THE EVOLUTION AND PRESENT STATE OF POLYETHYLENE(PE) WATER PIPES IN JAPAN

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Synopsis

In the Japan Water industry, there has been a strong movement recently to use PE piping. Till quite recently, PVC and iron(primarily ductile iron) have been used for water piping in Japan generally. The movement toward PE for water piping was pushed by The Great Hanshin-Awaji(Kobe) Earthquake occurred in 1995. By the failure of many of the conventional pipes, as a result of the earthquake a rapid reevaluation had begun of PE as a piping material. Until a point of the time, in the market of water PE pipe, the share was less than 14% for diameter under 50mm, for the one exceeding 50mm diameter almost zero. Now the situation is rapidly changing and even the manufacturers of PVC and iron pipe are participating to produce and install PE piping. The tasks has now begun to cover the broad area, including the further standardization of PE pipes and fittings, production lines and installation technology.

PE pipes has lagged for the main-stream of the market of water piping area. However, some PE pipe, PE composite pipe, has supplied to the water industry for over 25 years specialized area. It has been widely recognized that PE is superior material for the area where earth movement is likely to occur. It has also been recognized that PE is suitable materials for water transport such as inter-island submarine piping, hydrant water piping along the bridges, and many other applications.

1. Introduction

In Japan, the conversion of water distribution pipes to polyethylene (PE) material is far behind the level of European and American countries which are advanced in the field of PE pipe applications.

However, the Great Hanshin-Awaji Earthquake which took place in January, 1995 has proven, as an apparent fact, that PE pipes are "strong against earthquakes" and being recognized as an excellent material, the replacement of existing pipe materials to PE pipes is now being accelerated. In this paper, an outline of spreading and history of PE pipe in the field of water supply are given and further prospect is considered.

However, although it is a little different from an ordinary water supply pipe, a composite PE pipe has been in application in special fields utilizing its unique characteristics and winning a

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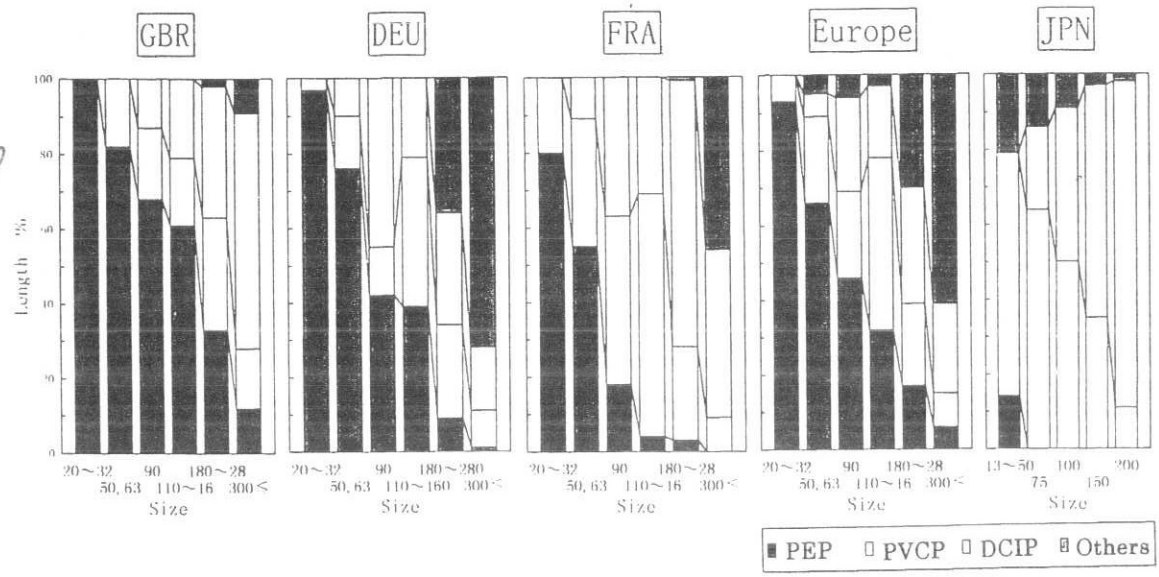
high reputation and steady growth. To our regret, it has not reached to overwhelm the pipe market and it has not been recognized well. Several examples of such applications are introduced below.

