CAST-IN-PLACE NON-REINFORCED CONCRETE PIPE

"The Pipe for the 21st Century"

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In the 20th Century concrete pipe has been one of the most economical and durable construction materials for underground drainage and sewerage. . The "Pipe of the 21st Century" may well be Non-reinforced Concrete Pipe slip-formed directly in an open cut trench. With thirty-five years of successful history in Western United States, CIPCP has been established as a simple, practical, economical and durable method of producing high quality concrete pipes from 24 inches to 120 inches in diameter rapidly and at sharply reduced cost in comparison to alternatives. More than 3,500 miles of this advanced pipe system are in daily service in Western irrigation, storm drainage and waste water systems.

CIPCP eliminates the customary precast manufacturing plant making large diameter concrete pipe economical and available wherever and whenever needed. Environmentally trucking and stringing of large pipe sections along an open ditch are important advantages of CIPCP. Heavy cranes and the usual heavy construction equipment are not needed. The installation process proceeds rapidly and with minimal disturbance in residential streets.

An industry developed National American Concrete Institute Specification, (ACI 346-90) and Recommendations for Cast-in-Place Non-reinforced Concrete Pipe (ACI 346R-90) are the result of 20 years of industry effort. While the CIPCP process is simple in concept, and the referenced specifications are fully responsive to the product there remains a requirement for the presence of a third-party professional engineer/inspector to assure field quality control over each construction phase from trenching, concrete placement and backfill to acceptance of the finished product. 2/,3/

The continuous and jointless monolithic casting process practically eliminates leakage providing a distinct advantage over jointed precast pipe where mortared joints are required for each precast pipe length. Even with rubber gasketed joints, the precast product does not surpass the monolithic CIPCP conduit's performance. There are no joints in the conduit other than construction joints at the start and finish of each pour. Hairline transverse shrinkage cracks occur at about 30-40 ft. intervals, but these close when wetted. If larger width cracks occur they are sealed.with cement mortar paste, epoxy injection or an elastomeric sealant.

The art of slip forming took a giant leap forward on January 24, l956 when the United States Patent Office issued Patent No. 2,731,698 for an APPARATUS FOR FORMING CONCRETE PIPE IN-SITU to Elmer Le Roy Tunsen assigned to NO-JOINT (TM) CONCRETE PIPE COMPANY, Butte Co.,California. Quoting in part from the Patent document, one of the objectives of the patent is...."to obviate the need for prefabricated pipe sections and pipe joints by casting cementitious pipe in a continuous manner directly in the ground in which the pipe is to lay." The Inventor chose diameters ranging upward from 24 inches, I.D.. in six (6) inch increments. Wall thicknesses are quite similar to those of Reinforced Concrete Culvert Pipe, ASTM C-76 Wall "B". Monolithic Cast-In-Place Pipe superseded the two-stage systems that were commonly used in irrigation systems and which were not generally acceptable of Public Works projects..2/

Not until 1961 and 1962 were other monolithic cast-in-place pipe systems patented and entered into competition with No-Joint (TM) Pipe. In the five years between 1961 and 1966 the Trademarked name "No-Joint" actually became the generic name for CIPCP. .4/5/6/

States, Cities Highway Departments, Flood Control Districts and other Public Agencies in the Columbia Basin of Washington, the Great Central Valley of California and the Salt River Valley of Arizona were leaders in specifying and purchasing slip-formed concrete pipe for Public Works Projects. Today CIPCP has has achieved more than 35 years of highly successful historical performance and the simplicity, economy and durability of CIPCP are filling the demand for cost-effective storm drainage and waste water systems throughout the Western United States. It is an excellent product for environmental control systems where suitable soils exist and sound concrete is near at hand.

