method and advantageous points compared with conventional methods are described.

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2. INTRODUCTION

A pipeline network is an essential asset for a gas distribution company, and aging pipes must be maintained to keep their safety conditions. Established in 1885, Tokyo Gas Co., Ltd. now supplies natural gas to over 10 million customers in the Tokyo metropolitan area through pipelines with a total length of 53,000 km. We still maintain approximately 3,200 km of gray cast-iron mains, which account for 16% of our low-pressure main pipelines (i.e. those with less than 3 kPa and a diameter of over 100 mm). Common gray cast-iron pipes, which were installed more than about 40 years ago, are prone to breakage and major gas leaks, and the failure of a pipe could be a gas leak accident; yet many gas companies and distributors still have a great number of such pipes. Besides open-cut replacement, there are no conventional method which can cope with these pipes in urban areas. In general, there are many lateral pipes in these areas and it is hard work to reconnect the laterals. Thus, an effective no-dig method of renovating these pipes is required.

It is very important for gas distribution companies in all countries to supply natural gas with reliability and safety. Therefore, reducing the cost of maintaining aging pipes is a challenge to almost all gas distribution companies with long business histories. Accordingly, we must renovate gray cast-iron pipes while considering the cost and reducing the risk of pipe breakage, to ensure a sustainably stable supply and the expansion of the gas industry.

3. BACKGROUND TO DEVELOPMENT

In order to renovate aging gray cast-iron pipes, some other methods such as the pipe-in-pipe method had been tried. However, without modifications these methods can only be used in certain areas, but not in specially congested areas in Tokyo, because the equipments required are large and heavy. Additionally, from the viewpoint of risk management, it is crucial to prevent gas leaks caused by breakage of gray cast-iron pipes, especially in downtown areas where the population density is high.

Pipelines in these areas usually have many lateral pipes such as service lines, the time allowed for construction is restricted to only a few hours a day for the users' convenience and excavations are not permitted to be left open in general. The conventional trenchless methods require digging in each section of the lateral pipes to split them off, which is a time-consuming job. Therefore, the ultimate trenchless method, "GBA (Gray Buster Advance)", has been developed for renovating gray cast-iron pipelines.

4. THE GBA METHOD

The GBA is a synthetic resin lining method which forms a thick membrane inside gray cast-iron pipes and seals joint gaps, thus preventing leaks caused by breakage of pipes and leaks from joints. The resin used in the GBA is polyurea-urethane, which is sprayed by a rotary head gun (Fig. 1).

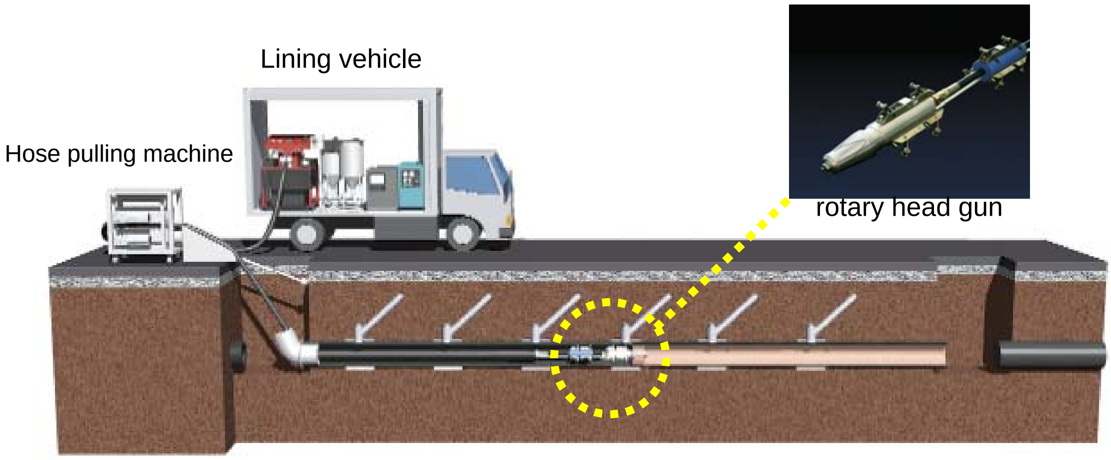


Fig.1 Outline of the GBA method

4.1. High performance

The GBA method creates a resin membrane that has almost the same performance as newly buried MDPE (medium-density polyethylene) pipes. In fact, the polyurea-urethane resin has a higher tensile strength than MDPE and becomes solid in about 2 minutes, and the rotary head gun can spray resin to form a thick membrane inside a pipe. The tensile strength and elongation of this resin membrane are 20 MPa and 250%, and the thickness of the membrane is 6-8 mm (Figs. 2 and 3).

