Innovation in Polyethylene Pipes for water transport, recycle and reuse

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According to data from the World Bank, India's 2015 population stands at 1.29 billion. This forms 17.2% of the world population at a growing rate of almost 1.8% p.a according to the World Development Report, with India predicted to overtake China as the worlds most populous country by 2025.

The continued rapid growth of India's population will significantly impact its economy and urban resources, especially with regard to water and sanitation. Today, an estimated 600 million Indians have no access to modern sanitation, and only a fifth of the country's collected sewage is treated. A study conducted by the Water and Sanitation program (2006) showed that the annual economic impact of inadequate sanitation in India amounted to an estimated USD 53.8 billion.

The running water supply of most Indian cities with populations exceeding 1 million is highly intermittent and under very low pressures due to the shortage of treated water and high water losses within underground pipe systems. Water supply planning, operations and maintenance operations are also not managed by a central authority, leading to low financial investments and a strong dependence on low capital subsidies from state governments.

The water scarcity is further aggravated by the huge amount of water needed for irrigation for production of foodgrains and vegetables to feed the huge population.

Therefore innovations are needed to mitigate the following issues :

- ✓ Reduction of leakages in the existing water networks and implementing use of leak proof, long life piping materials in new networks.
- ✓ Use efficient piping materials in sewage networks which are easy to install, join and tested for lifetime service with low maintenance.
- ✓ Efficient systems for rainwater harvesting and charging of ground water.
- ✓ Use of large diameter pressure pipes instead of open channel transportation of water and protecting them from corrosion

Borouge with its vision of "value creation thro' innovation" is continuously working in this direction, innovating new materials and promoting them to end users.

Best practices - materials and technology selection for drinking water networks

If we look at the water distribution systems it is clear that plastics and in particular polyethylene (PE) pipe systems provide the lowest cost and most durable system. PE pipes are being used for most critical Gas distribution networks since late 60's in UK and since early 70's in

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For past 19 years, he is working for Borouge for market development of Borstar PE grades for specialty applications. Borouge is a joint venture of Abu Dhabi National Oil co (UAE) and Borealis (Austria) with nameplate capacity of 4.5 Million TPA of Polyethylene and polypropylene.

Currently, as Application Marketing Manager (Pipe) he is in charge of marketing of Borouge PE and PP pipe products in Indian subcontinent. He leads the market development for Steel Pipe coating for whole Borouge territory. He is the winner of Borouge innovation award on 4 occasions and have 3 application patents.

India and have proved its reliability if quality materials and high standards are adopted. However, the question comes in the mind that if the same HDPE PE100/PE80 pipes are working so well for gas distribution for so many years, why do we often see failure of water pipes ?

The underlying reasons are that while for gas pipes in India pre compounded materials are specified following international standard ISO4437, for water, pipes made from a physical blend of of natural PE + carbon black masterbatch are allowed. Also the Indian standard for PE pipes is much more lenient compared to International standard ISO4427, which allows non standard material pass the requirements of standard.

In Europe over 70% of all new water mains are made of polyethylene material with the increasing use of PE100 compounds. In India also most of the 24X7 projects currently are using PE100 black HDPE and fittings pipes for network and house service connections to reduce the Unaccounted for Water (UFW) from over 40% to less than 5%. Malkapur in Maharashtra is an example of first 24X7 water supply in rural India where this has been demonstrated for past 10 years. The project has used pipes made from Precompound black PE100, Electrofusion fittings, Bentley's wáter network tool and many other best practices in the first 24X7 project in a village.

Fig. 1. Installation of PE100 pipes in progress at Malkapur

It is also heartening to note that the state of Andhra Pradesh, which had banned HDPE as a brittle material in early 80's due to widespread failure owing to poor quality material has over past 3 years executed the largest ever water supply project in India – Bhagiratha Project or Telengana state Water grid, where PE has been used for the distribution network. Over 50% of the HDPE pipes used in the project are made of precompounded black PE100. Hence having a strong specification in place and using high quality compounded PE materials can certainly bring in the reliability of gas pipe network in water distribution network also.