There are two principal construction methods for CIPCP. Both feature a semi-circular bottomed trench as the outer concrete form; one method uses internal metal forms while the other method features an inflated tube inner form. The latter developed many problems when diameters exceeded 48 inches.and is no longer an available construction option.. 4/5/6/

Today the metal form processes continue in use in diameters ranging from 24 inches to 120 inches The initial proprietary Patents and subordinate franchises have expired. There are many independent Contractor/Operators employing a variety of machines with modifications from the original Patents. Specifications are often written by individual contractors to exclude competitors and to protect their own interests, particularly as to workmanship and quality control. There is no CIPCP Industry Trade Association to promulgate uniform industry standards. Purchasers rely heavily on the individual Contractor/Operator to furnish design, construction and inspection know how. Our Engineering/Inspection Firm, The Moote Group has recognized and filled this void for more than 15 years, earning National recognition for leadership in CIPCP Engineering and Field Quality Control. Our services include feasibility studies, review and critique of design plans and furnishing expert technical supervision over field operations.

Installation of CIPCP begins as soon as a backhoe opens a trench. Daily production ranges from 800 feet/day for 24-inch to 350 feet/day for 120-inch pipe. Even larger diameters are feasible, if and when there is a need. Approximately four miles of 14-ft. I.D. CIPCP were laid and tested in Arizona in 1977 as an alternative storage system for the U.S. Air Force's MX-Missle.. The Moote Group was among the special consultants selected by Ralph M. Parsons to assist in this undertaking.

CIPCP is now firmly established among an increasing number of Western Professionals. The informed engineer knows that CIPCP has exceeded every load test, has an "n" factor (friction coefficient in the Manning equation) equal to that of reinforced concrete pipe alternates, is readily available wherever needed at 20 to 40 percent less cost than RCP. By eliminating the factory and manufacturing lead time CIPCP could well be discovered as "The Pipe for the 21st Century". There is a challenge and an opportunity for innovative minds to modernize and improve the CIPCP process. The original machinery designs and concept remain virtually unchanged. The process, although presently cost effective, is relatively labor intensive requiring an crew of 7 to 12 men.. Modernization of mechanical features and use of automation for concrete control would obviate the present need for third-party professional quality control in the field. 3/21/

Sacramento County, California was one of the earlier Public Works users of CIPCP starting in the year 1956. In the next 14 years the County installed 156,000 lineal feet of CIPCP in diameters from 24-inches to 84-inches at a savings of $2,000,000 to taxpayers. Sacramento County realized 30-40 percent cent installed cost savings in over conventional pipe. 7/

CIPCP trenches are excavated with a special semi-circular bucket for each pipe size. The typical CIPCP trench has a semi-circular bottom and must stand vertically to one-half of the pipe diameter above the crown of the pipe without sloughing Above that elevation the sidewalls may be sloped back to lessen the possibility of caving and to minimize the need for shoring. The trench is from 1-1/2 to 3 inches wider than the outside diameter of the slip-form (or "boat"). Prescribed line and grade are established by means of a laser set up in the trench and targeted on the digging bucket. Spoil is cast along one side of the trench so the opposite bank is clear for internal form stringing and accessible to transit mixed concrete delivery trucks. PHOTO

When ground water is encountered, a french drain is constructed along the trench invert center line. The slip form passes over the drain, filled with gravel, and water flows harmlessly beneath the pipe.

In locations where unsuitable soils are encountered the trench may be filled with suitable imported soil, compacted and re-excavated. Marston Negative Projecting Conduit Condition is the generally accepted method for Installing CIPCP. In this method the pipe is laid in shallow trench before the final embankment is placed to finished grade. (This method is well known to design engineers.).