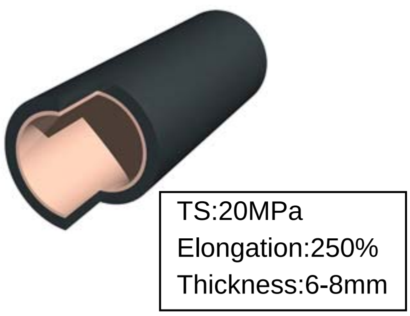


Fig.2 Resin specifications

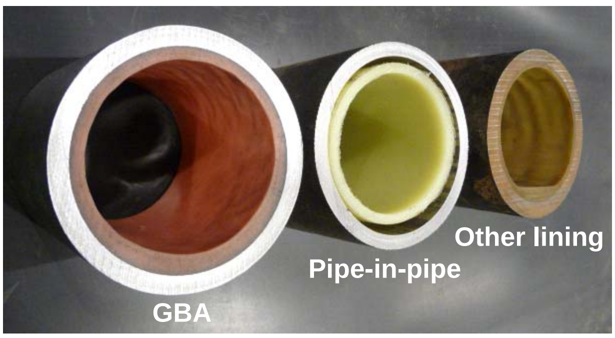


Fig.3 Comparison of cross-sections

4.2. Scope of application

The scope of application of the GBA method is shown in Table 1.

Table 1 Scope of application

Pressure	Less than 0.1 MPa
Diameter	100 mm, 150 mm
Span	Max. 70 m

4.3. Construction procedure of the GBA method

The flowchart of GBA is shown in Fig. 4, which includes pit excavation, gas shutoff, pipe cutting, cleaning, primer coating, resin lining, connection and pit backfill. These works must be completed within one day, because the time for road occupation is severely restricted and the pit must be backfilled every day. The three key processes will be introduced below.

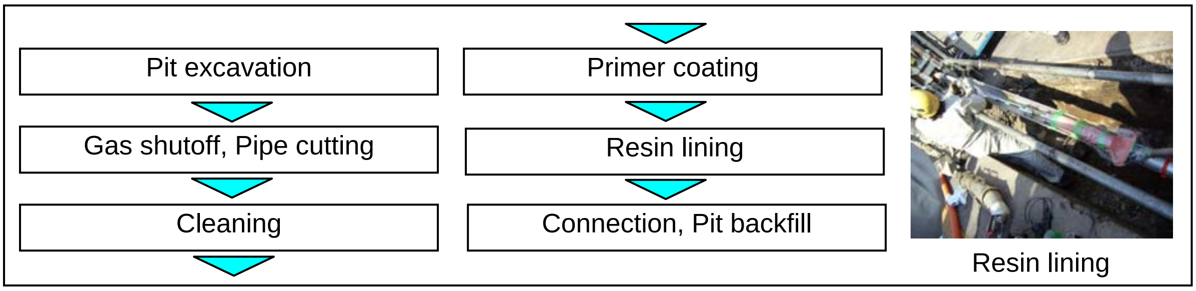


Fig.4 Flowchart of GBA method

Cleaning process

Aging gray cast-iron pipes usually contain large quantities of rust and dust. Therefore, after pit excavation, pipe cutting is carried out and cleaning equipment such as the scraper, wire brush and swabber are pulled through the pipes using a winch (Fig.5). In this way, rust and dust are mechanically removed from the pipe wall.

The cleaning equipment is shown in Fig.5(a)-(c). Fig.5(a) shows a scraper for scraping rust and dust. Fig.5(b) shows a wire brush for polishing surfaces. Fig.5(c) shows a swabber for discharge of rust and dust. These items are combined with each other according to the condition of the inner surface of the pipes.

