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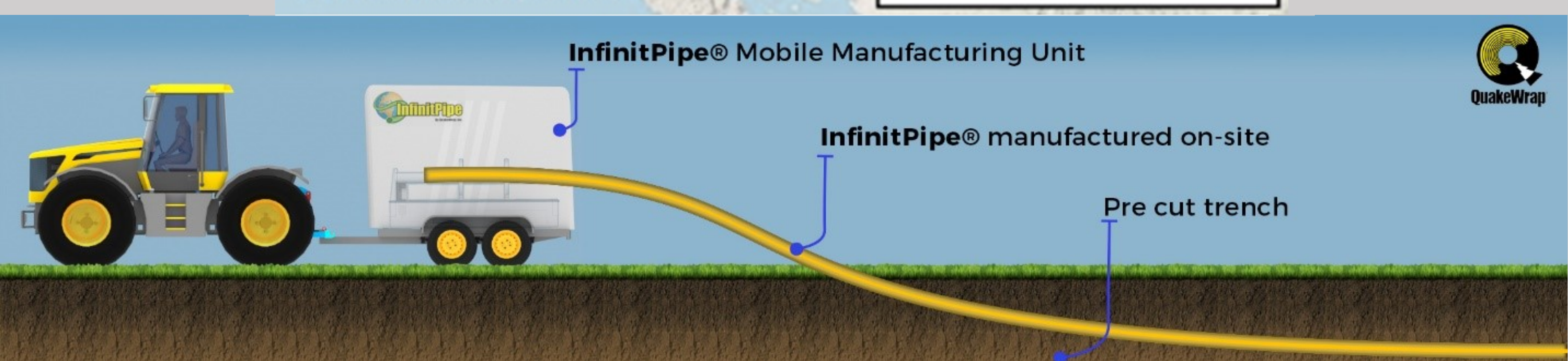
An Endless Pipe Made Onsite for Long-Distance Conveyance of Water

A novel, low-cost solution for solving the global water shortage

Developed through SBIR Grants from NSF & USDA



Introduction

Construction of pipes with available technologies require fairly heavy equipment and complex manufacturing facilities. As a result, pipes are constructed in short segments and shipped to the job site, where they are joined together. The result is a pipeline with joints every 20 feet (6 m) or so. These joints are a potential source of leaks, which can inflict significant loss of revenue as well as harm to the environment. The problem is so prevalent that the term Non-Revenue Water (NRW) has been globally accepted to refer to the potable and irrigation water that is lost primarily through leaks. A World Bank study puts the global estimate of physical water losses at 32 billion cubic meters each year, half of which occurs in developing countries. Water utilities suffer from the huge financial costs of treating and pumping water only to see it leak back into the ground, and the lost revenues from water that could have otherwise been sold. If the water losses in developing countries could be halved, the saved water would be enough to supply around 90 million people[1].

We offer the patented InfinitPipe® technology that enables making a joint-free pipe on-site, thereby essentially eliminating losses and reducing construction cost, especially in hard-to-reach remote areas.

The problem is exasperated with diminishing water resources due to climate change.

Over the last century many advances have been made in the materials from which pipes are made. Whereas steel, iron, and concrete used to be the materials of choice for decades, today many pipes are constructed from HDPE, PVC, or fiber-reinforced polymer (FRP) products. However, the technique for the manufacturing of pipelines has virtually remained the same. The current pipeline construction practices require manufacturing of 20-40 ft long segments of pipes in a plant that may be hundreds of miles away from the site. These segments are shipped to the jobsite via multiple truckloads.

Current Challenges

There are a number of shortcomings with the conventional construction practice of pipelines, including:

1. Pipeline construction requires existing roadway infrastructure to allow transportation of the pipe segments; this makes it virtually impractical to build pipelines in mountainous terrains, rural regions, developing countries, etc.

2. Conventional pipes are very heavy and trucking of the bulky pipe segments to the jobsite is an expensive activity that can account for 40-50% of the total project cost depending on the pipe diameter and the distance from the plant to the site.

3. When pipes are joined together in the field, these joints or connections become a major source of leakage that cause contamination of the water, pollution of the environment and a waste of this precious commodity.

