MONOLITHIC CONCRETE IRRIGATION PIPE

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INTRODUCTION

Monolithic concrete pipe (also known as "Cast-In-Place Concrete Pipe (CIPCP) or Cast-In-Place Pipe (CIPP)) is widely used in some regions for purposes such as storm, sewer, or irrigation pipelines. The earliest use of CIPCP was in 1922 in the Turlock Irrigation District of California. It is reported by The Sierra Group (Sierra, 1991) that there are over 15 million linear feet (4.6 million linear meters) of CIPCP under various applications. Nevertheless, many irrigation engineers, especially outside the U.S. are unaware of CIPCP. Monolithic concrete irrigation pipe is seldom mentioned in irrigation design literature.

This paper has been written to familiarize irrigation engineers with an additional design option. Cited references can be used to obtain technical and installation details.

CIPCP FOR IRRIGATION

CIPCP is a cast-in-place pipe which is underground, continuous non-reinforced concrete having no joints or seams except as necessitated by construction requirements (ACI, 1990). Pressures in CIPCP, including surge, are recommended in ACI 346R-90 to be less than 15 feet (4.5 m), and in practice most pressures are much lower than this. Common irrigation CIPCP diameters range from 30" - 84" (762 mm - 2134 mm), with minimum wall thicknesses of 3.5" - 8" (89 mm - 203 mm), respectively. With such large diameters, CIPCP is almost exclusively used for water conveyance and distribution systems in irrigation districts, rather than on-farm. Most buried low pressure on-farm pipelines in California were originally non-reinforced mortar jointed pipe. In the past 15 years, the use of non-reinforced mortar jointed pipe for on-farm use has been eclipsed by PVC pipe.

CIPCP is selected over other pipeline designs because of the low cost. It is suitable for very low pressure installations. The quality of the pipelines and the anticipated life appear to be highly dependent upon the amount of attention paid to trench compaction, concrete mixes, and curing. Some installations also have extremely shallow or deep covers, both of which can cause failure. The success may also be dependent upon the amount of soil settling and movement; these are significant in some areas with seismic activity or subsidence due to ground water extraction. Some irrigation districts have abandoned the use of CIPCP because of chronic leakage and cracks in older CIPCP installations, while other irrigation districts expand their use of CIPCP.

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USE OF CIPCP FOR IRRIGATION IN THE U.S.

CIPCP usage for irrigation is concentrated in Arizona and California. A major user in Arizona has been the Salt River Project. In California, some irrigation districts, primarily on the eastern side of the San Joaquin Valley, have used the pipe extensively.

In California and Arizona there is little new construction of irrigation district mainlines or laterals. Present construction with CIPCP almost always occurs as conversions of existing open ditches or canals into pipelines. Typical justifications cited by irrigation districts include:

- Water savings due to less seepage
- Easier operation than with canals
- Reduction in maintenance costs
- Increase in land area available for agricultural production
- Increase in land area available for commercial developers, as agricultural land shifts to urban uses
- Improved safety in and near cities. Drownings in canals occur annually in some irrigation districts.

The Irrigation Training and Research Center (ITRC) at Cal Poly, San Luis Obispo, CA, sent an informal mail survey to approximately 80 irrigation districts in California regarding their usage of CIPCP. Of the 41 districts which responded, 14 indicated that they have CIPCP and of those, 9 are currently installing more CIPCP. The authors are aware of other districts which have also installed CIPCP recently.

The informal ITRC survey indicated that the majority of pipe sizes used are in the 30" - 42" (762 mm - 1067 mm) range. Table 1 summarizes the results reported by the districts.

Table 1. CIPCP in irrigation districts responding to the survey.

Pipe Diameter		Lengths of CIPCP	
inches	**millimeters**	**feet**	**meters**
18	457	244,200	74,432
24	610	3,960	1,207
30	762	2,016,115	614,512
36	914	2,906,059	885,767
42	1067	1,708,608	520,784
48	1219	395,155	120,443
54	1372	175,718	53,559
60	1524	5,280	1,609
72	1829	2,904	885
84	2134	3,960	1,207
	Totals	**7,461,959**	**2,274,405**

Table 2 presents reported costs for CIPCP in various California irrigation districts. The installation costs which were reported by the districts were variable, and no attempt was made to verify the accuracy of the values or to determine why they might differ. However, there are wide ranges of installation techniques and equipment. Some districts use their own labor crews with outside equipment; some use outside contractors for the complete work; and other districts have their own crews and equipment. Personal observations indicate that there are also differences in the quality of the pipes. The costs of 72" (1829 mm) pipe reflect the true cost to Imperial Irrigation District (IID) in 1993 for pipe installed by contractors to conform to rigorous specifications which included frequent on-site concrete testing, over-excavation and bed compaction, and a special concrete mix.