This preference for PE in water distribution is primarily due to the material's high resistance to corrosion, its flexibility and the ability to weld sections together to make a continuous "leak free" pipeline with joints always stronger than the pipe. These characteristics enable PE pipes to be pulled through old leaking iron pipes to renovate them without having to dig up the street or for new systems to be installed by ploughing or directional drilling. These "No Dig" techniques significantly reduce the installation cost of the system. As the installation cost is significantly higher than the pipe and fitting cost and as most of these techniques can only be used with PE, it becomes the automatic choice on the basis of "Whole Life Costs". Nagpur is an example of first full city 24X7 water project on PPP basis, where compounded black PE100 pipes have been used for open cut as well as many HDD installations by Veolia Water and Orange City for a 25-year operation and maintenance contract. Subsequently Veolia also followed the same practices in 24X7 water distribution projects in Hubli-Dharwad, Bijapur, Ilkal and parts of Delhi, the National Capital.

The toughness of the material also enables the welded PE pipes to withstand the stresses due to ground movements which arise due to seasonal weather patterns and even the more severe ground movements due to earthquakes. This was clearly demonstrated by the Osaka Gas investigation following the "Great Earthquake of Kobe" in Japan in 1995 where many failures were observed in their iron and steel networks but none in their PE systems.

The development of PE pipes are taking place since 1955. From HDPE PE63 and PE80, MDPE PE80, HDPE PE100 and PE100+, the latest innovation is HSCR (high stress crack resistant) PE100. These materials have 5 to

Fig. 2. Installation of PE100 pipes by HDD technique at Nagpur Veolia project

10 times resistance to slow crack growth compared to a good PE100. Therefore they can provide 50-100 years lifetime despite notches and scratches imparted on them during tough installation techniques like horizontal directional drilling, pipe bursting etc.

To have a long maintenance free service life, it is a must to specify a precompounded material and follow an international standard like ISO 4427 for raw material, pipe and fittings. The welding and installation practices should also follow international standards.

Modern plastic systems replace concrete and asbestos cement sewerage systems

The continued urbanization throughout many parts of India places increasing demands on the infrastructure, including the buried sewage systems many of which are already old and in poor condition. Failures in the sewage systems can be extremely distressing to any community as these pipelines are vital in separating waste materials from fresh water which protects us all from many diseases. Failures are also extremely expensive to repair or replace as they are usually large diameter and deeply buried – the construction costs being many times the cost of the new pipes and fittings. Therefore it is very important to select systems that are going to provide a very long operational life without requiring maintenance.

Moreover the new plastic pipe systems are much lighter in weight. Typically a 12 meter PP double wall corrugated pipe length of 600 mm diameter will be 75% lower in weight compared to a 3 meter RCC pipe of same diameter. In addition, the pipe systems are lightweight, need a lower number of joints and are much faster and easier to install which will reduce the costs of construction, cut the installation time to half and reduce the hiring charges for heavy equipment. The lower level of disruption from using a light weight system will also have a lower impact on the environment and the lives of the local community.

One of their major concerns is the corrosion and erosion of concrete and asbestos cement sewage pipes due to the action of sulphuric acid developed inside the sewers. Corrosion occurs due to the formation of sulphuric acid (H_2SO_4) on the pipe wall from the oxidation of hydrogen sulphide (H_2S) in the atmosphere inside the sewer pipe. While metals are fully susceptible to Sulphuric acid, Polyethylene and Polypropylene pipes have hardly any impact.

In the 1990's there was an important project carried out in Virginia, South Africa which provided considerable insight into the performance of different sewer pipe materials under these conditions. They investigated the corrosion rates for nine different pipe materials in a section of 900mm diameter gravity sewer linking the town's main sewage pumping station and the treatment works over a five year period. After 5 years in operation the pipes were thoroughly examined and the polyethylene pipes and the concrete pipes lined with polyethylene were in the best condition followed in order by coated asbestos cement, uncoated asbestos cement, uncoated high alumina cement and the uncoated Portland cement sections.