4. Significant greenhouse gas (GHG) emissions incur from trucking of the pipe segments as well as production and installation of fittings and joining pipe segments in the field.

5. Larger diameter pipes that are built with reinforced concrete or steel corrode with age (especially if they are not lined internally and coated externally), adding significantly to their maintenance cost, reducing their service life, and potentially impairing water quality (e.g., "brown" water issues in iron pipes).

The high cost of pipeline construction is a major reason why many water delivery projects are put on hold or permanently discarded, and transportation of pipe segments, particularly to remote project sites, where they are mostly needed for water transmission, is a big part of the overall cost.

Conventional way of building pipes results in high logistics costs in addition to increased risk of water loss. Making a pipe on the jobsite offers the potential to save drastically on the overall project (lifecycle) cost and essentially eliminate water loss through joints.

In 2012 QuakeWrap's President, Prof. Mo Ehsani, who is regarded as a pioneer in use of fiber reinforced polymers (FRP) in infrastructure, came up with the idea of making a pipeline on-site utilizing high-strength, light-weight, and corrosion resistant FRP materials and a custom-design mobile manufacturing unit (MMU). The MMU is essentially a combination of a truck (or a tractor with a trailer) and a collapsible/heated mandrel on which the pipe is made within a short period of time (each segment is ready to be pulled off the mandrel in 15 minutes upon wrapping the FRP layers on it).

Technical Properties

InfinitPipe® can be designed to any internal pressure possible in a water transmission pipe used for irrigation and other purposes. Each design is customized to the loading requirements and site conditions of the project. For instance, if the internal pressure is high (e.g., more than 250 psi) then carbon fiber layer(s) would be added to the design to avoid using excessive layers of glass FRP fabric. (A carbon fiber laminate layer's tensile strength is, on average, three times greater than that of a glass fiber laminate or steel.)

InfinitPipe® internal surface has a smooth finish with an approximate Hazen-Williams C value of 145. This results in minimal head loss in a pressurized pipe system, thereby reducing pumping/energy costs in conveying water to long distances. Since there are no joints along straight sections, a pipeline built with InfinitPipe® will have no local (minor) head losses along straight pipe sections.

Design

Design of InfinitPipe® is based on QuakeWrap's extensive experience with FRP materials in addition to tests and finite element analyses conducted to date. Although, there is a good understanding of the properties of the InfinitPipe® made in small diameter, the design variations for InfinitPipe® are endless, and as the pressure or diameter goes up, so do the complexities added to the design. Such complexities are overcome with computational modeling and validation by lab tests.

Factors such as any shear slippage effect in multiple layer – high pressure systems are analyzed via such FEA models. Another advantage of FEA is that stress-strain, and deformation can be analyzed for each layer, which helps a great deal with the design (e.g., putting carbon fiber laminae in the inner layers to avoid higher strains on the fiber glass layers).

Bending Radius

Two of the important parameters in pipeline design are amount of deflection one can apply at joints and how much bending a pipe can tolerate over a long stretch to reduce the number of fittings (elbows) along the alignment.

As such, bending radius of a typical 6-in. InfinitPipe® was measured by applying a four-point bending test based on ASTM D7264 - *Standard Test Method for Flexural Properties of Polymer Matrix Composite Materials*. The minimum bending radius of the 6-in. InfinitPipe® was calculated by using a design stress that is one eighth of the short-term allowable bending stress (*AWWA M45 – Fiberglass Pipe Design*).

The sample pipe was bent to 5 deg of deflection at which point it reached its stress limit state. The geometric calculations based on the level of deflection resulted in a bending radius of 167 ft. which makes InfinitPipe® essentially as flexible as a PVC pipe. Based on this data and utilizing computational modeling with the FEM, the bending radius of any pipe configuration of InfinitPipe® can be calculated and validated (as necessary) for each project design.

