

Volume 52 No. 2 Summer 2000

# concretepipenews

The Magazine of the American Concrete Pipe Association

## Under The Boardwalk

PRECAST CONCRETE PIPE INTEGRAL PART OF  
ATLANTIC CITY-BRIGANTINE CONNECTOR



- **Concrete Pipe "Sure Bet" for Las Vegas Sanitary Sewer Systems**
- **Creative Uses of Precast Concrete Box Sections**
- **Shear Strength Design Provisions Explored**

**This issue:**

Volume 52, Number 2  
Summer 2000

*Concrete Pipe News* is designed to provide a communication forum for the concrete pipe industry to facilitate the exchange of information regarding product use and applications, industry technology and trends among members of the American Concrete Pipe Association, contractors, engineers, vendors, suppliers and other interested parties.

**American Concrete Pipe Association Staff**

John J. Duffy  
*President*

Mike Saubert  
*Director of Marketing*

Josh Beakley  
*Director of Technical Services*

Carol LeSueur  
*Director of Member Services*

Wendy Lambert  
*Controller*

**Media Task Group**

Scott Olson, Chairman  
*The Cretex Companies,  
Elk River, Minnesota*

Bill Dunn  
*Lombard Pre-Cast, Inc.,  
Victoria, British Columbia*

Bill Gardner  
*Madison Concrete Pipe, Inc.,  
Madison, Wisconsin*

Bill Hobson  
*N.C. Products Corp.,  
Raleigh, North Carolina*

Merle Headington  
*Zeidlers, Inc.,  
Waterloo, Iowa*

**Contract Editorial Staff**

A. Grant Lee  
*AGL Marketing Limited  
Executive Editor*

Gary Wilder  
*Wilder Studios  
Production*

**Published by:**

American Concrete Pipe Association  
222 W. Las Colinas Blvd., Suite 641  
Irving, Texas 75039-5423  
Phone: (972) 506-7216  
Fax: (972) 506-7682  
E-mail: info@concrete-pipe.org



*Opinions expressed by authors other than staff of the American Concrete Pipe Association do not necessarily reflect the official positions or policies of the Association.*

# Table of Contents

## Regular Departments

**President's Report** ..... 3  
From Association President John J. Duffy

**Industry Spotlight** ..... 4  
Leonard L. Klein, P.E., Concrete Accessory Manufacturing of Ludington, Michigan

## Features

**Atlantic City-Brigantine Connector Includes Large Quantity of RCP** ..... 5  
More than five miles of precast concrete pipe in various sizes and classes was used for the 2.3-mile road and tunnel linking the Atlantic City Expressway with the City's Marina District.

**Specially Designed Concrete Pipe Used in Arid Las Vegas Environment** ..... 7  
Two ongoing projects in Las Vegas are using precast concrete pipe to accommodate potentially corrosive sanitary sewer conditions.

**Thinking Outside the Box** ..... 9  
"Square pipe" in the form of box sections is being used in creative and economical ways to help municipalities and industry overcome interesting challenges.

**Shear Strength Design Provisions** ..... 11  
One of the foremost authorities on reinforced concrete pipe design compares shear strength design provisions based upon AASHTO LRFD Bridge Specifications with generally accepted industry practices.

*Precast concrete pipe is playing an important part in the massive Atlantic City-Brigantine Connector project. The \$190.6 million highway and tunnel project will provide direct access to the new Atlantic City Convention Center.*





*John J. Diffy*

## Concrete Pipe Equates with Renewal And Innovation

Our cover story highlights the renewal of Atlantic City, after it had fallen on hard times following World War II. The City rose like the Phoenix with the passage of the Casino Gambling referendum in 1976 and entered into a second era of rapid growth.

Throughout its history, Atlantic City's merchants battled with the ever-present sand that was a nuisance to its beautiful hotels, elegant restaurants and transportation. The solution was the renowned "Boardwalk" that was built in 1870, costing half of the town's tax revenue that year. The late 1800s was a tremendous growth period, and the City became known for its entertainment and resort amenities throughout the world, including the Miss America pageants in the 1930s. The City went into a steep economic decline following World War II, and only began to recover in the late seventies with the growth of casinos along the waterfront to complement the historical boardwalk and century-old buildings.

In 1997 approvals were granted for the design and construction of the Atlantic City-Brigantine Connector - a highway and tunnel project in Atlantic City, that would provide long-needed traffic and emergency vehicle relief to the City of Brigantine and easy access to the world-class casinos. Construction of this massive project made use of more than five

miles of reinforced concrete pipe of various sizes and classes, thereby underscoring the importance of precast concrete drainage systems to projects designed to last several lifetimes.

The Las Vegas basin is a very challenging environment for buried infrastructure. CSR Hydro Conduit has met this challenge for over 50 years and has developed special applications of precast concrete pipe for sanitary sewer systems. Tony Lopez describes current projects that make extensive use of concrete pipe.

A story by Mike Shook of Choctaw challenges designers of drainage systems to use precast concrete products to solve problems in economical ways that cannot be done using any other product except precast concrete. He presents two applications of precast concrete box sections that equated to great savings in time and tax dollars. His message is to "think outside the box", and work with readily available precast concrete products when looking for lasting solutions.

Leonard L. Klein, P.E., is featured in our Industry Spotlight. He is a highly regarded engineer who has served member firms of the American Concrete Pipe Association, and the Association itself, for over 40 years. Leonard offers practical comments about concrete pipe design, and notes that when specifiers specify other products, they hope they have made the right choice, but when concrete pipe is specified, the right thing has been done.

Our technical article compares shear strength design provisions, based on the newly adopted AASHTO LRFD Bridge Specifications, with generally accepted industry practices for precast reinforced concrete pipe. Written by Frank J. Heger, P.E., and senior principal of Simpson Gumpertz & Heger, the technical brief demonstrates a consistent relationship between shear strength provisions developed for concrete pipe in the 1970s and 1980s and the AASHTO LRFD specifications. The shear strength provisions for concrete pipe were incorporated into the ASCE and AASHTO specifications several years ago. It is another example of innovation with concrete pipe leading the way.

