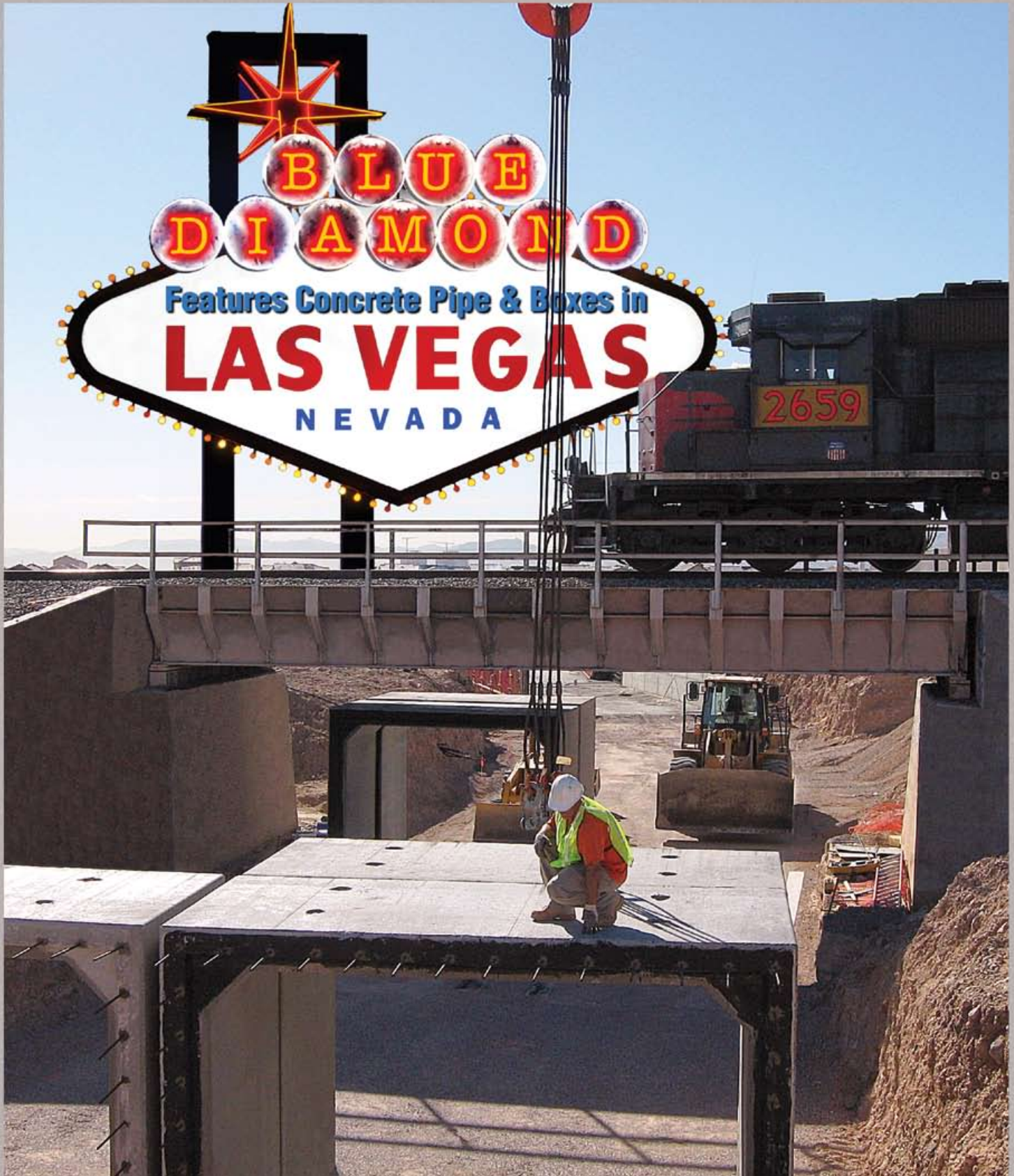


CONCRETE PIPE NEWS



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American **Concrete Pipe** Association



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Concrete Pipe News is published four times each year by the American Concrete Pipe Association. It is designed to provide information on the use and installation of precast concrete pipe products for a wide variety of applications, including drainage and pollution control systems. Industry technology, research and trends are also important subjects of the publication. Readers include engineers, specifiers, public works officials, contractors, suppliers, vendors and members of the American Concrete Pipe Association.

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Boxes Set in Record Time For Construction of Prestigious Hockey Field 13

Managing storm water runoff for the reconstruction of the hockey field at the prestigious John Burroughs School in St. Louis was a major challenge. Design of the buried storm water management structure required for runoff from the field and an existing stream was originally specified to be constructed with corrugated metal pipe. The specification was changed to precast concrete boxes because the service life of the concrete boxes far exceeded the service life of corrugated metal.

The 140-foot section of precast dual boxes was completed in nearly three days with both ends of the precast culvert being tied into a cast-in-place open channel waterway.