2. History and Present Status of Spreading of Polyethylene Pipe for Water Distribution in Japan

In Europe and American countries, PE pipes have been adopted for natural gas and water distribution since late 1960's and thereafter, the conversion to PE pipes has been accelerated but in Japan, almost none was used except for some small diameter water supply pipes(water pipe branching from the water distribution pipe reaching to the water consumption meter of each consumer). For reference, the shares of materials for water supply in total length in three major European countries and overall Europe and Japan are shown in **Figure 1.**

Figure 1 Share of Type of Pipe in Water Distribution Market (Total length, %)



The rate of use of PE pipe in Japan is only 14% for a diameter smaller than 50mm and for those larger than 75mm, it is 0% which is rather far behind the spread of this type of pipe in European countries. Not only for water supply but the use of PE pipe is generally low and against the fact that "in Europe, approximately half of all PE pipes in the world is used and it is assumed to be approximately 540 thousand tons in 1995(1)" and "approximately 200 thousand tons out of the above figure is for water supply (2) (37%)", in Japan "it is approximately 110 thousand tons (3)" and out of this "approximately 12 thousand tons is for water supply(11%) in past several years(4)". Further, comparing the same plastic pipe, "the rate to PVC,. PE pipe/PVC pipe (for all water supply, gas and other applications) is 9% in weight ratio (in 1992)(5) while in European countries , it is "Germany 73%, England 49%, France 36%, Italy 74% and overall 45% in weight ratio" (2).

In other words, for water supply, comparatively small size pipes were unrivaled by PVC pipes and a large size pipes were ductile cast iron pipes (hereinafter referred to as DCIP). This is also due to the fact that influences from DCIP and PVC pipe manufacturers were strong in these fields.

In Japan, PE pipe was standardized as JWWA (Japanese Water Works Association) standard in 1958 and in the following 1959, it was standardized as JIS. However, this was a standard for water supply application and limited to small diameter pipes of 13mm~50mm. Of course, the standardization has been made for a general purpose pipes up to 300 mm diameter but it was merely applied to an inner pressure of 0.5 MPa for 50 mm and 0.3 MPa for 200mm pipes and cannot be used for water works.

However, the Great Hanshin-Awaji Earthquake which took place in January, 1995 became a big impact to turn over this situation at a stroke.

Kobe City where was the central area attacked by the disaster had water leaks from water distribution pipes at approximately 1,600 locations, which was caused by joints coming out (63%), broken pipe (20%) and other damages to the fixture (17%). Water leak from water supply pipes reached approximately 90 thousand and most of them were broken pipes(6). This means that with DCIP, the joints coming loose and with PVC pipe, the broken pipe were the major cause of water leak.

According to the report, there was no water leak problem with the PE pipe.

The rate of damage caused to each type of pipe in three victim cities (Kobe, Nishinomiya, Ashiya) is shown in **Table** I. The situation of gas pipes which have been converted more to PE pipes compared with water work pipes and which has long distribution length is as shown on **Table** II. In this case, there was also no damage to PE pipes. The pipe size and the joint method are different from those for water works and therefore, there is a difference in the rate of damages.

Table I
Rate of Damage of Each Type
(For cities of Kobe, Nishinomiya,Ashiya)

Type of Pipe	Rate of Damage
DCIP	0.488
CIP	1.508
PVC Pipe	1.430
Steel Pipe	0.437
A/C Pipe	1.782
PE Pipe	0.000

(Source: Japan Water Works Association-Damage to Water Work Pipes during The Great Hanshin-Awaji Earthquake and their Evaluatio, 1996 Feb.)

Table II
Damage Conditions of Gas Distribution Pipes
(Number of damaged portions of each type of low pressure gas distribution pipe)

	Steel Pipe	DCIP	PE Pipe
Total Length (km)	21,338	12,204	1,458
Number of damages	25,821	630	0
Rate of damage (place/km)	1.210	0.052	0.000

(Source: Resources and Energy Office, Gas Earthquake Countermeasures Committee -Gas Earthquake Countermeasures Study Group Report, 1996)

The Ministry of Public Welfare has recognized the above fact from the survey report of "The Great Hanshin-Awaji Earthquake Water Works Survey Committee" established immediately

utilization.