This issue of *Concrete Pipe News* demonstrates how concrete pipe, in its various shapes and sizes, parallels the ever-changing infrastructure landscape of North America. Concrete pipe has been around for hundreds of years and gone through its share of renewal, and is now enjoying unprecedented innovation. We invite you to join ACPA members in taking another look at precast concrete pipe as a lasting and enduring product that forms the buried lifelines of our nation. ☺



## Leonard L. Klein, P.E.

The success of most companies or organizations, including Associations, can be traced to the work of a handful of active members working together on committees, or the efforts of highly motivated individuals. The work of Leonard Klein covers both. He is a highly regarded engineer who has served member firms of the American Concrete Pipe Association, and the Association itself, for over 40 years.



Klein's career reads like a treatise about success and achievement. He attended Yale University during World War II and received a commission as an Engineering Officer upon graduation in 1943. During the war years, Klein served as the Group Engineering Officer for the U.S. Army Air Corps at their B-26 Bomber Transition School in Dodge City, Kansas. He was responsible for certifying the "airworthiness" of the bomber aircraft used to train new pilots in preparation for their Allied mission. Klein separated from the service in 1946 to attend Michigan State University.

In 1949, he received his degree in civil engineering from Michigan State University, and worked for Armco Steel for seven years. In 1957, he joined Superior Products Co. as an engineer, retiring in 1987. It was during this period with Superior Products that he accomplished one of his greatest achievements.

In 1973, Mr. Klein was instrumental in the design and installation of the world's largest precast concrete gravity storm sewer pipe. The 204-inch diameter (17-foot internal diameter) pipe forms part of the Henry-Graham Drain, a

key link in the master drainage plan for the City of Troy in suburban Detroit. Superior Products supplied 574 pieces of 8-foot long, 17-foot (ID) pipe.

While working with Superior Products, Klein served on ASTM Committee C-13 where he received the *Award of Merit*. Klein was also Chairman of Subcommittee C13-02. Leonard is a life member of the American Society of Civil Engineers, Grade of Fellow, past President of the Michigan section and was awarded *Engineer of the Year*.

Klein served on the ACPA Technical Committee for many years and was Chairman in 1986-87. He is a past member of the National Society of Professional Engineers. Since 1988, he has been working for Concrete Accessory Manufacturing of Ludington, Michigan designing reinforced concrete pipe, precast boxes and shear reinforcement for these products. He is a regular speaker at the ACPA Short Course Schools.

Based on his wealth of experience and depth of engineering expertise, we expected Mr. Klein to provide a practical perspective about concrete pipe design when we asked him a few questions. We were not disappointed.

**Q:** *What different types of reinforcement are now available, other than wire and wire mesh?*

**Klein:** There are a variety of different types of reinforcement available to producers of precast concrete products – some proven, others in development stages. Research continues in this area, such as fiber reinforcement using cellulose and carbon steel fibers, and fiberglass strands. At present, cold drawn wire and hot rolled bars remain the products of choice for reinforcement in concrete pipe.

**Q:** *What should an engineer take into consideration when designing a pipe using reinforcement?*

**Klein:** The engineer has to consider a broad range of parameters but primarily, service loads and final conditions. To name a few, these

continued on page 15

# Atlantic City-Brigantine Connector **Precast Concrete Pipe Abounds**

*By Bruce Carnovale, Project Engineer  
Yonkers Contracting Company, Inc., Yonkers, NY and  
Herman Jamnik, RCP Sales Manager  
Vianini Pipe, Inc., Whitehouse Station, NJ  
908-534-4021*

The Atlantic City-Brigantine Connector is a highway and tunnel project in Atlantic City, New Jersey that will provide long-needed traffic and emergency vehicle relief to the City of Brigantine. The project will also provide direct access to the new Atlantic City Convention Center. The three main sections of the project are the link from the expressway to the Convention Center, the covered roadway section along Penrose Canal to the north side of Route 30, and the Marina and Brigantine connection as the road emerges on the other side of Route 30. When the project is completed, Brigantine will have a seamless connection to Atlantic City and the regional highway system that links the two island communities of Atlantic City and Brigantine to the mainland.

Construction of the connector will have immediate benefits for the City. It will ensure improved cross-town connections. Visitors to the Atlantic City Convention Center and Brigantine will find a much easier route with less congestion. There will be direct access from the Atlantic City Expressway to Route 30. Construction of the connector is also helping revitalize Atlantic City by creating thousands of jobs and attracting billions of dollars in private sector investment, including three new casinos.

The scope of the project involves design and construction of a 2.3-mile road and tunnel linking the Atlantic City Expressway with the City's Marina District. Work includes 16 bridges, interchange modifications, 23 retaining walls, a 2,900-foot cut and cover tunnel with open depressed roadway sections at both ends, and over 5 miles of precast concrete pipe. The tunnel

that goes under Route 30 and an adjacent residential area includes storm water pump stations, ventilation systems and numerous utilities and related appurtenances.

The design of the connector initially specified the use of corrugated metal pipe (CMP). The CMP pipe installation soon ran into problems when some joints separated due to settlement into



the soft sand.

The contractor, Yonkers Contracting Company, asked for and received a specification change to precast concrete pipe. The structural integrity of precast concrete pipe, along with the ability to obtain class-rated products for varying soil conditions and installation depths, were factors in selecting RCP for the massive project.

Yonkers contracted with Vianini Pipe, Inc., Whitehouse Station, New Jersey (a member of the American Concrete Pipe Association), to supply the storm sewer pipe for the project. Shipment began in April 1999 and continued into the summer of 2000. The first order called for 630 feet of 15-inch diameter Class V precast concrete pipe. The entire project will be constructed in soils that may be contaminated, so it

was imperative that the buried pipe system be water tight to resist infiltration. This was accomplished by using O-ring gaskets to seal every joint.