Table 2. Reported costs for CIPCP for California irrigation districts.

Pipe Diameter		Reported Costs	
inches	**millimeters**	**$/foot**	**$/meter**
18	457	22	72
24	610	23	75
30	762	15 - 17	48 - 54
36	914	17 - 38	56 - 125
42	1067	17 - 45	56 - 148
48	1219	35 - 50	113 - 164
54	1372	40	132
60	1524	47	154
72	1829	185	607
84	2134	85	279

CIPCP CONSTRUCTION

Casting requires the construction of a trench with a semicircular bottom, which serves as the outer form for the bottom and sides of the pipe. There are several different techniques available to form the side walls and top of the pipe. Original pouring techniques favored a two-step pour process (first the bottom, and later the top) by hand. This two-step process resulted in a weak horizontal construction joints either because of dirty joints or insufficient plasticity of the concrete on the lower half (and therefore weak bonding) when the top half was poured.

For over 40 years there have been a variety of improved single-stage (hence the term, "monolithic") construction techniques. Some have used an inflated bladder as a form which is pulled down the trench. Most contracted installations now use a pipe casting machine or "boat" which winches itself along a pre-formed trench, continuously receiving concrete from trucks. ACI346R-90 (ACI, 1990) provides a good description of various techniques and equipment. The process used at the Imperial Irrigation District in 1993 for the construction of 0.55 miles (.88 km) of 72" (1829 mm) pipe is described briefly as follows (IID, 1993a, 1993b; Tremont, 1990):

- A trench is over-excavated by a minimum of 2 feet (.61 m) on each side of the pipe outside diameter (OD) and 4 feet (1.21 m) below the pipe bed. It is backfilled, and compacted to 85% of maximum Proctor density up to the top of the proposed pipe.
- A trench is excavated to the desired outside diameter of the pipe with round bottom buckets to provide a three-sided mold. Bucket movement is assisted by laser guides.

- The pipe machine (boat) is placed into the trench. The boat is equipped with a hopper to receive concrete from trucks, an auger and assembly of vibrators to force the concrete between the forms (the bottom outside form is the trench soil), room for a person to stand inside to adjust inside forms, and a winch for self-propulsion. The rear of the machine has an upper trowel plate which forms the outside crown of the pipe, and a lower trowel plate which forms the inside bottom (invert) of the pipe.
- A person working outside the machine feeds aluminum sheets and support brackets to another person working inside the machine. These aluminum sheets temporarily support the upper 270□ of the concrete.
- Low slump concrete is fed into a hopper on the machine from trucks positioned alongside the trench. The concrete is tamped and vibrated to ensure uniform density and high pipe strength. The concrete at IID was reinforced with a minimum of 1.5 pounds per cubic yard (.82 kg/m^3) of collated, fillibrated polypropylene fibers. The concrete met the requirements of ASTM designation C150 for Type II cement and met the low alkali and false-set limitations specified therein. Concrete was tested a minimum of once per every 50 cubic yards (42 m^3) of concrete placed.
- As the pipe is formed, the machine winches itself along with a cable attached to a deadman positioned ahead in the trench. In practice, lengths of pipe poured per day range from about 100' to 400' (30.5 m - 122 m) for 120" - 24" (3048 mm - 610 mm) diameters.
- The newly cast pipe is immediately covered with a thin (.0015 in; .038 mm) polyethylene sheet for moisture retention and optimum curing. No longer than six hours after casting, a 6" (152 mm) layer of loose moist soil is placed on the top of the pipe, without damaging the polyethylene film or pipe. The soil is kept moist until backfill operations are completed. Backfill operations are not completed until the concrete attains the 28 day strength specified (3000 psi or 20.7 MPa).
- A special joint is installed at the end of the day in order to obtain a good bond with the next day's pour. The pipe end is covered to enhance curing.
- Forms are removed within 2 to 18 hours and are re-positioned along the trench for the next day's pour.

Various agencies have special requirements that need to be placed in the writing of the specifications such as water deliveries, road closures, etc. The concrete design mix can be altered, by a qualified geotechnical lab, to achieve early compression strengths of 3000 PSI (20,685 kPa) in 24 hours. This allows early water deliveries, and backfilling of the trench can start the next day.

SUMMARY

Cast-In-Place Concrete Pipe (CIPCP) is traditionally about 33% cheaper to install than comparable pre-cast concrete pipe. In these days of tight construction budgets and urban expansion into existing farm lands, CIPCP is an economical approach to putting open working irrigation and drainage conveyance systems underground.

REFERENCES

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