The No-Joint (TM) slip form comprises two parts. The outer hull, or "boat" contains the diesel or electric power unit and cable winch and an after section or "mandrel" that unitizes the concrete hopper, electric vibrators and the upper and lower skirts which shape the extruded concrete. The mandrel is vertically hinge mounted to provide articulation in negotiating curves. Curve radii are limited to 45 feet for 24-inch and 160 feet for 120-inch ID CIPCP. Precast RCP pipe manufactured to the specified radius are inserted in curves having radii too short to be negotiated by CIPCP. The steel "boat" serves as a sturdy safety shield to protect CIPCP workmen.. Photo Fig --

Aluminum alloy forms, equipped with hook and eye linkage bars are lapped and fed through the mandrel beneath the concrete hopper. Metal spreaders (semi circular trusses) are placed at the 6-inch form laps by workmen within the mandrel. The weight of the fresh concrete sets the metal forms in position. The 90 degree exposed pipe invert is smoothly troweled as the slip form advances. A variable speed electric powered winch driving a cable anchored to a dead man within the trench advances the slip form. Larger slip forms have a half-track in the "boat" to decrease towing friction.

When the concrete takes its initial set (in 4-6 hours), spreaders are removed, the linked forms are dropped onto the invert, pulled out of the pipe cleaned and oiled for the next day's pour. The conduit is quickly inspected for repairable deficiencies. Openings to the conduit are closed and the heat of hydration of the cement raises the ambient temperature as much as 30-40 degrees providing an ideal warm moist curing environment. The exposed outer upper quadrant of the pipe is immediately covered with a plastic sheet and "shaded" with 6 inches of loose native material. The concrete reaches 80 per cent of design strength in 48 hours, more or less, and full design strength in 5-7 days.

Photo Fig. --

It is important that the initial 24-inches of backfill be compacted to the relative density of the trench soil. The soil envelope surrounding the CIPCP must be a homogeneous and of uniform density to assure uniform 180 degree load distribution over the pipe crown. Backfill above the initial 24 inches is placed and compacted as directed by the Soils Engineer to satisfy overlying structural requirements (such as roads streets, etc.). Backfilling commences when concrete test cylinders reach 80 to 100 per cent of design strength and continues thereafter without interruption.

The Soils Engineer. furnishes a Soils Report, renders his judgment as to the suitability of the soil for CIPCP, and provides soils information to the design Engineer required for structural calculations. Data includes unit compacted soil weight and the At Rest lateral soil pressure. Field soils technicians inspect and direct excavation, backfilling and testing. The Project Engineer depends upon the Soils Engineer for for all of the soils data that affect the CIPCP product and uses the data when evaluating the load carrying capability of the CIPCP..8/

The At Rest lateral pressure Coefficient (Ko=1-Sin phi) is a conservative design criterion., as numerous load tests have corroborated. Casagrande says " (In the case of buried concrete pipes)........ "horizontal earth pressures often surpass at-rest pressures and approach the passive pressure range.".9/

Quoting from Project No. 15-3 Final Report on "Rational Structural Analysis and Design of Pipe Culverts" by the Department of Civil Engineering, Northwestern University, page 39. "..On the basis of 0.003 (in/in) strain limit for concrete, and other assumptions, Lum found that the allowable conduit deformation is equal to the square of the pipe diameter (in inches) divided by 1200 times the wall thickness (in inches)".. 11/. As an example, a 60 inch CIPCP with a 6 inch wall could theoretically deflect 0.5 inch before failure. In no In Situ Load Bearing Test of CIPCP has a measured vertical and/or horizontal deflection ever been measured in excess of 7 per cent of the theoretical ultimate.13/14/

As loads are imposed on the pipe,the elastic CIPCP ring tends to deflect and presses against the restraining trench The unusually high test loads and small deflections bear this out. In the case of 96-inch CIPCP, the maximum recorded deflection was 0.034 inch under a static load of 52,250 lbs. Applying the above deflection formula the 96 inch CIPCP could deflect 0.833 inch before failure. The actual deflection is only 4 (four) per cent of the failure mode.10/

Northwestern University Department of Civil Engineering developed a formula for computing Moments from measured deflections in concrete rings. The result Moment = 3.6 x EI X Delta R/Delta R squared., where R = measured deflection of radius. 11/.