Photos: Jay Young of Geneva Pipe



editorial

*Matt Childs, P.E.
President*

American Concrete Pipe Association



Ours Is a Specifications-Driven and Science-Based Industry

The gravity pipe industry is, and will continue to be, a specifications-driven industry. Although it is impossible to know what the industry will look like in 2107, it will be based on advances in scientific knowledge and the application of that science by engineers. It is impossible to know what the industry will look like in 2107. With globalization quickly engulfing our economy and subsequently our industry, projecting what the industry may be like even ten years from now is a challenge. There are signs however, that do cast some light on the road ahead. In 2018, I will read this editorial and know

if my predictions about pipe performance were prophetic.

Specifications written for sanitary and storm sewers, as well as storm water management projects, are the bread and butter of the gravity pipe industry. The concrete pipe industry and its competitors respond to specifications, presented by contractors and engineers, with a wide range of products and manufacturers' performance claims.

The choice of materials generally includes concrete, high density polyethylene, polyvinyl chloride and corrugated metal. Others on the market include fiberglass, clay, and emerging materials entering the US markets from abroad.

It is incumbent upon the American Concrete Pipe Association, its producer members, and associates to focus on research and development and the modification of standards to keep pace with change, driven by science, to offer products that meet specifications. I foresee a period of intense research and development in collaboration with the cement and steel industries to produce stronger concrete pipe and boxes with less steel.

The Association will also become more involved with scientists and labs in leading North American universities and researchers in Europe to build an irrefutable body of knowledge on the performance of high density polyethylene conduits. Products from this material are installation sensitive, and some may claim that HDPE conduits are easy to install. It is becoming clear that HDPE conduits are certainly easy to install - incorrectly, and this leads to poor performance. Strong third party evidence of poor performance of HDPE is already surfacing

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Feature Story

By Randy Wahlen, P.E.
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You may not notice from inside the casinos that the Las Vegas Strip is at the heart of one of the most difficult-to-manage storm water basins in the world. Recent urban sprawl has created a population of approximately 2 million. This development has significantly increased the hard surface areas associated with rapid runoff. These surfaces, along with steep mountain slopes and the armored desert floor are flooding surface water into the dry desert washes more frequently than any time in recorded history. While the average rainfall in the Las Vegas Valley is 4.49 inches, a half inch of rain falling over the entire valley can bring major roads to a standstill. Summer thunderstorms can drop half of the annual rainfall, leading to deaths and major property damage. Water flowing through Las Vegas Valley channels and detention basins can rise as fast as one foot per minute and move as quickly as 30 miles per hour. National statistics show that more deaths occur in floods each year than any other natural disaster.

The Clark County Regional Flood Control District was created in early 1985 by a Clark County ordinance to fund and coordinate the construction of flood control facilities. The District was charged with developing and overseeing a coordinated and comprehensive flood control master plan to alleviate flooding in Clark County, and to regulate land use in flood hazard areas. On September 2 1986, voters approved a quarter cent sales tax to fund construction of regional flood control facilities. In 1987, the Regional Flood Control District began receiving sales tax revenues and started constructing flood control projects. It is anticipated that it will take another 25-30 years of construction before the entire Master Plan is completed.

The Blue Diamond Watershed, located in the southwest portion of the Las Vegas



Valley, totals approximately 131 square miles. While it is comprised mainly of detention basins connected by conveyance facilities, construction has become more difficult as the facilities approach previously developed sections of the city. The Blue

Diamond Flood Control Project from Valley View Boulevard to Decatur Boulevard parallels the busy Blue Diamond Road for nearly two miles. With the rapid growth on the southwest side of the Valley, Blue Diamond Road has become the major traffic corridor. Precast concrete pipe with a 100-year maintenance-free design life was therefore a natural design choice for any works associated with the roadway. Nearly 10,000 feet of storm sewers were installed in this corridor, including 60-inch diameter reinforced concrete pipes and various sized precast reinforced boxes including 4-foot x 4-foot, 6-foot x 4-foot, 8-foot x 4-foot and 10-foot x 4-foot sections. Concrete pipe comprises the major trunk line along Blue Diamond Road.

In addition to traditional concrete pipe



Photos: Jay Young
of Geneva Pipe

installations, a large concrete box culvert was installed at a railroad crossing. The Nevada Department of Transportation and Clark County Flood Control District oversaw this portion of the project. Construction of the dual width 12-foot x 10-foot precast reinforced concrete box culvert required significant coordination of all parties. Hydraulic modeling showed that the existing railroad structure could be damaged from a flash flood with over 4,000 cfs of storm water. While it would have been ideal to replace the existing railroad structure, the railroad required a construction window of 12 hours of downtime to the existing tracks. Construction of the new embankment over the box culvert and reconstruction of the railroad tracks could not be completed during the available timeframe, although the precast box culvert could be placed quickly and backfilled immediately. It was determined that the dual box culvert could be completed underneath the existing railroad tracks without disturbing the tracks or structure.