When construction started on the covered roadway section, numerous storm sewers had to be relocated to carry runoff to the City's canal system. The large 54-inch diameter concrete pipe was installed alongside and beneath the tunnel structure to restore the storm water drainage system. Other concrete pipe, up to 36-inch diameter, were installed as deep as 30 feet under the new access roads that were constructed with excavated material from the tunnel site.

Environmental mitigation measures include watertight joints in the concrete pipe system, as well as local amenities such as a landscaped park, and pedestrian bridges. Many local streets will also be widened and resurfaced. Information published by Granite Construction Company ([www.graniteconstruction.com](http://www.graniteconstruction.com)) notes that several city blocks of residential housing as well as portions of the Atlantic Energy power facility will be demolished or relocated.

The project is being constructed by Yonkers Contracting Company, Inc., of Yonkers, New York and Granite Construction Company of Watsonville, California who were awarded the \$190.6 million design and construction contract in 1997. In total, Vianini shipped over five miles of 12-inch (300 mm) diameter through 54-inch (1370 mm) diameter precast concrete pipe to the project. Maintenance of the concrete pipe system should be negligible for decades, thereby minimizing maintenance costs and interruption to residential, tourist and business traffic.

<b>Project:</b>	Atlantic City—Brigantine Connector
<b>Owner:</b>	Private/Public Partnership New Jersey Department of Transportation South Jersey Transportation Authority Atlandia Design (a subsidiary of Mirage Resorts Inc.)
<b>Designer:</b>	URS Greiner, New York City, New York
<b>Contractor:</b>	Yonkers Contracting Company, Inc., Yonkers, New York Granite Construction Company Watsonville, California (a joint venture)
<b>Quantities:</b>	Precast Concrete Pipe
	7,912 feet    15-inch diameter Class III
	6,200 feet    18-inch diameter Class III
	352 feet      21-inch diameter Class III
	3,264 feet    24-inch diameter Class III
	2,872 feet    30-inch diameter Class III
	1,128 feet    36-inch diameter Class III
	1,008 feet    54-inch diameter Class III
	814 feet      15-inch diameter Class V
	96 feet       18-inch diameter Class V
<b>Producer:</b>	Vianini Pipe, Inc., Whitehouse, NJ Herman Jamnik, RCP Sales Manager

*More than five miles of precast concrete pipe will be installed as part of the Atlantic City-Brigantine Connector project.*



## **Specially Designed Concrete Pipe Used in Arid Las Vegas Environment**

*A dual line of 60-inch diameter ASTM Class C-351 reinforced concrete low-head pressure pipe emerges from Las Vegas' Central Plant Bar Screen Facility.*

*By Tony Lopez, P.E.  
CSR Hydro Conduit, Henderson, Nevada  
702-565-8721*

A desert basin is not a friendly environment for sanitary sewer systems. The flat terrain, temperature and arid climate are local conditions that contribute to the generation of hydrogen sulfide that may lead to the formation of sulfuric acid in sanitary sewers. The waste water treatment and sanitary sewer collection system in Clark County, Nevada (population 1,321,000) and the City of Las Vegas have been designed to accommodate the extremes of the desert temperatures and potentially corrosive conditions.

CSR Hydro Conduit, a member of the American Concrete Pipe Association, has supplied much of the City's buried concrete infrastructure for over 50 years. Established in the early 1950s, the CSR Las Vegas plant and its Staff have advanced the technology for producing precast concrete pipe systems capable of meeting the stringent requirements in the Las Vegas Valley.

The Clark County Sanitation District

implemented a series of projects, collectively called the Crosstown Interceptor Sewer, which starts on the west end of city, extends across the Las Vegas "Strip", and ends on the east side of city at the wastewater treatment facility. CSR Hydro Conduit supplied most of the precast concrete pipe for these projects. In the past year, the Las Vegas plant supplied 3,810 feet of 60-inch diameter reinforced concrete jacking pipe; 3,443 feet of 60-inch to 84-inch reinforced concrete low-head pressure pipe; 7,598 feet of 60-inch diameter reinforced concrete pipe; 1,185 feet of 72-inch diameter reinforced concrete pipe; and 8,136 feet of 84-inch diameter reinforced concrete pipe for three separate segments of the project. Except for the low-head concrete pressure pipe, all pipe was produced to ASTM C-76 specifications.

All of the Crosstown Interceptor Sewer segments had PVC lining and used Type V cement because of the great potential for corrosive conditions. Special requirements in the manufacturing of the product, included sacrificial concrete, absorption and joint shear testing. The pipe was manufactured by the dry cast method using the "multiple core



*The 60-inch diameter ASTM C-351, C-50 reinforced concrete low-head pressure pipe is supported on a concrete slab and will be encased in concrete.*

process”, where the inner core remains with the pipe for a minimum specified period. This technique helps lock the liner into the wall of the pipe by inducing the initial “set” of the concrete prior to removing the inner mold.

This year, the Central Plant Bar Screen Facility project is under construction. It is expected to be completed by 2002. Supplies of reinforced concrete pipe used for the facility include 2,008 feet of 60-inch diameter; 1,185 feet of 72-inch diameter; and 250 feet of 84-inch diameter reinforced concrete low-head pressure pipe. The original design had called for PVC lining for all concrete pipe, but these pipelines are to be installed in submerged conditions. Pipelines that flow full, or are submerged, are not susceptible to corrosion attack, thereby eliminating the need for PVC lining in the reinforced concrete pipe.

CSR’s Las Vegas plant submitted a “value engineering” proposal to delete the PVC liner on the reinforced concrete pipe, that would operate in the submerged condition. By accepting the proposal, the Clark County Sanitation District benefited from huge costs savings.