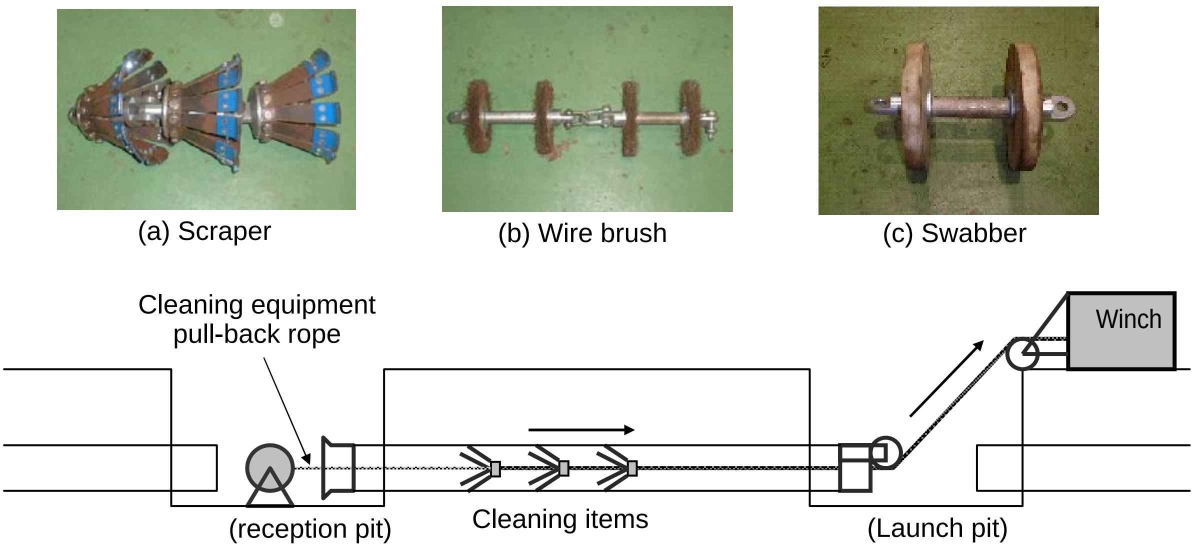
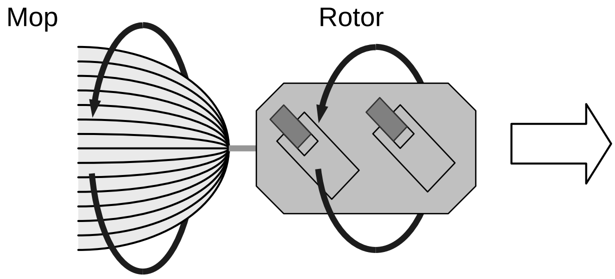


Fig.5 Cleaning process

Primer coating process

After cleaning, the inner surfaces of the pipes are undercoated by primer to enhance the adhesion of the synthetic resins to the inner surface. A rotor is used to rotate a mop, making it possible to undercoat the primer uniformly (Fig.6). The inner surfaces are undercoated uniformly by the rotating mop. The rotation is obtained by pulling the rotor, which transforms the pulling force into rotating force.



Structure of the rotor

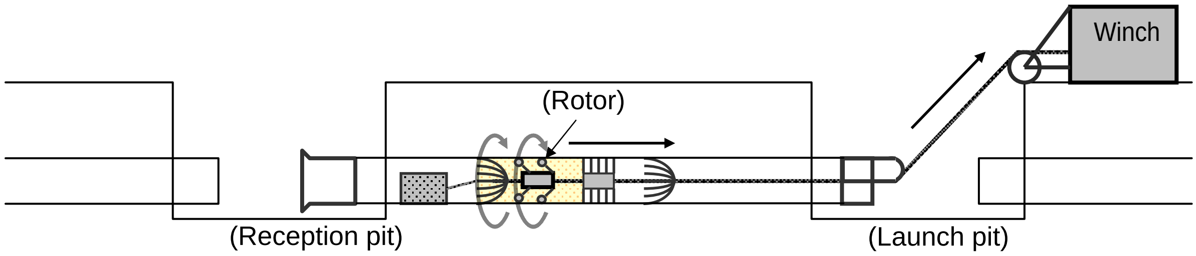


Fig.6 Primer coating process

Resin lining process

Fig. 7 shows the synthetic resin lining process. First, the rotary head gun and hose for the resin lining are inserted into the pipes by the winch until the rotary head gun arrives at the launch pit. Second, the resin supply system starts to deliver resins to the rotary head gun and the gun starts rotating at the launch pit. The rotary head gun is pulled at a uniform speed by a hose-pulling machine until the gun arrives at the reception pit. A membrane about 6-8mm thick is formed inside the pipes by carrying out this process.