The initial precast box sections, supplied by Geneva Pipe Company, were set on the upstream side of the tracks as close to the existing structure as possible. Additional sections were placed on the downstream side of the tracks, and then slid underneath the track bed until they were homed with the precast sections on the other side. The construction procedures were simplified by installing concrete footings to grade under the existing structure. The footings were then used to slide the box sections into position. Very fine graphite pellets were placed on the footings, so that a D-6 bulldozer could push the 25-ton sections into place easily. There was no difficulty in maintaining grade, due to the concrete footing. The most challenging part of the procedure was

properly aligning the initial sections of the box culvert. Work proceeded uninterrupted, except for the passage of an occasional train. The 140-foot section of precast dual boxes was completed in nearly three days with both ends of the precast culvert being tied into a cast-in-place open channel waterway.

Clark County continues to grow at a rapid pace of almost 6,000 residents each month with a current population of 1.9 million people. Although residential development slowed in 2007, public works projects continued to ensure the safety of the many new residents and the 40 million tourists that visit Las Vegas Valley annually. ☺

Project:	Blue Diamond Corridor from Valley View to Decatur Clark County, Nevada
Owner:	Regional Flood Control District, Clark County, Nevada
Consulting Engineers:	VTN Consulting Las Vegas, Nevada HDR, Inc. Las Vegas, Nevada
Contractor:	Capriati Construction Corporation Las Vegas, Nevada
Producer:	Geneva Pipe Company Las Vegas, Nevada Plant
Quantities:	10,000 feet (approximately) of pipe product, including: 3,932 feet of 4-foot rise reinforced concrete box sections (4 foot through 10-foot spans) 284 feet of 12-foot x 10-foot reinforced concrete box sections (culvert for railroad crossing) 3,252 feet of 18 to 54-inch diameter reinforced concrete pipe 2,076 feet of 60-inch diameter reinforced concrete pipe Assorted elliptical pipe and pipe end sections



The Las Vegas branch of Geneva Pipe has been producing pipe and boxes for over 7 years. Geneva Pipe Company, headquartered in Orem, Utah, has been in operation for over 50 years and offers a variety of products depending on plant location. See www.geneva-pipe.com for product information and location of facilities.

Perseverance and Due Diligence a Winning Combination for Urban Transitway

By Jean M. Caron
 Technical Resources Engineer
 Hanson Pipe & Precast
 401-741-2418

Challenges facing city engineers are not getting any easier in a time of rapid urban growth that places pressure on delivery of vital services and public works. Demands from elected representatives to satisfy constituencies, and allocation of tax revenue for capital works while seeking federal and state assistance and approvals add to the daily mix of problems to be solved. In addition, city engineers must cope with a myriad of materials and products proposed to meet specifications and standards for infrastructure. The bidding process for the Stamford Urban Transitway (SUT in Connecticut), and its outcome is a story of perseverance by the City Engineer to deliver a project that met the specifications of the City for a high performance mile-long road to provide a direct connection to the Stamford Intermodal Transportation Center (SITC).

The Stamford Urban Transitway was designed to improve traffic operations along I-95 service roads and access to the train station area. The SUT corridor is a critical element to the overall south end master plan, and will enhance the public transportation network by improving access to the SITC. These improvements in conjunction

with the street alignment and traffic signal improvements proposed with the SUT project will improve the traffic operations of the area for bus, rail, car and pedestrian traffic. The road is expected to encourage use of the Metro-North Railroad by giving drivers a more direct way to get to the train station from the east side and to serve traffic from new development in the south side of the city. City officials

consider the transitway as a gateway to a revitalized south end of the city

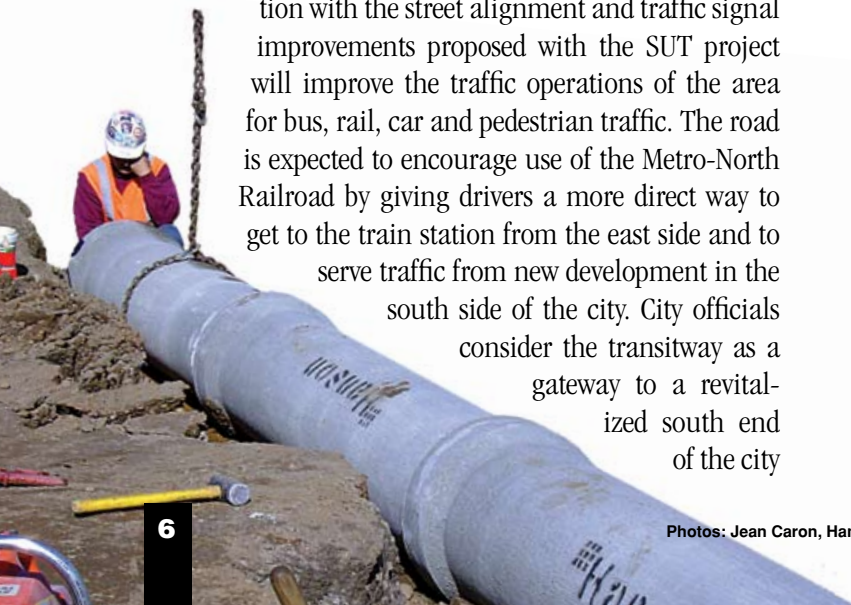
comprised of new housing, offices and retail within walking distance of the train station. Antares Investment Partners plans to build an 80-acre development, once the transitway is complete.