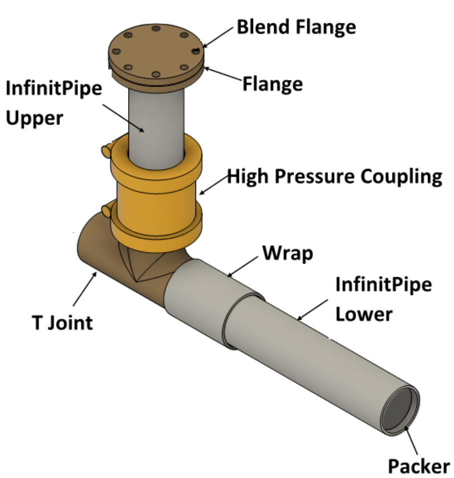
Branch Connections & Fittings

Another important aspect of pipeline design and construction is to use the right type of fittings for tee, wye, and other branch connections, as well as transitioning to pipes of other materials via couplings.

Two types of fittings were tested with respect to transitioning to other pipes (e.g., ductile iron) and branch connections.

1. *Direct Socket:* In this configuration, no additional pieces are necessary. The fittings (tee, wye, etc.) are made of FRP with a slightly larger diameter than the main pipe. Once the pipe connections are inserted into the fittings, they are secured in place by applying resin (e.g., epoxy).

2. *Flanged Connection:* This is essentially the same as any type of flanged/mechanical connections used for other types of pipes. A flange ring is affixed on each spool piece to be connected, then the two flanged pieces are bolted together. The flange usually has a sealant gasket to prevent leaks.



The closest type of pipe material to InfinitPipe® is fiberglass pipe, and the design of fittings is based on what is used in that industry.

A test setup was built at the QuakeWrap facility, and pressure tests were run on the pipe setup with branch connections. In addition to the direct socket and mechanical (blind flange) connections, the test setup included a mechanical coupling that would enable transition to any type of pipe with matched outside diameters. No leaks were observed up to the maximum test pressure of 300 psi.

Automated Manufacturing of InfinitPipe®

InfinitPipe® is currently manufactured on a custom-design collapsible mandrel, which is manually operated. Pipes from 6 to 72 in. diameter have been made successfully by QuakeWrap using this method.

Nevertheless, there is a need to improve efficiency in production particularly for large projects with miles of pipelines. Accordingly, automating the manufacturing process on a mandrel is currently in progress. We anticipate the automated MMU will be operable to be used in actual projects by 2023.

Water Conveyance with InfinitPipe®

The water conveyance/ pipeline market in the USA and around the globe is quite large and would be difficult to put an exact price on due to uncertainties with the market conditions, project type, and location. Nevertheless, it is safe to assume the potential market for a novel piping system just for irrigation could be in the $ billions. Water conveyance for irrigation is gaining more momentum due to diminishing fresh water supplies around the globe, and the need for moving large quantities of water to long distances is an ever-growing trend.

For instance, for the first time in 2021 the US Bureau of Reclamation (USBR) declared shortage on the Colorado River. As such, the USBR is enforcing cuts on the lower basin states Arizona, New Mexico, and California with Arizona getting the biggest cut as 20% of the water received from the Colorado River for the Central Arizona Project will no longer be available. Lake Mead's level has gone down to 1050 ft above sea level by the end of the year, a level not seen since the Hoover dam was built in the 1930s[3,4].

Local, statewide, and federal governments scramble to find a sustainable solution and the situation is only expected to get worse due to global warming and increasing population. The short-term solution is using other fresh water supplies such as groundwater, but that is reaching,

Mobile Manufacturing Unit (MMU) prototype under development.

The InfinitPipe® technology has already gained national interest and support by receiving multiple SBIR grants for development from National Science Foundation (NSF) and US Department of Agriculture (USDA). Commercialization of the product is currently underway and acknowledgements at the national level include a recent coverage by the Leaders Innovation Forum for Technology (LIFT), a multi-faceted initiative 0075ndertaken by The Water Research Foundation and the Water Environment Federation to guide water innovation to implementation. InfinitPipe® was included in the LIFT website in 2020 as a recent technology on the spotlight. InfinitPipe® was also selected as a finalist for the Valley Venture 5 (V5) Cohort and included in the startup accelerator program set forth by Fresno State University, CA in support of sustainable water supply.

if not exceeding, its sustainability limits as well. Arguably, the most sustainable alternative is using the ocean as an endless source by desalination. For water supplied through desalination the three major cost items are treatment, brine disposal, and conveyance. The portion of conveyance cost increases as the receiving end gets farther away from the treatment plant, typically on the coast. ***By using InfinitPipe® the cost of conveyance can be reduced drastically in addition to increased speed of construction along rugged trains that are otherwise hard to reach with semi-trucks loaded with long stacks of pipes in the conventional way.***