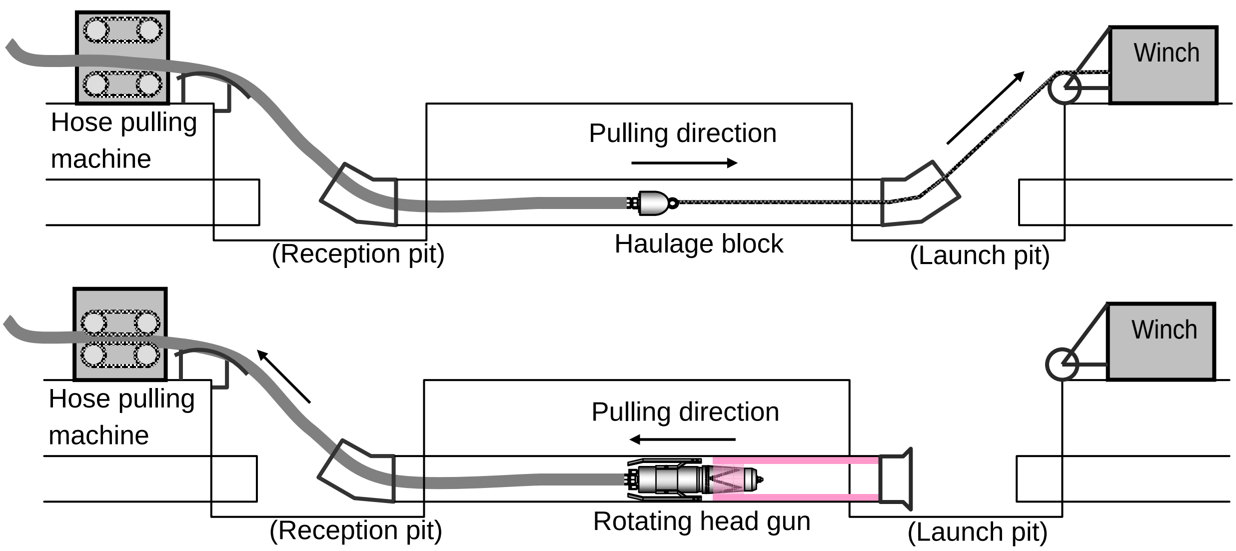


Fig.7 Resin lining process

4.4. Time schedule

When excavating a public road in Japan, the excavation pits are basically backfilled and restored the site every day. Authorization for use of a public road is generally limited to a period of 8 hours from 9:00 am to 5:00 pm. Considering the time required for excavation and backfilling during this period, the work from cleaning to resin lining should be no more than 4 hours. Since these processes actually take about 3 hours, they are within the target period of 4 hours (Fig. 8).