The project corridor is a densely developed area located in south-central Stamford, characterized by a network of storm sewers that outlet into the tidal waters of the East Branch of Stamford Harbor. A series of tide gates, pump stations and dikes isolate portions of the storm water system from the high tide levels of Long Island Sound.

Low points along the corridor were poorly drained and resulted in roadway flooding during heavy rain events. The drainage design for the transitway is based on the City of Stamford's criteria of a 25-year storm frequency and a mean high water (MHW) elevation of 6.5 feet. Due to the generally flat grades and roadway elevations close to the MHW, tailwater conditions are high and result in outlet control backwater conditions during the design storm. Without tide gate controls, roadway flooding during high Long Island Sound water events would be unavoidable.

After more than a decade of lobbying and seeking state and federal funding, the City posted the 30-month project for public bidding in March 2007. Only one contractor submitted a proposal that was well over the estimated budget. Contractors were reluctant to bid on the project because it was a high-risk contract. The environmental cleanup in certain sections of the alignment could expand once the contractor started testing soil, and delays caused by coordination problems with utility companies or Metro-North Railroad could reduce profitability. The City Engineer realized that a successful award of the contract would require revisiting the design and specifications and re-bidding the project. The only bidder, Earth Technology, was \$7 million over the \$16 million budget for construction and environmental cleanup.

Fuss & O'Neill, a consulting engineering firm specializing in environmental, structural, transportation, building systems, industrial and infrastructure services, designed the transitway. The City Engineer worked with the consultant to review the design and look for opportunities to modify the specifications for a second bid. Among the changes was a request from the City to change storm sewer piping products from reinforced concrete pipe to high density polyethylene (HDPE) conduit in sizes 36-inch diameter and smaller. It was at this point that Hanson Pipe & Precast became involved to assist the design engineer, city engineers and federal funding agency (the



Federal Transit Administration) in coming to terms with the costs and performance of rigid and flexible gravity pipe for the storm drainage system.

The City Engineer played a significant role in balancing the interests of the funding agency with the technical needs of the project (identified by the consulting engineer's design), and the bid of the contractor to construct a high performance connecting road. The City Engineer pressed the pipe producer and design engineer, under the watchful eyes of the funding agency, to produce the hard evidence that would justify the case for a more expensive capital cost of concrete pipe over a lower capital cost for high density polyethylene conduit.

The Connecticut Department of Transportation (CONNDOT) does not allow HDPE under vehicle loads without additional structural design calculations. In addition to pipe strength calculations for HDPE in accordance with AASHTO, the Connecticut Department of Transportation requires AASHTO strength calculations for fills greater than 8 feet, fills less than 3 feet, adverse soil conditions, and high water tables. One section of the sewer installation was thirteen feet deep, while underground storage tanks had to be remediated on another.

The Connecticut Department of Transportation drainage design manual states "Designers must recognize that a buried plastic pipe is a composite structure made up of a plastic ring and the soil envelope and that both materials play a vital part in the structural integrity of the plastic pipe. In contrast, a buried reinforced concrete element is less influenced by the soil envelope." The City Engineer issued an addendum, removing all HDPE from the project, replacing it with reinforced concrete pipe, as originally specified.

The project was bid a second time. Again, the only contractor to respond was Earth Technology, but their bid increased from \$23.5 million to \$25 million, forcing city engineers to evaluate whether to rebid the project a third time, or negotiate with the contractor. With all costs in for the construction of the storm sewer, the total price differ-

ence for the pipe supply between HDPE and concrete pipe was \$2,771.

The overall contract was firmed up and Earth Technology awarded the project. To ensure that products were being installed according to specifications, the City retained the services of AI Engineers, Inc. from Middletown, Connecticut as their field inspection engineer.

Earth Technology started installing 15-inch diameter profile gasket reinforced concrete pipe in October. To accommodate other underground utilities and minimum cover constraints, 160 feet of 43-inch by 68-inch elliptical concrete pipe would be installed. The City's standard installation detail for storm drainage pipe with less than three feet of cover was to encase the pipe with concrete. This is a good practice with HDPE pipe, but was unnecessary with Class IV RCP that is approved for installation with only one foot of cover. Thus, significant cost savings were achieved.

In some locations of the sewer alignment, there is a high ground water table. When the tide comes in,

the tailwater is just below the surface. Earth Technology had to use well points in these areas to lower the ground water for trench excavation and proper installation of the pipe. On sites where there is a high water table or tidal situation, the mass of concrete pipe makes it a most appropriate selection to avoid complications associated with pipe buoyancy.

In a low laying or marshy environment, the buoyancy of buried pipelines depends on the mass of the pipe material, the weight of the volume of water displaced by the pipe, the weight of the liquid load carried by the pipe, and the weight of the backfill material. Whenever the water table level is above the invert of the pipeline, the potential for flotation or buoyancy exists. Although the trench for a pipe installation in an area characterized by a high water table is dewatered, the trench area downstream (after initial backfill) may become saturated. This would lead to a buoyant effect on the pipe. The mass of the concrete pipe typically counteracts this buoyant force. Alternate materials such as thermoplastic pipe and corrugated metal pipe



may heave vertically or snake horizontally in wetland conditions. During the backfill operation, the fill may accumulate more on one side of the pipe than the other. The massive weight of the concrete pipe resists lateral forces, and the structure itself remains true to line and grade.