However, by comparing with the imported products, the quality level of extruded products (deviation for product dimension compared from the standard value) is apparently high and the quality control level is deemed to be at quite high level and it is without any doubt that Japan can reach the level of advanced countries in quite a short term including the above mentioned technology for pipe production.

(4) Pipe laying technology, particularly joining technology and joining equipment

ABF (Automatic Butt Fusion) and EF (Electrofusion) technologies have been established and commercially applied in the field of gas industry. Therefore, basically, it is planned to convert these technologies into water works but for the water work constructors, these technologies are totally new and they have to satisfy in a short term the material, tolerance and application condition differences as well as training of contractors and they need to exert rapid and detailed efforts. It is also necessary to establish a common universal system such as standardization of joining procedures, method of judgment of joint quality, technical training and qualification which had already been established in gas industry.

For fusion equipment, it was considered as a special equipment in case of gas industry but for water works, it will be a popular equipment which has to be used in a wide field and therefore, there are many economical and operational matters to be learned from European and American advanced countries who have abundant experience. The improvement of technology is indispensable.

5. Examples of Application of PE Composite Pipes in Special Fields

We have been stating above the PE pipes for general water distribution, but in Japan, PE composite pipes with unique and excellent characteristics have been adopted since about 25 years ago in special fields. They have been used exclusively in fields where they cannot be replaced with other types and have won high reputations. Some of the typical applications are described below.

(1) Submerged Water Supply Pipe (WNG Pipe)

Japan has about 6,900 islands and approximately 330 of them are inhabited. These islands are generally poor in water supply conditions and it is quite difficult for them to secure drinking water. To cope with the situations, there are several measures taken under the "Isolated Islands Promotion Act" and for 146 islands, water is now supplied from the mainland by the submerged water supply pipes. For pipe laying, burying under sea bed is mandatory in order to cause no disturbance to fishing industry. Further, because it is

impossible to repair the underwater buried pipe and to cause no disturbance to the ocean going vessels, it is necessary to lay the jointless pipe in a short period of time. It is also an absolute requirement to have sufficient specific density against sea water so that the pipes will stay on sea bed even when they become empty and exposed by moving of sea bed sand. In order to satisfy these requirements, a composite pipe with PE pipe as an inner pipe has been developed and has been applied widely. The structure of this pipe is shown on **Figure 2.** This pipe is manufactured continuously in one piece and transported to site in a roll on a barge with a reel made for this purpose. During pipe laying, the sea bed sand is excavated, pipe is laid and back filled at the same time(simultaneous laying) and in case of bedrock or coral, pipe is laid in a ditch excavated beforehand and back filled for protection. **Figure 3** shows the pipe reel on the barge. The longest pipe which have been laid is 13 km/one piece and the diameter was maximum 400mm. Our experience of laying this type of pipe since 1975 to date is 70 cased reaching to total length of 140 km.