For flexible plastic pipes, as the traffic load or ground loading from buildings and construction are transmitted

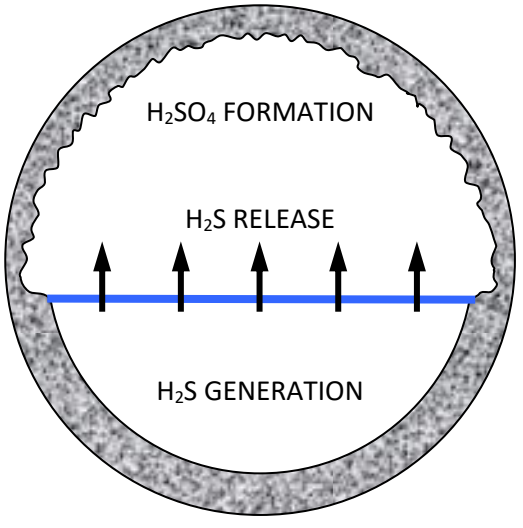

Fig. 3. Corrosion mechanism for concrete and asbestos cement pipes

A. Goynes 2005

Fig. 4. Installation of PP DWC waste water pipes at the chemical park in China.

by the soil to the pipe the plastic pipe will slowly deform. As it deforms it transfers the load to the soil surrounding the pipe, until the pipe and the soil are in equilibrium and the load has been redistributed. Therefore the stresses in the pipe wall are much lower and can easily be sustained by the pipe without any damage or further deformation. However a rigid pipe cannot deform and the stress just builds up until the pipe cracks and eventually the sewer collapses. This process will be accelerated in concrete sewers by any erosion that takes place inside the crown of the pipe due to the build up of acid in the sewer.

The smooth bore of Double wall corrugated pipes also mean lower friction and less chance of blockages in the system. As the material surface does not corrode or deteriorate with time this low coefficient of friction is maintained through the life of the system.

Double wall corrugated pipes are made both from PE and PP. However High Modulus PP grades have 50% higher stiffness than HDPE which is the most important property for sewage pipes. At the same time PP has extremely high ESCR, whereas HDPE loses it ESCR property as the stiffness goes up. Therefore High modulus PP DWC pipes are the optimum choice for modern sewage systems.

Stormwater boxes - a solution for climate change impact on water management

Due to the combination of climate change impact, resulting in many regions of the world having a heavier and unpredictable rainfall, together with increased urbanization, the possibility for lower natural infiltration of the water into the soil has created a real challenge for storm water management systems. Forecast scenarios for both the short- and long-term future are also indicating that these trends will continue to develop.

The plastic pipe industry has successfully faced this challenge over the last few years, through the development and use of "rainwater boxes" or "infiltration boxes", mainly made from polypropylene. These boxes are designed to create a buffer below ground for temporary storage of this excessive water.

The products are intended to be installed for long periods, up to 50 years and are subject to specific constraints that are somewhat different from pipes .To ensure the long-term structural integrity and fitness for purpose of the installed boxes, the proper combination of material properties and manufacturing design is essential, without compromising on the processing performance.

The advantages of infiltration box systems over conventional rainwater management systems (crushed rock systems, concrete structures and drainage pipes) are easy handling and installation due to the comparatively small weight of the individual parts, high flexibility and high efficiency due to the high void ratio and easy maintenance due to integrated inspection channels.

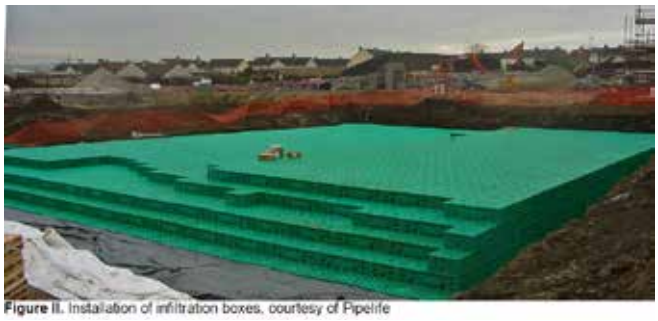

Figure II. Installation of infiltration boxes, courtesy of Pipelife

Products for waste water discharge especially infiltration boxes are part of a growing market. Product requirements have been translated into the corresponding material requirements and defined as target setting for a dedicated material development. Tailor made materials for infiltration boxes combine excellent processability for the injection molding of large parts with superior load bearing resistance and long term thermal stability. It was demonstrated that creep testing and subsequent modelling are valuable tools during product development in order to compare the long term performance of different materials under load, similar to real life operation conditions.