For instance, as a part of an ongoing evaluation project led by Black & Veatch (Kansas, USA) and Libra Ingenieros Civiles (Baja California, Mexico), several alternatives are being entertained for water supply to the agricultural areas in the Sonoran Desert via desalination of seawater from the Sea of Cortez (Gulf of California). The preliminary estimates (capital cost) for those alternatives are well over $3 billion with approximately $750 million for the pipeline only as the biggest cost item of the overall system. With respect to one of the alternatives entertained (i.e., conveying desalinated water from a facility between Bahia San Jorge and Puerto Lobos in Sonora to Morelos Dam at the international boundary near Yuma, Arizona) we estimate 5 lines of, 200 miles long, 42-in InfinitPipe® can be made on site for approximately $275 million ($50-$55/ft/pipe) to meet the required transmission capacity, thereby potentially saving $100s of millions on such a conveyance system. The InfinitPipe® system would have redundancy as well, i.e., one of the pipelines can be taken out of service any time for maintenance.

Another reason for the increased demand of using pipelines to convey irrigation water is the shift from gravity fed systems to pressurized systems for improved efficiency. InfinitPipe can provide an economical, feasible, and reliable alternative in transitioning from open channel systems to the more efficient pressurized pipelines for conveyance of irrigation water, particularly in more arid areas of the globe.

Intellectual Property

Several patents have been issued and applied for to date for InfinitPipe® with respect to various applications:

1. Ehsani, M.R., "Trenchless Pipe-Laying" U.S. Patent No. 10,436,350, October 8, 2019.

2. Ehsani, M.R., "Method and Apparatus for Mining Copper," U.S. Patent No. 10,571,052, Feb 25, 2020.

3. Ehsani, M.R., "Pumped Hydro Storage and Real-Time Stress Monitoring in Penstocks," U.S. Patent Application No. 63/198,614, Filed on Oct. 29, 2020.

References

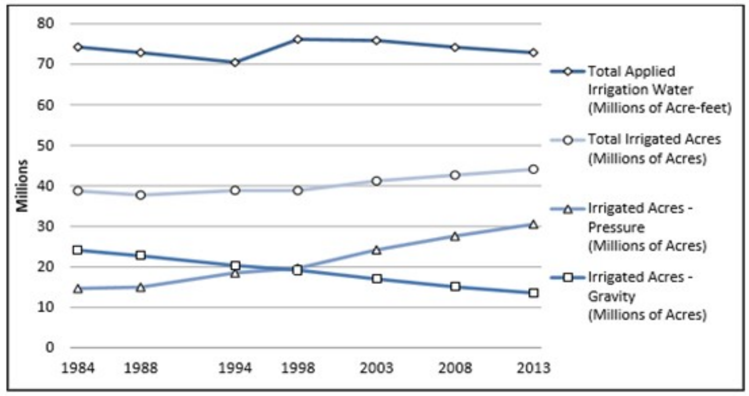
1. Last accessed in September 2021: https://blogs.worldbank.org/water/what-non-revenue-water-how-can-we-reduce-it-better-water-service

2. Ehsani, M.R., 2015. How to manufacture and endless pipe on-site. Proceedings – ASCE

Pipelines, Aug 23-26, 2015, Baltimore, MD, USA.

3. Last accessed in May 2022: Binational Study of Water Desalination Opportunities in the Sea of Cortez (Study by Black & Veatch and Libra): https://tinyurl.com/hv7jyp7f

4. "In a First, U.S. Declares Shortage on Colorado River, Forcing Water Cuts," *NY Times*, https://www.nytimes.com/2021/08/16/climate/colorado-river-water-cuts.html



Source: CRS from Glenn Schaible and Marcel Aillery, *Irrigation and Water Use: Background*, USDA, Economic Research Service (ERS), June 7, 2013, http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx; and USDA, NASS, *2013 Farm and Ranch Irrigation Survey*, Tables 4, 29, 30, and 31, http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/.

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