Concrete pipe is known as a rigid pipe that provides both structure and conduit when it arrives on site. Flexible pipe systems including high density polyethylene, polyvinyl chloride, and corrugated metal provide the conduit only. Backfill must be properly engineered and constructed to provide structure. Imported fill is usually required for flexible pipe systems. All of this adds to the cost of a flexible pipe installation that is often overlooked by the low initial (capital) cost.

Concrete pipe is recognized for quality of manufacturing, consistent strength, availability in designs and sizes to serve many installations, contractor friendly, and competitive with poured-in-place concrete structures and flexible pipe under many circumstances. Concrete pipe is a rigid pipe system that is over 85% dependent on the pipe strength and only 15% dependent on the strength derived from the soil envelope. The inherent strength of concrete pipe compensates for construction shortcomings, higher fill heights, and trench depths such as the 13-foot deep section of the SUT corridor.

Concrete pipe is less susceptible to damage during construction and maintains its shape, unlike flexible pipe. Some job sites along the route of the transitway had little room for the installation, and by using concrete pipe, there was less chance of damage to the pipeline due to construction traffic. Flexible pipe must deflect to reach its maximum installed performance. Flexible pipe is at least 95% dependent on soil support and the installation expertise of the contractor. This is the single most critical factor for using flexible pipe. Specifiers of flexible pipe products must consider design theory balanced against the practicality of installing the products in each application. Concrete pipe in comparison, has an unlimited range of pipe strengths from which to choose, and strength is demonstrated prior to installation. By specifying concrete pipe, the designer has more control over pipe strength than any other facet of the project. There is less reliance on quality installation by the installer, and there is lower embedment material cost. With less compaction required, it is easier to maintain grade and alignment and there are no excess deflection concerns with concrete pipe. In addition to these features of reinforced concrete pipe, there is a lower

life cycle cost and predictable maintenance costs over the design life of the project. Overall, when installing a reinforced concrete pipeline, there is lower risk for the specifier, designer and owner of the project, and reduced liability to the public after the project has been commissioned.

Stamford's City Engineer had to make tough decisions and choices in securing a contract for the construction of the transitway. He facilitated acceptance of a proposed bid that, although higher than expected, resulted in a contract that would meet the expectations of City Council and commuters that depend on road and rail services. The decision to use concrete pipe was not taken lightly, but after the addendum to the contract was issued, the city was assured a high performance storm drainage system for the design life of the project. ☺

Project:	Stamford Urban Transitway Stamford, Connecticut
Owner:	City of Stamford
Consulting	Fuss & O'Neill, Inc.
Engineers:	Manchester, Connecticut
Contractor:	Earth Technology Inc. North Haven, Connecticut
Producer:	Hanson Pipe & Precast Wakefield, Rhode Island
Quantities:	856 feet of 12-inch diameter Class IV RCP 3328 feet of 15-inch diameter Class IV RCP 248 feet of 18-inch diameter Class IV RCP 128 feet of 21-inch diameter Class IV RCP 1,800 feet of 24-inch diameter Class IV RCP 304 feet of 30-inch diameter Class IV RCP 1,352 feet of 36-inch diameter Class IV RCP 760 feet of 42-inch diameter Class IV RCP 56 feet of 48-inch diameter Class IV RCP 168 feet of 43-inch x 68-inch Elliptical Class IV RCP 72 feet of 12-inch diameter Class V RCP 32 feet of 15-inch diameter Class V RCP 40 feet of 30-inch diameter Class V RCP 40 feet of 42-inch diameter Class V RCP

Hanson Pipe & Precast is the largest manufacturer of concrete pipe and precast products in North America. The company has participated in some of the nation's largest public works, airport and highway construction projects. State Departments of Transportation, major cities and counties, public authorities, the Army Corps of Engineers, major airports and numerous private entities are among Hanson's customers. See www.hansonpipeandprecast.com for details.

Investigations of Shear Behavior in Reinforced Concrete Boxes

By Ali Abolmaali, Ph.D., P.E.

Associate Professor, Department of Civil and Environmental Engineering, UTA

Director, University of Texas at Arlington Center for Structural Engineering Research

Professor-in-Charge, NSF Funded Structural Simulation Laboratory, UTA

Introduction

Box culverts have been used increasingly since 1965 to meet drainage requirements where the site conditions and loads acting upon them have been appropriate. It is believed that 80% of single barrel culvert installations are precast, and manufactured in a range of span and rise combinations. Box sections are typically defined by their span, rise, and design height of fill measured from finished grade to the top of the box section. The joint or "laying" length is a function of the form equipment accessible to the individual producer. The inside corners of the wall and slabs are tapered to create a haunch, which usually has equal horizontal and vertical dimensions. The haunch dimensions are equal to the wall thickness though some producers utilize form equipment, which yields a fixed haunch dimension. With the exception of the special design cases, the thickness of culvert walls, top slab and bottom slab varies from 4 inches to 12 inches (10 cm to 30 cm) and is a function of the span. Boxes are reinforced with the inside and the outside layers of plain or deformed steel welded wire reinforcement per ASTM A 185 (2001) and A 497 (2001). These reinforcing layers are pro-

portioned to resist the calculated moments and thrusts in the member's sections.