Storm water boxes are installed in a high demanding application. Therefore the need for qualified materials in combination with proper product design is essential to ensure the long-term performance. Ideally these requirements and characteristics should be implemented in an international standard, which is currently not yet available for this application.

Polyethylene coating for Protecting High pressure large diameter Steel water mains

The current government has presented ambitious plans for India's development and is highlighting water security as a priority. These plans will place a strong focus on the greater use of water efficient irrigation systems to increase food production whilst reducing groundwater withdrawals.

In India, the open channel transportation of water is increasingly being replaced by buried pipeline transport and that too at a high pressure in order to increase the volume flow. For large dia and high pressure pipes,

steel is the best option. However these pipes are subjected to corrosion and needs to be protected. The earlier practice of Guniting which was a time consuming, manual and inconsistent method, is being increasingly replaced by 3 layer PE (3LPE coating), where the coating weight gets reduced to only 5% of Guniting, there is no curing time and has excellent oxygen and moisture barrier contributed by Epoxy and PE layers respectively and can easily deliver 30-50 years' service life. Such pipes are being used for Oil and gas transportation in India and abroad for many years and is the most reliable method for steel pipeline protection. In 3LPE coating, the steel surface is blast cleaned to get the desired roughness profile, followed by Induction heating to 200^{o}C, spray application of Fusion Bonded Epoxy (FBE) powder, side wrapping of grafted MDPE adhesive and the final layer of Black HDPE Top coat. The total coating is of over 3.5 mm thickness to give complete protection from mechanical damage, outdoor weathering, and moisture and oxygen permeation.

Fig. 6. Installation of 3LPE coated steel pipes in GWIL project.

Fig. 7. 3LPE coating of steel pipes in progress.

To improve water security in Gujarat the State Government since 2011 launched the GWIL Project (Gujarat Water Infrastructure Ltd) where 434 kms of large diameter steel pipelines, ranging between 1.8 meters to 2.4 meters dia with 3LPE anticorrosion coating were installed for transportation of drinking water to the seven districts of Saurashtra, Kutch region and parts of Ahmedabad, Sabarakantha, Mehsana districts of North Gujarat and Panchmahals.

Later in 2013, Gujarat Govt launched SAUNI (Saurashtra Narmada Avtaran Irrigation) Yojana water conservation scheme. This huge project involves charging 115 reservoirs in the Saurashtra district with water from the Narmada River and linking them with 464km of large steel pipelines up to 3 m in diameter and 640 kms of smaller pipelines. In order to ensure the highest level of protection against corrosion, once again 3LPE coating system was selected over Guniting used in previous water projects. Borouge's HDPE top coat was used for major part of the project.

All these demanding project and environmental requirements in India and the many other "hot spots" in the Asia-Pacific region will create an increasing demand for PE and PP pipes to transport water and domestic and industrial wastewater and rainwater harvesting for recycle and reuse. Whilst this is great news for the plastic pipe industry it is essential that pipe suppliers and end users maintain a high quality in order to ensure that the engineer's expectations are achieved – news of premature failures quickly spreads and will undermine confidence in the materials. The key precursor to producing high quality products is to use a high level standard, high quality raw material from a recognized supplier such as Borouge and using good jointing and installation techniques by certified workmen.

Conclusion :

For long life and sustainable infrastructure, it is of utmost importance to use a strong project specification and specify pre compounded material, so that use of low quality material and mixing of material at converter premises are avoided. There are new generation HDPE materials available which are suitable for demanding installation techniques like Horizontal Directional drilling, where the pipe can deliver over 50 years lifetime, despite notches and scratches during installation process. It is also essential to have good specification in place for welding and installation as faulty welding and improper installation may render a good quality pipe useless. Proper enforcement of the specification through stringent inspection will ensure success of each project and give peace of mind to the utility owner and consumers.