The Central Plant Bar Screen Facility required reinforced concrete low-head pressure pipe designed to ASTM C-361, Class C-50. All fittings are manufactured with half-inch steel plate with reinforcing ribs. A field hydrostatic test with minimal allowable leakage was required. Pipe manufactured according to this specification are designed to operate under hydrostatic heads of up to 125 feet. Class C-50 pipe is designed to operate under hydrostatic pressure up to 50 feet.

CSR’s Las Vegas plant has been a mainstay of the community, contributing to its growth over the

past five decades. The plant itself has been expanded several times, responding to the population dynamics of the area. It is currently producing round and horizontal elliptical pipe as well as a variety of reinforced concrete boxes, including “mega boxes” with spans in excess of 12 feet. ☺

<b>Project:</b>	Central Plant Bar Screen Facility	
<b>Owner:</b>	The Clark County Sanitation District Las Vegas, Nevada Brent Moser (Principal Civil Engineer in charged of construction management)	
<b>Designer:</b>	Carollo Engineers Las Vegas, Nevada Eric G. Leveque, P.E.	
<b>Contractor:</b>	Western Summit Contractors, Inc./TIC The Industrial Company (a Joint Venture) <a href="http://www.westernsummit.com">www.westernsummit.com</a>	
<b>Quantities:</b>	2,008 feet	60-inch reinforced concrete low-head pressure pipe
	1,185 feet	72-inch reinforced concrete low-head pressure pipe
	250 feet	84-inch reinforced concrete low-head pressure pipe
	Approximate combined totals for the year (Central Plant Bar Screen Facility and Crosstown Interceptor Phases J1, J2 and K)	
<b>Quantities:</b>	3,810 feet	60-inch RCP for jacking
	3,443 feet	60-inch to 84-inch reinforced concrete low- head pressure pipe
	7,598 feet	60-inch diameter RCP
	1,185 feet	72-inch diameter RCP
	8,136 feet	84-inch diameter RCP
<b>Producer:</b>	CSR Hydro Conduit Corporation Henderson, Nevada Tony Lopez, P.E., Product Engineer Richard Ferre, Area Manager	



# THINKING

PRECAST CONCRETE SECTIONS  
PROVIDE UNIQUE SOLUTIONS

# OUTSIDE THE BOX

*By Mike Shook, Director of Technical Marketing  
Choctaw Inc., Memphis, Tenn.  
901-346-1400*

Legend has it that football coach Knute Rockne got the idea for Notre Dame's "Four Horsemen" formation while watching a dance performance. World War I military designers borrowed from the art of Picasso to create more effective camouflage patterns, and the 'unbreakable' US military code used in World War II was based on the Navajo language. These were instances when people allowed their imaginations to soar, and develop an extraordinary solution to a problem based on the obvious. People involved in solving problems this way are "thinking outside the box."

Over the past twenty years, the concrete pipe industry has been working on ideas for solving problems with new precast concrete products and materials. The introduction of "square pipe" in the form of box

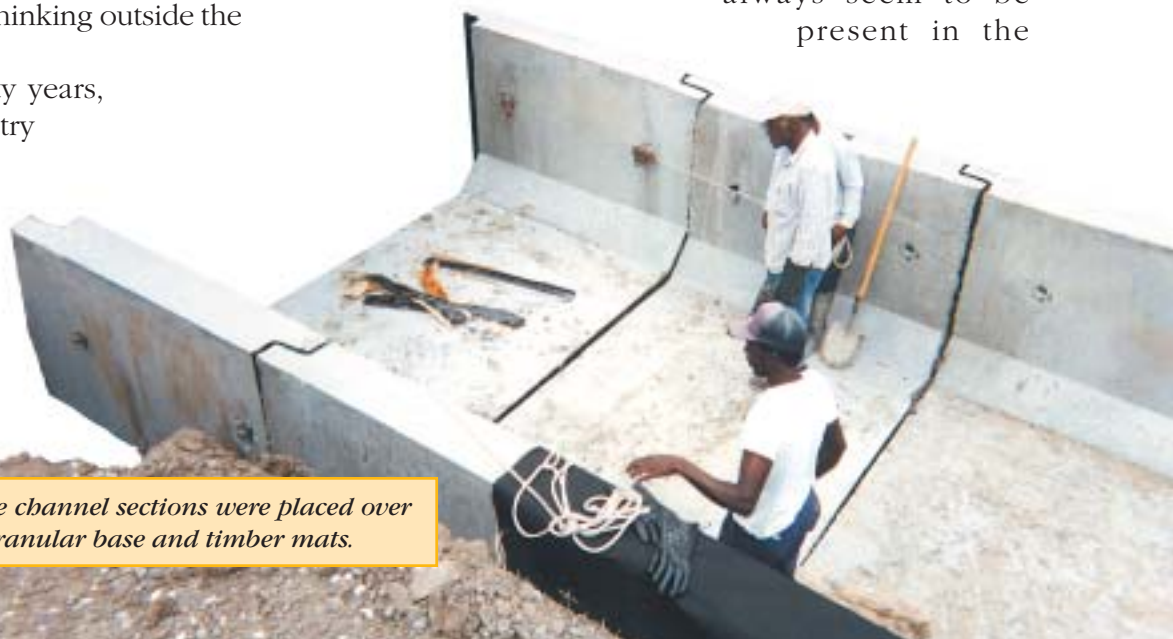


sections was a new concept for those who always thought of round or elliptical pipe for conveyance structures. Nowadays, box sections are being used to solve problems in the most creative and economical ways. Choctaw Inc., a Memphis, Tennessee-based member of the

American Concrete Pipe Association, is in the forefront of this process and is breaking new ground.

## **Precast Box Sections Used to Overcome Poor Soil Conditions**

Challenging soil conditions always seem to be present in the



*U-shaped precast concrete channel sections were placed over a nonwoven geotextile, granular base and timber mats.*

southern part of Louisiana. The soils at Cain’s Ditch, in Jefferson Parish located just outside the City of New Orleans were no exception. Land development plans called for the construction of a drainage structure in soil conditions not favorable for construction.