Precast box sections used to be designed as per ASTM C 789 for highway loading with earth cover of 2 feet (61 cm) or more or as per ASTM C 850 for highway loading with earth cover less than 2 feet (61 cm). Since 2003, ASTM C 1433 (2003) has replaced C 789 and C 850 for both loading conditions.

Precast box sections are typically cast by either the drycast



or wetcast method with batches designed to yield 5000 psi (34.5 MPa). Drycasting is characterized by the use of very low water/cement (w/c) ratios (0.35 or less) while wetcast uses standard mix designs yielding slumps in the range of 4 inches (10 cm) to 6 inches (15 cm).

Research Need

Box culverts are typically designed similar to bridges, and the new design concepts for bridges are based on the Load and Resistance Factor Design (LRFD) developed by AASHTO 1998. These specifications introduced new provisions for distributing live loads to the reinforced concrete bridge decks, which also apply to the design of reinforced concrete boxes with depths of fill less than 2 feet (61 cm).

The AASHTO (1998) provisions introduced three separate equations for the height of fill less than 2 feet (61 cm) based on axle load for distributing live load to the top slab of box culverts. These equations include one equation for spans greater than 15 feet (4.6 m) and two equations for spans less than 15 feet (4.6 m), depending on the sign of the bending moment. McGrath et al. (2004) reported that the distribution width equation for spans greater than 15 feet (4.6 m) were developed based on the National Cooperative Highway Research Program (NCHRP) Project 12-26, while the distribution width for spans less than 15 feet (4.6 m) were based on a study conducted by Modjeski and Masters (2003).

AASHTO (2002) provisions provided a single equation for distribution width for heights of fill less than 2 feet (61 cm), based on a single axle load on the top slab of boxes. This distribution applies to all span lengths for both positive and negative bending moments and shear force. Compatible comparisons of the distribution width for depth of fill less than 2 feet (61 cm), calculated based on AASHTO (1998) and AASHTO (2002) indicate noticeable differences.

To address these differences and develop a more simple distribution, McGrath et al. (2004) used the element method (FEM) to investigate the live load distribution widths for reinforced concrete boxes. This study concluded that the distribution width for shear in general was narrower than that of positive and negative bending moments, and it governed the behavior. The results of this study are

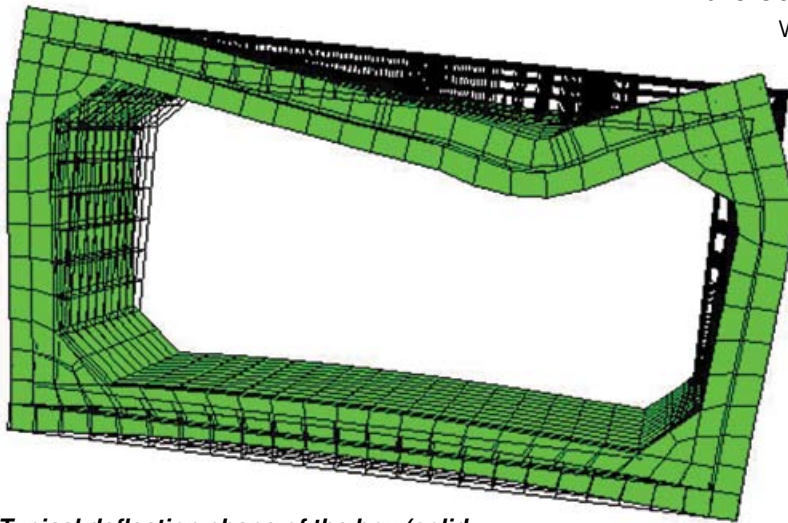
implemented in the Interim AASHTO (2005) specification, which provides new distribution width equations based on shear force distribution. The provisions suggest a means of transfer should be provided across the joint, if the calculated distribution width exceeds the length between the two adjacent joints.

AASHTO (1998) specifications require design check for shear at all depths of fills, while the AASHTO (2002) specifications only require it for depth of fill more than 2 feet (61 cm). This is because the shear strength characteristic of boxes with depth of the fill less than 2 feet (61 cm) is controversial, since boxes are constructed with spans as small as 3 feet (91 cm) with slabs thinner than typical bridge decks. Prior to Interim AASHTO (2005) specifications, boxes were not required to be designed with joints to transfer direct shear across the joints. This concept was based on the research studies conducted by James (1984) and Frederick et al. (1988), which reported that shear transfer was not critical with zero fill depth across the joint due to the small deflections and strains that caused no cracks at service load. However, both the aforementioned studies placed the wheel live load at the edge of the bell or spigot ends, at the middle of the culvert's span during their experimental testing and/or modeling. Therefore, this raised concerns that the wheel load location may not have produced the critical shear stresses, since it was placed away from the vicinity of box's wall (support).