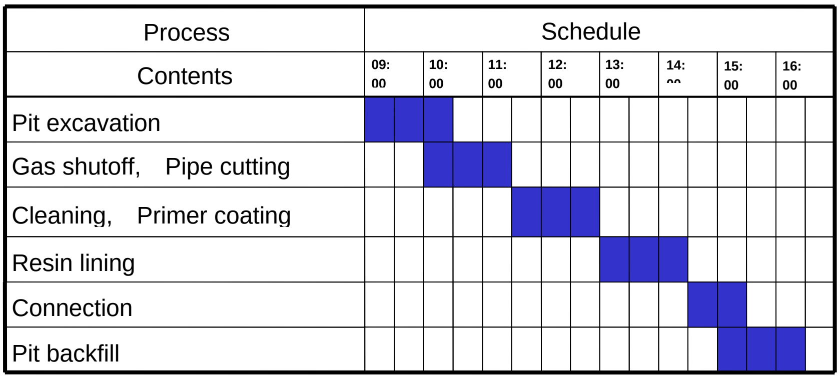


Fig.8 Typical process and work time of GBA

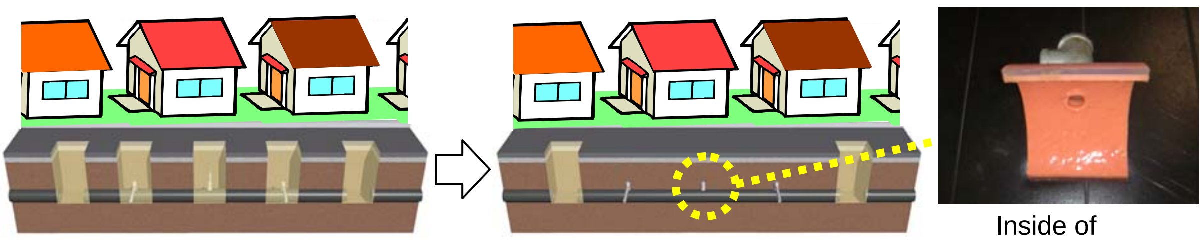
4.5. Advantageous points of the GBA method

The GBA method shortens the construction period and reduces the construction cost compared with conventional methods. In addition, it also reduces inconvenience for the neighborhood. These characteristics in pipeline construction are very important in an urban area such as Tokyo.

Less excavation required

The greatest advantage of applying this method is that re-connection work of lateral pipes is not required, unlike the conventional method (Fig. 9). In the conventional method, digging at each point connected to a lateral service pipe is required, but the GBA method does not require such digging because the blocking of branch connection points by the resin membrane is avoided by blowing air from the end of the service pipe during resin lining. Therefore, usually only two pits are required. This not only reduces the construction cost such as for digging, filling and re-paving, but also minimizes the emission of carbon dioxide related to these works. With GBA, the cost per meter is reduced by 30% than the usual replacement cost.

In the case of the conventional renovation method in the downtown area of Tokyo, a span of only about 10 meters can be replaced in one day. With the GBA method, however, 70 meters of pipe can be renovated at one time.



Conventional trenchless method GBA method Inside of branch point

Fig.9 Comparison of GBA with another method

4.6. Results of performance tests

A pipe bending test, a joint vibration test, a chemical resistance test and other tests were carried out. These tests are regulated by Japanese national standards. The test results show that the performance of the pipes lined by GBA is as good as new pipes. The results confirmed that no leakage occurred from cracks caused by bending and tensile tests, nor from the joints of pipes after the vibration test.

Pipe bending test

A pipe bending test was carried out to check whether leakage occurs or not when lined pipes are intentionally broken (Fig. 10). The procedure was as follows. First, an internal pressure of 10kPa is applied to the test pipe. The load is applied to the pipe until it broke, and inspection for gas leakage is carried out. We confirmed that no gas leakage occurred when the pipe was broken. As an additional criterion, we pushed the pipe further to the maximum displacement described in the standard. Once again, the result showed that no leakage occurred, and the resin membrane of all test pieces showed no defects after the test. It is concluded that the method effectively prevents leakage from gray cast-iron pipes when cracked or broken.

Fig.10 Pipe bending test

Joint vibration test

A joint vibration test was conducted to check whether leakage occurs when joints of lined pipes are intentionally vibrated by test equipment (Fig. 11). In the test, the pipe was vibrated 1.4 million times, which is equivalent to vibration by vehicles during 30 years as regulated by the standard in Japan. As with the pipe bending test, the resin membrane of all test pipes showed no defect after the test.