The problem was that Cain’s Ditch would need to be excavated, shaped and stabilized before construction of any structure. In addition to handling the anticipated flow from the development, the drainage structure would have to provide structural support for the movement of small equipment used to clean the ditch of trash and debris. The local consulting firm in charge of design of the drainage structure, Meyer Engineering, specified U-shaped precast concrete channel sections.

The U-shaped sections were manufactured at Choctaw’s New Orleans plant. The sections were 10 feet wide, 4 feet high and 6 feet in length. The project called for 75 sections, each weighing approximately 15,000 lbs. Trucks arrived on site, each carrying three sections. The tongue and groove joint was sealed using a preformed plastic gasket that met the requirements of AASHTO M198 Type B.

The ditch was excavated and a nonwoven geotextile was laid for both stabilization and separation. A granular bedding material was placed on top of the geotextile and timber mats were laid to provide additional support. Finally, the flat bottom precast channel sections were carefully lowered onto the well-constructed base.

The U-shaped precast concrete ditch was a unique application of a readily available product that is designed for long-term performance. By thinking outside the box, designers were able to provide a multi use structure that can be maintained easily and efficiently by the municipality.

<b>Project:</b>	Cain’s Ditch	Wal-Mart Supercenter
<b>Owner:</b>	Jefferson Parish, Louisiana	Wal-Mart Bentonville, Arkansas
<b>Designer:</b>	Meyer Engineering Jefferson Parish, La	CEI Engineering Bentonville, Arkansas Simpson Gumpertz & Heger Inc. Arlington, Massachusetts
<b>Contractor:</b>	Don Clements Contracting Jefferson Parish, La	Forsgren Inc. Ft. Smith, Arkansas Steve Forsgren Vic Braddy
<b>Quantities:</b>	75 (10-foot x 4-foot x 6-foot) U-shaped sections	14 (9-foot x 5-foot x 6-foot) drycast box sections 7 (9-inch x 10-foot 6-inch) wetcast link slabs
<b>Producer:</b>	Choctaw Inc. New Orleans, Louisiana	Choctaw Inc. Ft. Smith, Arkansas

### Creative Precast Box Application Yields Cost Savings

In Van Buren, Arkansas, Choctaw staff presented two options to Forsgren Inc., Ft. Smith, Arkansas, the subcontractor for a precast concrete box culvert at a new Wal-Mart store. The first option, which called for three separate individual cells of 9-foot x 5-foot sections, exceeded estimates. Forsgren staff believed that money could be saved by constructing the box culverts in the field. The second option, the ‘Link Slab’ design would eliminate the need for two additional sidewalls, thereby reducing costs. The savings were enough to convince Forsgren to allow Choctaw to furnish the precast concrete boxes for the project.

CEI Engineers of Bentonville, Arkansas had specified the triple line box culvert (9-foot x 5-foot sections) as poured-in-place at the Wal-Mart Supercenter. Wal-Mart, whose headquarters are located in Bentonville, has used CEI Engineers on hundreds of store projects in the last several years. After studying the concept presented to Forsgren Inc. by Choctaw, CEI agreed to proceed with the ‘Link Slab’ design.

The unique feature about the ‘Link Slab’ is the way it was constructed. The two outside rows



*Two rows of precast concrete box sections, spaced nine feet apart, serve as the outer most structure of the multi-cell drainage culvert.*



*Installation crews positioned the "link slabs" atop the precast rectangular box sections.*



*All box sections and link slabs were set in only 17 hours, reducing project manpower requirements and on-site equipment expense.*

of culverts are standard four-sided rectangular box culverts. These two outside culverts, spaced nine feet apart – inside wall to inside wall – are linked by a precast flat slab. This design uses the inside walls of the other box sections for support of the slab.

Simpson Gumpertz & Heger Inc., Arlington, Mass., designed the 'Link Slab' boxes using the BOXCAR software program. The precast sections were manufactured at Choctaw's Ft. Smith, Arkansas plant. Each section was furnished with 7-inch walls, and weighed approximately 1.38 tons per foot. The slabs were 9 inches thick and 10 feet 6 inches long. This length allowed for 9 inches of bearing on both rows of box culverts. Holes were provided on the outside edges of the slabs on 2-foot centers. Forsgren workers positioned the link slabs at the proper location and drilled into the sidewalls. The top slab was then doweled into the parallel culverts using #6 rebar. A 6-inch concrete floor was poured in the base, running the full length of the middle cell. Vic Braddy, Forsgren's chief estimator, commented that all the precast sections and slabs were set in only 17 hours. The speed of installation further contributed to the project cost savings by reducing manpower requirements and on-site equipment expense.

Both the Cain's Ditch channel structure in Jefferson Parish and 'Link Slab' box culvert in Van Buren are cases of unique problem solving with precast concrete products. Who can tell what kinds of applications await concrete box sections when people are willing to think outside the box? Only the versatility and endurance of concrete allow these possibilities to happen. ☺

## Shear Strength Design Provisions Based on the AASHTO LRFD Specification Applied to Concrete Pipe and Compared with Industry Practice

By Frank J. Heger, P.E., Senior Principal  
Simpson Gumpertz & Heger, Arlington, MA and  
San Francisco, CA  
781-643-2000

The author has used his practical approximations of the relatively complex general shear strength provisions given in Section 5 in the new AASHTO LRFD Bridge Specification<sup>1</sup> to evaluate the shear strength of precast reinforced concrete pipe. The purpose of this brief technical note is to compare the results of using the author's proposed shear strength design provisions (derived from the above AASHTO LRFD Bridge Specification) with empirical three-edge bearing strength designs in ASTM C76<sup>2</sup>, shear strength designs for three-edge bearing strength and for buried reinforced concrete gravity flow pipe in ASCE 15 (SIDD) installations<sup>3</sup>, and low-head pressure pipe designs given in ASTM C361<sup>4</sup>.