The early attempts to assign D-Loads to CIPCP proved fallacious. D-Load is determined in a 3-edge bearing test. and is the load on one foot of conduit that produces a 12-inch long crack .01 inch in width. The ratio of the test load/foot divided by the pipe diameter in feet., is termed "D-Load (.01)" Upon pipe installation a Load Factor corresponding to one of four classes of bedding enhances the the D-Load (.01) to the design D-Load. The Load Factor of 3.0 is usually assigned to a CONCRETE cradle. CIPCP qualifies for a load factor of at least 3.0, but the D-Load approach, which neglects modern soil mechanics, is grossly inappropriate for CIPCP..

The Working Stress Design Method is the more appropriate method. The conduit is subjected to earth and live loads which are ameliorated by At Rest lateral pressures. Structural calculations using Paris Coefficients (16/) to determine the working stress are based on applying uniform 180 degree load distribution and reaction of earth and live loads and five loading conditions . These are (1) Vertical earth load (2) Live Load (10 feet of cover maximum), (3) Triangular Lateral Support, (4) Uniform Lateral Support, (5) Weight of the conduit. (Water load is neglected in storm drainage.) A safety factor of 2 is applied based on the Modulus of Rupture in Flexure of the particular concrete design. (Usually 650 psi for concrete f'c = 4,000 psi. permitting a working stress of 350 psi.)

Manning's equation (V=1.486/"n"R2/3S1/2), is used for calculating open channel flow in CIPCP. Manning's "n" of 0.013 is the proper coefficient for both CIPCP and RCP alternates. .Comprehensive tests performed by the U.S. Bureau of Reclamation and The Salt River Project, jointly, on an operating irrigation system over a 3-year period on CIPCP lines 24 to 54 inches in diameter, and ranging in lengths from 856 feet to 4,267 feet, clearly establish this as the correct "n" value to apply to CIPCP. No equally comprehensive "n" factor test has ever been performed on reinforced concrete pipe alternates. All of the test lines included in-line structures, bends, detritis and silt accumulation. The scope of these tests is unprecedented and conclusive. 21/

Cast-In-Place Non-reinforced Concrete Pipe has earned the title "Pipe for the 21st Century" in 35 years of meeting and exceeding every challenge. While it is a utilitarian conduit and not to be touted as the "pipe for all seasons" it will satisfy the requirements for gravity and low head (under 25 ft) storm, irrigation and even in certain waste water conduit systems (where H_2SO_4 is not generated) in the future. Environmental and pollution control problems recognized 20 years ago by Fischer (Retired Editor of Harper's) (17/) and H.U.D. Official Jones (18/) remain unsolved and far greater problems loom on the horizon. CIPCP is a "sleeping giant" awaiting discovery;. This product, at one time used in India, South Africa, Mexico and in some South American countries under franchises of NO JOINT (TM) patent owners has never been promoted beyond a few "Western States. CIPCP is so versatile, simple to install and cost effective that it certainly will have applications beyond the arid lands of the West... It provides the means of building large diameter conduits at any place and at any time without the usual supporting concrete pipe factory.

CIPCP has inherent advantages.: (1) The supporting strength of a Tunnel, (2) Proven economy and speed of installation, (3) Almost "bottle tight" leakage performance, (4) Simplicity of Design, (5) Independence from Factory Manufacture, (6) Availability at any suitable location without lead time. (6) Availability at any suitable location without a factory and attendant manufacturing lead time, and (7), CIPCP is a prototype for other slip-formed concrete product configurations such as horseshoes and arches.

The CIPCP. industry lacks a professional Trade Association to promote its products. The basic machines have undergone only minor improvements. This opens an opportunity of unprecedented magnitude.for developing the "Sleeping Giant". For the adventurous entrepreneur, modern technology, computer chips, and mechanical improvements supported by well directed research and engineering, portends opening exciting new horizons.

The needs in America, Europe, Russia, Asia, and Third World Countries are certainly fertile ground.

Who will build The Pipe for the 21st Century?.

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