A recent study at the University of Texas at Arlington (UTA) was undertaken to enhance the knowledge gained from the McGrath (2004) research which utilized linear elastic modeling without experimental verification of the model. In addition, a better grasp of the behavior of boxes was needed. The UTA research report is based on the findings of a major and comprehensive full-scale experimental and finite element study that considers all practical culvert span sizes with and without distribution steel (As6) in the top slab. Twenty-four full-scale experimental tests were conducted on the common ASTM C1433

boxes with varying sizes. Several tests were also conducted to identify the location of the wheel load, that produces the maximum shear effects. A comprehensive nonlinear inelastic three dimensional finite element model was developed with capabilities to predict crack initiation and propagation that is validated with the conducted full-scale tests. Finally, the developed models were used to obtain the distribution width values for shear, which were then used to calculate the shear capacity of the ASTM C1433 precast boxes.

Conclusion



Typical deflection shape of the box (solid – Deformed, and wireframe – undeformed)

The full-scale experimental tests indicated that flexure governed the behavior for all the test specimens up to and beyond the AASHTO factored live load. For all the test specimens the flexural cracks formed initially on the inside face of the top or bottom slab, which extended to the spigot or bell toward the middle of the load plate. No flexural cracks were observed at loads below the AASHTO service load.

Another series of cracks, for all the test specimens, were negative moment cracks which formed on the wall closest to the load plate along the joint length at a distance equal to approximately one-third from the top slab. These cracks normally extended to the spigot and bell ends.

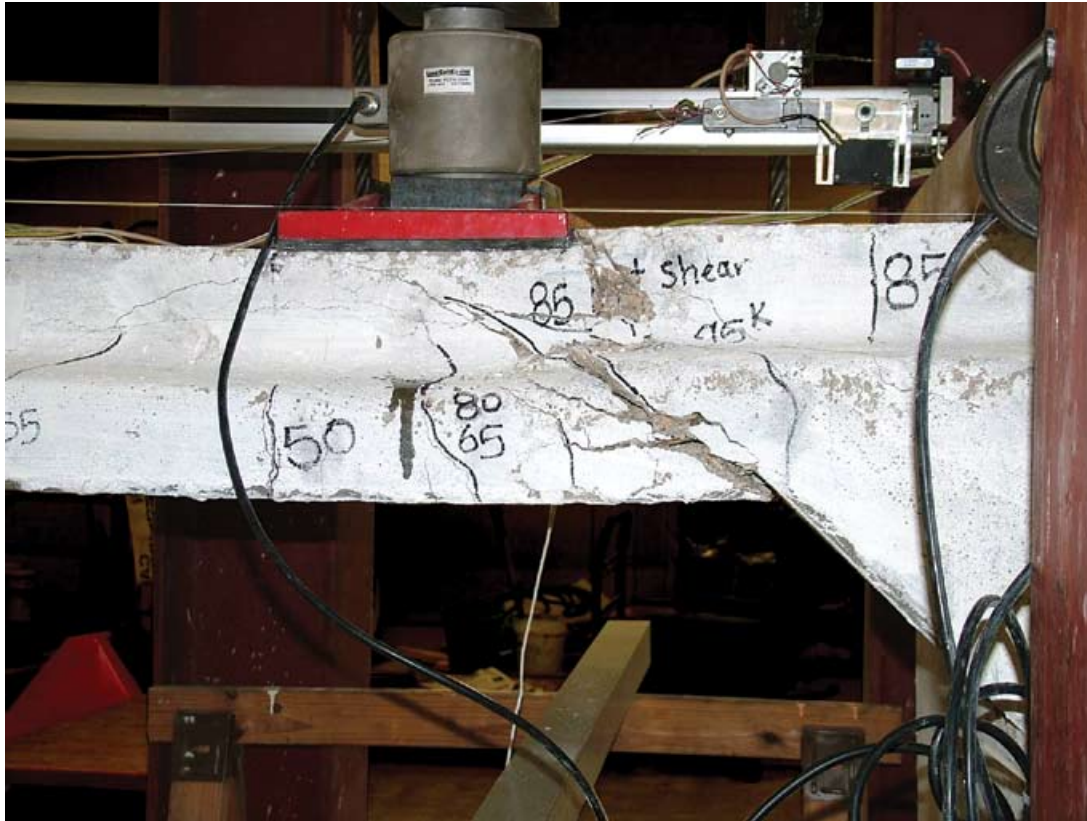
The shear cracks were among the final cracks observed. For all of the test specimens, shear cracks formed at approximately 72 kip (320 kN) of load (almost twice the AASHTO factored load). These cracks initiated independently from the tip of the haunch (on the spigot or bell testing end) and extended toward the edge of the load plate. By independent shear crack, we mean that it did not initiate at the tip of the flexural cracks. No shear crack was observed before flexural cracks in any of the specimens tested.