Shear strength of pipe is calculated using either the proposed provisions, or the equations in current industry practice<sup>5</sup>, by multiplying the square root of design concrete compressive strength in psi by a shear coefficient,  $\beta$ . In ACI 318<sup>6</sup>,  $\beta$  is simply taken as 2. In present pipe industry practice<sup>3,5</sup> and in the author's proposed LRFD provisions,  $\beta$  is calculated by multiplying 2 by a depth factor,  $F_d$ , a strain factor,  $F_{ex}$  and a curvature factor,  $1/F_c$ .  $F_d$  has been found to be the same and  $F_c$  is taken as the same in both the proposed LRFD approximation and the SIDD equations<sup>3,5</sup>. The proposed strain factor,  $F_{ex}$ , is calculated based on the reinforcement strain,  $\epsilon_{xu}$ , (stress/modulus of elasticity) at the governing section for shear in the LRFD provision while in the SIDD practice it is a function of both the steel ratio,  $\rho$ , and the thrust factor,  $F_N$ . Thus, shear strength,  $V_c$ , is calculated using the following equations:

$$V_c = \beta \sqrt{f_c} 'bd \quad \beta = 2F_d F_{ex} / F_c$$

$$F_d = 0.8 + 1.6/d \quad \text{in both methods}$$

$$F_{ex} = 2.2(1 - 3\epsilon_{xu})^{.25} \quad \text{in the author's provisions}$$

$$F_{ex} = (1.1 + 63\rho)F_N \quad \text{in current industry practice}$$

$$F_N = 1 + N/2000bh \quad \text{for compressive thrust}$$

$$F_N = 1 + N/500bh \quad \text{for tensile strength}$$

$$F_c = 1 + d/2r \quad \text{in both methods}$$

Except for members subject to internal pressure producing axial tension, the differences in the shear coefficient,  $\beta$ , given by the two methods are essentially small differences in the strain factor,  $F_{ex}$ . For members with axial tension (low-head pressure pipe), the thrust factor,  $F_N$ , taken from ACI 318 has been found to be extremely conservative and inaccurate. Another difference is for members with distributed load where moment decreases with increasing shear. In the proposed method the location of the section for governing shear strength is taken at  $M/Vd = 2.5$ , compared to  $M/Vd = 3$  in current industry methods, where  $M$  is the effective moment modified by compressive or tensile thrust.

### COMPARISONS OF DESIGN RESULTS FOR PIPE WITH EXISTING INDUSTRY PRACTICE

#### Three-Edge Strength of Gravity Flow Pipe

Table 1 gives a comparison of three edge bearing strengths calculated using the proposed shear strength design provisions with strengths specified for 13 empirical pipe designs given in ASTM C76-98 whose limiting ultimate strength is governed by shear. A similar comparison is provided using the shear strength provisions given in the ACPA Concrete Pipe Technology Handbook<sup>5</sup>. The calculated values of the shear strength coefficients,  $\beta$  and  $\beta_{acpa}$  are also given for each of the two design procedures.

Concrete strengths and reinforcement areas are those specified in the ASTM C76 tabular designs for the class and wall designs in the table, except 5000 psi is used for all the Class 4 pipe while C76 allows 4000 psi for some of the smaller sizes in this class. A  $f$  factor of 1.0 is used for comparing the predicted strengths using both of the direct design procedures to the D-load ultimate strengths required in C76.

The results shown in Table 1 demonstrate that both the proposed LRFD approximation and the SIDD (ACPA Concrete Pipe Technology Handbook) provisions give accurate though slightly conservative representation of shear strengths that have been derived from many tests using a variety of concrete materials and processes. They also show that the results obtained with the industry equations and the proposed provisions based on the general shear provisions in the LRFD Standard are about the same.

#### Direct Design of Gravity Flow Pipe For Shear In SIDD Installations

Table 2 gives a comparison of maximum fill heights determined for buried pipe designs in SIDD standard installations governed by shear strength using both the author's proposed shear strength provisions based on the new LRFD Bridge Specification and the shear

**Table 1 - Comparison of Calculated 3-Edge Bearing D-Loads with ACPA Technology Handbook Calculated D-Loads and C76 D-Loads for Pipe Whose Strength Is Governed by Shear**

Inside Diam in	Class /Wall	h in	d in	A <sub>si</sub> in <sup>2</sup> /ft	f <sub>c</sub> ' ksi	C76 DL psf	LRFD β DL	calc DL psf	Acpa β <sub>acpa</sub>	Design CalcDL <sub>a</sub> psf	Ratio β/β <sub>acpa</sub>
36	4 – B	4	2.87	0.30	5	3000	1.95	3089	2.10	3343	0.93
36	5 – B	4	2.82	0.50	6	3750	2.22	3812	2.62	4531	0.85
48	4 – B	5	3.84	0.42	5	3000	1.86	2906	1.92	3003	0.97
48	5 – B	5	3.79	0.73	6	3750	2.11	3619	2.43	4198	0.87
60	4 – B	6	4.82	0.59	5	3000	1.84	2847	1.85	2878	0.99
60	5 – C	6.75	5.55	0.70	6	3750	1.81	3593	1.79	3538	1.01
72	3 – B	7	5.83	0.49	4	2000	1.66	2242	1.55	2075	1.07
72	4 – B	7	5.79	0.79	5	3000	1.83	2804	1.84	2817	1.00
72	5 – C	7.75	6.52	0.99	6	3750	1.84	3536	1.85	3553	0.99
84	3 – B	8	6.87	0.64	5	2000	1.62	2460	1.54	2317	1.05
84	4 – C	8.75	7.53	0.85	5	3000	1.71	2884	1.60	2666	1.07
96	3 – B	9	7.79	0.76	5	2000	1.61	2386	1.52	2228	1.06
108	3 – B	10	8.50	1.08	5	2000	1.63	2293	1.64	2308	0.99

**Note: Calculated D-Loads are based on a f factor of 1.0**

strength provisions given in ASCE 15 (SIDD). The author's provisions use the equations with strain factor from the LRFD Standard given above at a governing section for shear at the location where the M/Vd ratio is 2.5, while the SIDD provisions use the alternate strain factor given above for current industry practice at a governing location where M/Vd ratio is 3.0.