Figure 2 WNG Pipe Structure

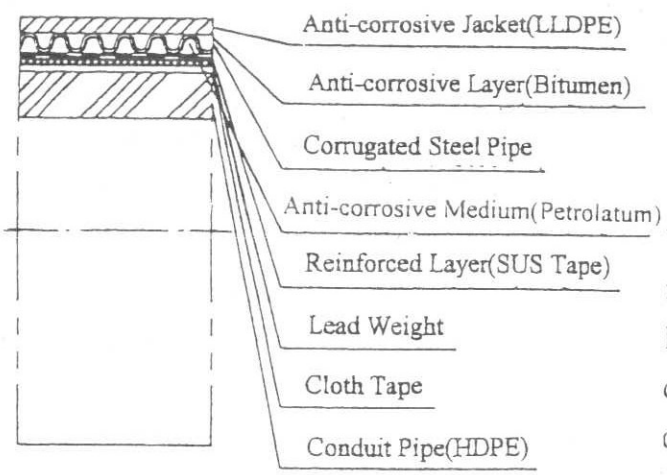
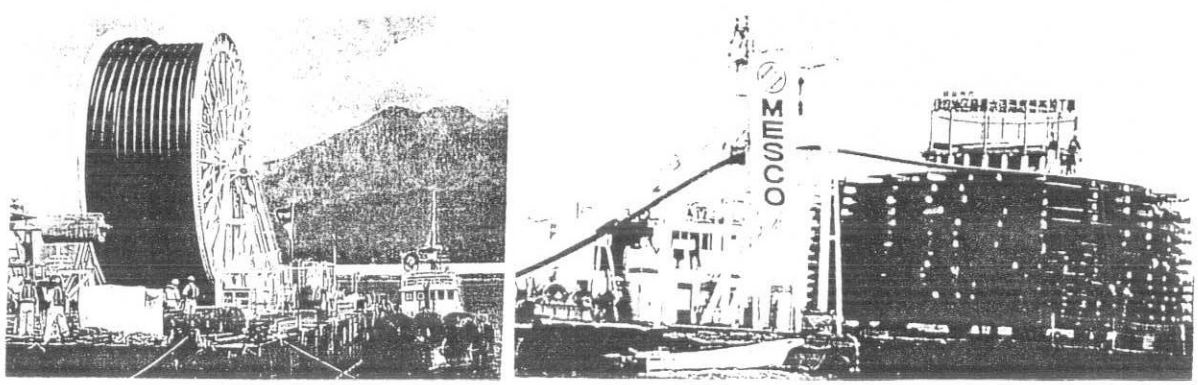


Figure 3, WNG Installation(Vertical Pay-off; left & Horizontal Pay-off; right)

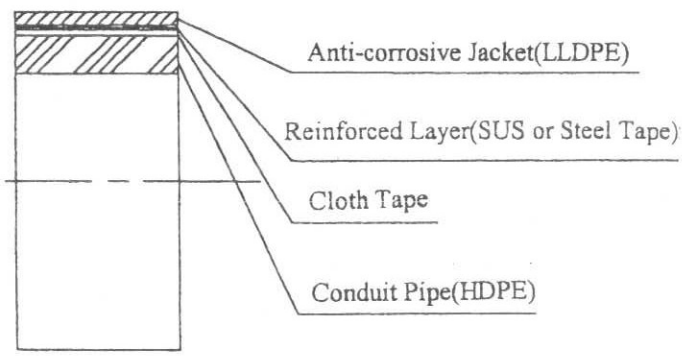


(2) Water Supply and Distribution Pipe (WEET Pipe)

Because Japan is an island country, there are many cases in which facilities are located on a coastal region or reclaimed area where subsidence of ground is big. If the conventional rigid type pipes are used in these places, there is a big possibility of damages or joints coming loose and further, there is a great possibility of corrosion due to salty underground water. For the measures to protect against subsidence and corrosion, the cost becomes significant. Further, in a steep mountainous area or in a scenic spot where no changes to appearance is

permitted, the piping has to detour the trees and rocks. In such case, no rigid pipe can be used. For the projects in such areas, the characteristics of prefabricated PE composite pipe which can meet the changes of ground base, can be laid detouring the natural obstacles, and which has been treated in plant for corrosion resistance are well exhibited. At the same time, in recent Japan, there are only few skilled workers who can do these works and the rise of labor cost is significant. It is strongly requested to suppress the construction cost by prefabricating the joining and corrosion proofing to minimize the site work. The prefabricated PE composite pipe used on ground has been in use since 23 years ago and at present, it is widely used in Japan. The structure of this pipe is shown on **Figure 4.**

Figure 4 WEET Pipe Structure



Pipes with diameter below 150 mm are transported by bundles or reels and pipes with diameter larger than 200 mm are by one piece of 10 meters.