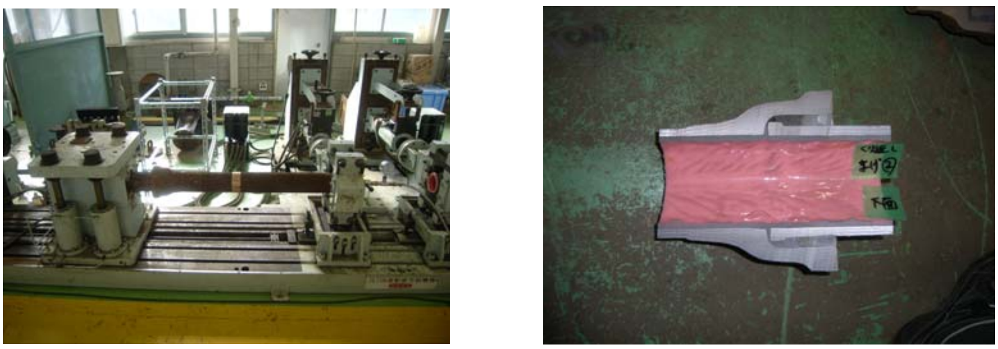


Fig.11 Joint vibration test

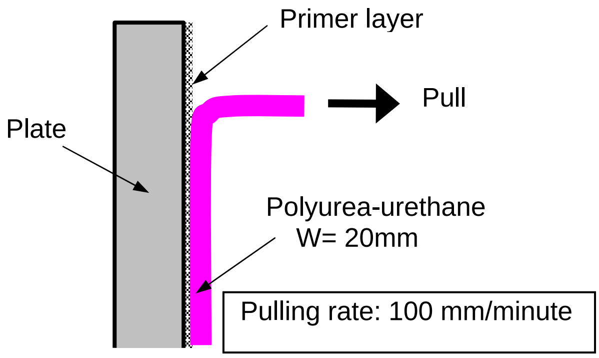
Chemical resistance test

A chemical resistance test was carried out to check whether the tensile strength, elongation and weight of the resin membrane change significantly after test pieces have been soaked in the various liquids such as distilled water, sulfuric acid, sodium hydrate, etc. for a standard period of 120 days. The allowable limits of the degradation rate were as follows; −20% for tensile strength, −20% for elongation, and −3% or +14% for weight. The all measured degradation rates were within the allowable limits, and it was found that the resin membrane has enough chemical resistance to the various chemical liquids.

Resin adhesion test

Lined pipes were cut to check whether the resin membrane exfoliates from the inner surface of the pipe. As shown in Fig. 12, the resin membrane does not exfoliate at all thanks to its high adhesion. We also conducted a reference peeling test, and found that GBA resin adhesion to the inner surface of the pipe is far higher than the value of 10 N/cm given in the ASTM (Americn Society for Testing and Materials) (Fig. 13).

Fig.12 Hole sawing and cutting test



Test piece	Exfoliation load
Steel plate (No primer layer)	8N
Steel plate (with primer layer)	66N
Gray cast-iron pipe (with primer layer)	44N

Fig.13 Peeling test

Evaluation of the membrane thickness

Some lined pipes have been excavated and the thicknesses of the resin membranes at various points inside the pipes were checked. As shown in Table 2, the thicknesses were within the range of 6-8mm. This shows that a thick membrane is reliably formed inside the pipes between the launch pit and the reception pit, because the volume of resin sprayed by the rotary head gun for a fixed period of time is controlled by the resin dispenser and the rotary head gun is pulled at a uniform speed by the hose-pulling machine.

Table2　Thickness of the resin membrane

Sample Number	Thickness at the top surface（mm）	Position
1	7.1	Near the Launch Pit
2	7.5	
3	6.6	
4	6.0	Near the Reception Pit
5	6.4	
6	6.1	

5. CONCLUSIONS

The GBA method can form a thick membrane inside gray cast-iron pipes and prevent leakage from breakpoints and joints. GBA has been used for 35,000 meters of pipeline in total since March 2008, and has produced good results in the Tokyo Gas area.

However, while we have achieved some positive results from the application of GBA so far, it is true that some improvements are still needed for a better performance. The most important challenge is to improve the applicability of the method. The main factor in this challenge is the technical constraint on the applicable shape of the piping system and the diameter of pipes. Generally speaking, pipelines contain some bends, especially in urban areas. GBA cannot cope with the pipelines that include bends, for whatever reasons. This limitation tends to decrease applicability. For example, the GBA rotary head gun cannot go through the bends if they are not cut off in advance. In order to change this situation, a more compact rotary head gun has to be developed. Furthermore, the diameter of application is limited to 100mm and 150mm. To improve the applicability to diameters other than 100mm and 150mm, the GBA method has to be improved throughout the system.

However, by improving and applying this method, we are confident that we will be able to renovate the aged gray cast-iron pipes more efficiently. Furthermore, we believe the method will also be useful for the aged pipelines in other parts of the world.

6. REFERENCES

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7. LIST OF TABLES

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