The table shows that the design fill heights are nearly the same using either shear design method. This provides a further confirmation that either of these methods is an accurate representation of shear strength of precast reinforced concrete pipe.

**Direct Design of Low-Head Pressure Pipe For Shear In SIDD Installations**

Table 3 gives a comparison of maximum fill heights determined for buried low-head pressure pipe designs

in SIDD standard installations with reinforcement areas, concrete compressive strengths, wall thickness, and maximum internal pressure as given in ASTM C361. Designs using both the author's proposed shear strength provisions based on the new LRFD Bridge Specification and the shear strength provisions given in ASCE 15 (SIDD) are compared. The governing criteria for the C361 reinforcement areas, flexure or shear, is given as "f" for flexure, or "sh" for shear, or "f,sh" for approximately equal flexure and shear limits.

The strain factor used with the author's proposed provisions is calculated at a governing section where shear is maximum, while the strain factor used with the SIDD provisions is the alternate strain factor containing the ACI based tensile thrust factor calculated at the same governing location where shear is maximum. The maximum shear is used because

**Table 2 - Comparison fo Shear Strength Coefficients and Max Height of Earth for Example ASCE 15 Buried Gravity Flow Concrete Pipe**

SIDD Instal Type	Inside Diam In	h in	d in	A <sub>si</sub> in <sup>2</sup> /ft	LRFD β <sub>2.5</sub>	PROP Max H ft	ASCE β <sub>3</sub>	15 DES Max H ft
1	96	9	7.79	0.798	1.77	25.6	1.58	24.7
2	96	9	7.77	0.864	1.80	17.8	1.61	17.0
4	96	9	7.77	0.961	1.83	9.9	1.65	11.2
2	72	7	5.80	0.702	1.90	20.1	1.78	20.8

**Notes: f<sub>c</sub>' = 5000 psi; Ø = 0.90; f<sub>y</sub> = 65000 psi; wire space =2 in; Load Factor = 1.3**

**Table 3 - Comparison of Shear Strength Coefficients and Fill Heights for ASTM C361 Standard Designs for Low-Head Pressure Pipe Under 54 PSI (125 ft head) Internal Pressure**

Design Parameters					Proposed LRFD Shear		ASCE 15 SIDD	
Pipe Inside Diameter (in.)	h (in.)	d (in.)	A <sub>si</sub> * (in. <sup>2</sup> /ft)	SIDD Install Type	β	Max H** ft	β <sub>SIDD</sub>	Max H <sub>SIDD</sub> ** ft
42	4.5	3.28	0.86	1	2.51	20 f	1.22	20 f,sh
60	6	4.75	1.22	1	2.20	20.5 f	.95	9.5 sh
84	8	6.68	1.79	1	2.01	22 f,sh	.82	2.8 sh
108	9.5	8.12	2.32	1	1.93	20 f,sh	.63	-4.4 sh

**Notes**

\*Inside reinforcement area – ASTM C361; Max design f<sub>y</sub> = 40,000 psi

\*\*Unit Weight Earth: 120 lbs/cu ft; f indicates flexure governs A<sub>si</sub>;f, sh indicates both shear and flexure  
 Concrete Compr Strength-4500 psi; Flexure-φ<sub>f</sub> = .95; Shear- φ<sub>v</sub> = 0.9; Load Factors: Flexure-1.7; Shear-1.4

the large axial force produced by the internal pressure causes the effective M/Vd to be larger than 2.5 or 3.0 for all locations.

The principal reason why the designs based on SIDD criteria have very low calculated shear strengths is the use of the ACI tensile thrust factor in the SIDD shear calculations.

However, it should be noted that ASCE 15 excludes the design of pipe having internal pressure greater than 50 ft of head and ASCE 15 designs are included in Table 3 only to show that the ACI tensile thrust factor is much too conservative to use for practical design of pipe with substantial internal pressure.

The design tables in ASTM C361 are based on reinforcing areas obtained using a maximum design yield strength of 40,000 psi and a load/φ factor of 1.8 for flexure plus axial tension. These conservative flexure criteria are used in order to minimize cracking that might result in leakage. However, as yet no published criteria for shear limits are in ASTM or AWWA standards. A load factor of 1.4 and a φ factor of 0.90 for shear are proposed for a new ASCE SIDD standard for low-head pressure pipe<sup>7,8</sup>. These are used for the designs in Table 3.

The tabulated designs show that the ASTM C361 designs have adequate flexural and shear strength provided they are installed in high quality installations. The good correlation with the fill height and internal pressure limits given in the C361 Tables is another confirmation of the author's proposed shear strength provisions.

**Conclusion**

The example pipe design results shown above demonstrate that the shear design provisions originally developed for concrete pipe in the 1970 and 80<sup>6</sup> are confirmed by the study of the author's proposed new

shear strength criteria derived based on the provisions of the recently published AASHTO LRFD Bridge Specification. The one exception is the thrust factor for axial tension. This was taken from ACI 318 but has been shown to be too conservative and inaccurate for determining the shear strength of low-head pressure pipe. The shear strength of this pipe may be calculated using the new procedure as codified in a proposed new SIDD Standard for Concrete Low-Head Pressure Pipe<sup>7</sup>.