An example of pipe laying work is shown on **Figure 5.** The largest diameter up to date was 710 mm and approximately 1300 km were laid up to the end of 1996. In past 5 years, 100~200 km are laid each year. (**Figure 6**)

Figure 5 WEET Installation

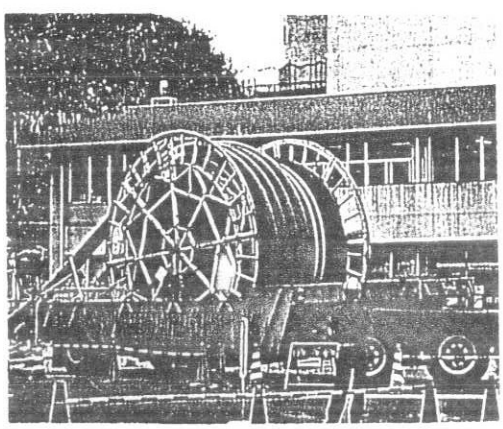
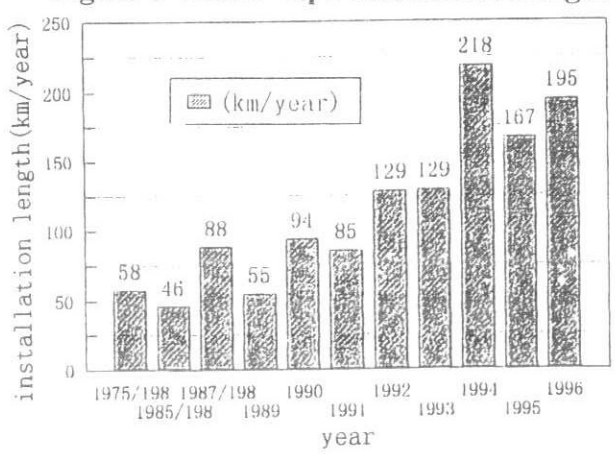


Figure 6 WEET Pipe Installation Length



(3) Pipes for Bridges (WEET Pipe, WEETM Pipe, GNGW Pipe)

A super long Honshu-Shikoku Bridge which was opened for traffic in 1988 (approx. 12 km) and the world's longest suspension bridge Akashi Kaikyou Bridge (approx. 4 km) opened this year have hydrants all along both sides of the bridge with 50~70m intervals. These hydrants are connected with 125 and 150 mm pipes of the same structure as item (2) **(Figure 7)**. These pipes were adopted because of their characteristics to follow the expansion and

shrinkage of the bridge structure and for maintenance free requirement. In some high pressure parts, reinforced type is used. Not only in these super long bridges but in an ordinary bridges, these pipes are also used because of their light weight, maintenance free characteristics and quick laying capability. In cold areas, the prefabricated insulated pipes are used to prevent freezing **(Figure 8)**.

Figure 7 WEET Pipe installed on Akashi Kaikyo Bridge

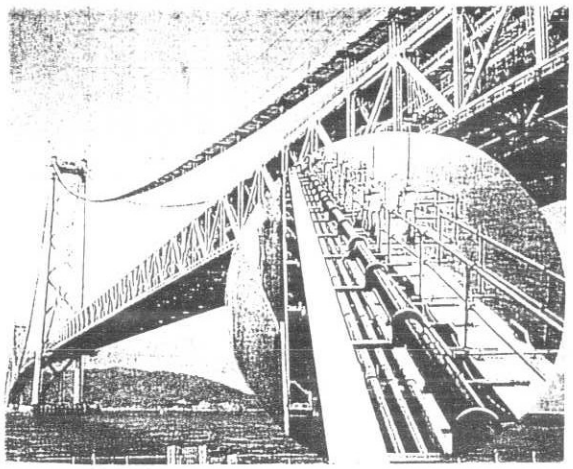
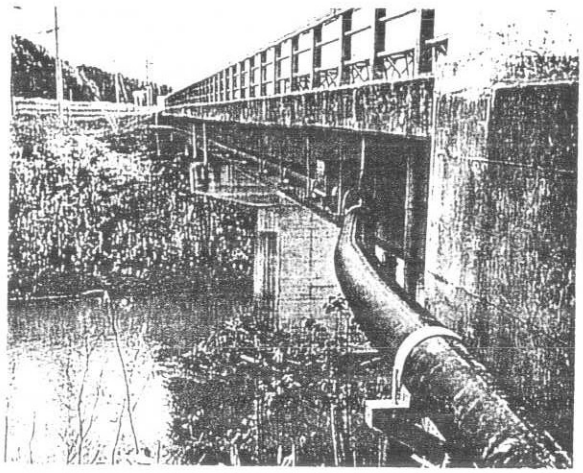


Figure 8 Prefab insulated Pipe in Hokkaido area



(4) Hot spa and geothermal water supply pipe (GNG Pipe)

Japan is one of the most volcanic countries in the world and there are may hot spas all round the country as well as abundant in geothermal energy. For the transportation of such hot spa water, ceramic and other inorganic pipes have been used as well as FRP pipes and other plastic pipes depending on quality of water and other conditions.

In past 20~30 years, these pipe materials are being reconsidered from the point of hot spa source exhaustion and effective utilization of geothermal energy.

In 1980, when City of Suwa, Nagano Prefecture, which is one of the most famous hot spa spots in Japan decided to integrate all their hot spa sources, they also decided to replace all pipe lines. It was requested from them to develop a prefabricated insulated composite pipe with excellent characteristics in thermal insulation, anti scaling, easy construction work and maintenance free. As a result a composite pipe with XLPE as conduit pipe was developed. Since then, this pipe has been in use as hot spa and geothermal water supply pipe. **Figure 9** shown its structure. This pipe can stand maximum temperature of 85℃ and 1.0MPa pressure and is produced with the maximum diameter of 250mm. Up to 150mm diameter pipes are supplied in bundles or reels and over 200 mm is supplied as 10 meters one piece. For site joining of XLPE conduit pipe, butt fusion joining which has been developed by our company is applied. The laying results of this pipe is total approx. 600 km since 1980 and in

past several years, 60~70 km are laid each year(**Figure 10**).

Figure 9 GNG Pipe Structure

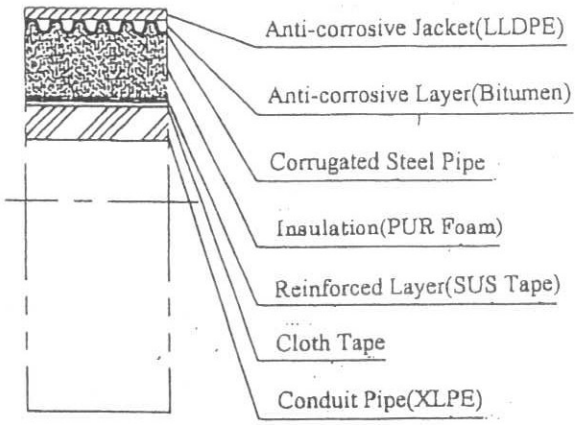
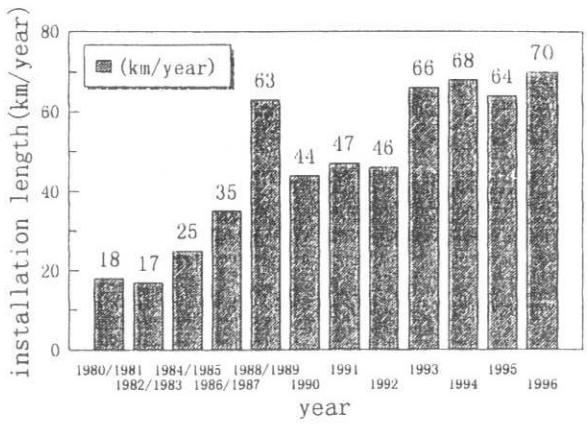


Figure 10 GNG Pipe Installation Length



(5) Other applications

Aside from the above, there are many composite pipes with PE and XLPE as conduit pipes developed to meet different requirements and also laying methods for each of them are developed and have won high reputation in the market.

6. Conclusion

We have introduced some examples of application of PE composite pipes in special fields. In Japan, it is assumed that conversion to PE pipe will be promoted rapidly not only in the field of gas industry and sewer but also in water works. In this regards, there are many things to be learned from European and American countries which are advanced in conversion to PE pipes and we are quite interested to do so.

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