**References**

1. AASHTO LRFD *Bridge Design Specifications and Commentary*, 2<sup>nd</sup> ed., American Association of State Highway and Transportation Officials, Washington, D.C., 1998.
2. ASTM C76–98a, "Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe", *Annual book of ASTM Standard*, Vol. 04.05, 1998.
3. ASCE 15-93, "Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD). 1993.
4. ASTM C361–98, "Specifications for Reinforced Concrete Low-Head Pressure Pipe", *Annual book of Standards*, Vol. 04.05, 1998.
5. American Concrete Pipe Association, *Concrete Pipe Technology Handbook*, 2nd printing, 1994.
6. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318–99) and Commentary (ACI 318R–99)", American Concrete Institute, Farmington Hills, Mich., 1999.
7. ASCE, Proposed Standard Practice for Direct Design of Buried Precast Concrete Low-Head Pressure Pipe Using Standard Installations (SIDD). Committee Draft, June 2000.
8. Heger, F.J., "SIDD Installation and Direct Design for Reinforced Concrete Low-Head Pressure Pipe, ASTM STP 1368, "Concrete Pipe for the New Millennium," May 1997.

## Leonard L. Klien

continued from page 4

include lateral pressure, surcharge load (hydraulics), product inlet and outlet conditions, junctions and change in direction, line loss, and hydrogen sulfide in some instances.

**Q:** *What is the most common misconception regarding reinforcement?*

**Klein:** The most common misconception is that placement of the steel is not important. This is very critical and production people sometimes don't realize this, especially with elliptical pipe. If the design calls for an inch of cover, then the production people must follow the specification.

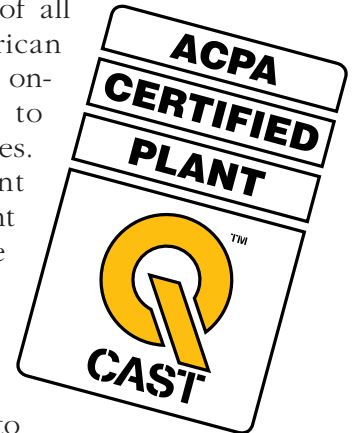
**Q:** *Did the 204-inch Henry Drain installation set any precedents in the design of reinforcement for large diameter concrete pipe?*

**Klein:** I still believe that this project is the largest gravity sewer pipe in the world. To get to this size was an evolutionary process and we developed the design as we increased sizes. When we started out to design the sewer, we had experience with large diameter pipe. We had to be sure that there was equipment capable of handling the product – and it was readily available. The tender for the project called for a poured-in-place box sewer. However, when we proposed precast concrete pipe instead, it proved to be less costly and faster to install.

Mr. Klein concluded his interview by remarking that when specifiers specify other products, they hope they have made the right choice. But, when you specify concrete pipe, you know you have done the right thing. ☺

## “Quality Cast” Certified Plants

To improve the overall quality of all concrete pipe products, the American Concrete Pipe Association offers an on-going quality assurance program to member and non-member companies. Called the “Quality Cast” Plant Certification Program, the 124-point audit-inspection program covers the inspection of materials, finished products and handling/storage procedures, as well as performance testing and quality control documentation. Plants are certified to provide storm sewer and culvert pipe or sanitary sewer, storm sewer and culvert pipe under a combined program. The following plants have been certified under ACPA’s Quality Cast Certification Program:



### Storm Sewer and Culvert Pipe

- Cayuga Concrete Pipe Company (Oldcastle, Inc.),  
New Britain, PA  
Edward Pentecost
- Sherman-Dixie Concrete Industries, Inc., Chattanooga, TN  
Earl Knox
- Sherman-Dixie Concrete Industries, Inc., Franklin, TN  
Roy Webb
- Tarmac America, Inc., Charleston, SC  
Bill Gary

### Sanitary Sewer, Storm Sewer and Culvert Pipe

- Amcor Precast (Oldcastle, Inc.), Nampa, ID  
Mike Burke
- Amcor Precast (Oldcastle, Inc.) Ogden, UT  
Tim Wayment
- CSR Hydro Conduit Corporation, Tulsa, OK  
Jeff Bassett
- Elk River Concrete Products (Cretex), Elk River, MN  
Bryan Olson
- Geneva Pipe Company, Orem, UT  
Fred Klug
- Kansas City Concrete Pipe Co. (Cretex), Shawnee, KS  
Rich Allison
- N.C. Products (Oldcastle, Inc.), Fayetteville, NC  
Preston McIntosh
- Ocean Construction Supplies Limited (Inland Pipe),  
Vancouver, BC, Canada  
Rod Boyes
- W.R. White Company, Ogden, UT  
J. P. Conn

# Precast Concrete Box Sections Design Software Available

ACPA has just released Version 2.0 of BOXCAR – an innovative software program that can help engineers and specifiers significantly reduce design time and costly over-designs on projects using precast concrete box sections. Deriving its name from “Box Culvert Analysis and Reinforcing Design”, this popular interactive software program can be used to calculate reinforcing steel areas for user-specified box geometry, material properties and loading data. Boxcar Version 2.0 is available on CD-ROM.

BOXCAR Version 2.0 is an update of the original software program developed by the Federal Highway Administration, in cooperation with the American Concrete Pipe Association. The Windows® based program incorporates the direct method of design for the structural analysis and design of precast reinforced concrete box culvert sections. It provides complete

structural analysis for loads due to box weight, soil weight, internal gravity fluid weight, live loads and user specified surcharge loads. Structural design methods conform to standards set by the American Association of State Highway Transportation Officials (AASHTO) and include ultimate flexure, shear and service load crack control.

To order BOXCAR Version 2.0, contact the ACPA Resource Center at (800) 290-2272, fax (972) 291-0622. Cost: \$75.00 member, \$150.00 non-member, plus shipping and handling. Visa, MasterCard and American Express are

accepted. Specify resource item #15-901. For further information, contact the American Concrete Pipe Association, (972) 506-7216, or e-mail: [info@concrete-pipe.org](mailto:info@concrete-pipe.org) ☺



American **Concrete Pipe** Association  
222 W. Las Colinas Blvd., Suite 641  
Irving, TX 75039-5423

-----  
[www.concrete-pipe.org](http://www.concrete-pipe.org)

Bulk Mail  
U.S. Postage  
PAID  
Dallas, TX  
Permit No. 1883