Even though the load plate was placed at distance “d” from the tip of the haunch to the edge of the load plate, the box’s behavior was governed by flexural cracks during the experiment up to high load levels. This was due to the box’s joint rotation, which contributed significantly to the box’s bending moment. Thus, it was concluded that the behavior of the box was different than that of the bridge slabs. Furthermore, the AASHTO bridge design concept for the distribution width was not justifiable for culverts.

The comparison of the test results, with and without top slab top face distribution steel, showed that the effect of the distribution steel in the top slab is insignificant. This comparison was made with respect to crack initiation and propagation as well as the load-deflection plots. The overall box behaviors during the course of experiments were almost identical for the specimens with and without top slab distribution steel.

The final failure for all the test specimens was due to shear/bond failure at loads ranging from 72 kip (320 kN) to 160 kip (712 kN) or above for all the boxes tested.

The finite element model exhibited close correlation with the experimental results for load-deflection and crack prediction for all the test specimens. The FEM analyses showed that when the load plate was placed at the distance “d” from the tip of the haunch to the edge of the load plate, the value of the maxi-



Photograph of a 244 cm (8 foot) Span and 122 cm (4 foot) joint length specimens at failure

imum shear force was located between the edge of the haunch and the edge of the load plate for all the boxes' geometry used in the experimental program. Indeed, for 70% of the boxes tested, the maximum shear force value was at one-half the distance between the tip of the haunch and edge of the load-plate.

It was shown that the maximum value of the shear force increased as the boxes' span increased for the same load. This counter intuitive finding is because the wheel load plate was placed at a distance "d" from the tip of the haunch to the edge of the load plate, and since the span increases in a larger magnitude 3 feet (91 cm) to 12 feet (366 cm) compared to the increase in "d" 6 inches (15 cm) to 12 inches (30 cm), the **span / "d"** ratio was larger for the larger span boxes. This implies that for the shorter span boxes, the load plate was closer to the center of the span which forces more bending than shear behavior.

The values of the distribution width calculated based on the validated FEM analyses

in this study were between one-fourth and one-third of those calculated, based on the AASHTO 2005. Since experimental testing of 24 test specimens and FEM analyses of 42 ASTM C1433 box geometries confirmed that shear was not governing the behavioral mode (particularly at service

and factored AASHTO loads), it is concluded that there are no relations between the AASHTO 2005 distribution width equations and the box's behavior.

The critical factored shear force for all the ASTM C1433 precast boxes were calculated and compared with the two ACI shear capacity equations: $w c 2b d f'$ (lower bound) and $w c 3.5b d f'$ (upper bound). It was shown that the shear capacity exceeds the critical shear force for all the aforementioned cases.

The study recommends that the AASHTO 2005 distribution width for boxes needs to be revisited. It is highly recommended the following statement "shear transfer device should be provided across the joint, if the calculated distribution width exceeds the length between the two adjacent joints" be eliminated from the AASHTO 2005 provisions. ☺

Note: This article is an abstract of the study entitled, "Experimental and Finite Element Based Investigations of Shear Behavior in Reinforced Concrete Box Culverts." Contact Dr. Abolmaali at 817-272-3877 for a complete report.

Boxes Set in Record Time for Construction of Prestigious School's Hockey Field

By Tony Russo • Independent Concrete Pipe Company • 314-842-2900



- 1. Boxes ready for just in time delivery**
- 2. Trench and bedding prepared in advance of arrival of crane and boxes**
- 3. Single box offloaded and installed every 15 to 20 minutes**
- 4. Structure completed within one day**

Founded in 1923, John Burroughs School is a private, non-sectarian preparatory school with students in grades 7 to 12. It is named for the U.S. naturalist and philosopher, John Burroughs. The school's 47.5-acre campus is located in Ladue Missouri, an affluent suburb of Saint Louis. Its graduates go on to four-year colleges and Ivy League schools. The prestigious school has a distinguished athletics pro-

gram and varsity teams.

Burroughs is planning for its future through a master plan and fundraising campaign that is expected to raise more than \$65 million. The Phase One program has a target of \$32 million for land acquisition, endowment growth through scholarships, and faculty support. Planned campus expansion and improvements included a new football field, hockey field, Clayton Road entrance and parking, spectator stands, and among others, a major renovation to the fine arts building.

Field hockey players now compete on the same type of artificial turf as many professionals. The artificial surface is similar to that of the school's football field, which has received an overwhelmingly positive response from athletes and coaches. The artificial surface provides safer playing conditions, particularly in poor weather, plus faster and more consistent play of the ball. In addition, it reduces the number of game cancellations because of wet field conditions. Since lines are factory installed, the artificial surface reduces maintenance on a game-to-game basis. Construction of the new hockey field required acquisition of property in conjunction with other elements of Phase 1A of the Master Plan campus improvements.

After the contract was awarded to Fred M. Luth and Sons in May 2006, the south side of the campus was transfigured during the summer and fall of 2006. Demolition crews arrived

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less than a week after graduation to construct a new parking lot and the hockey field. The project involved filling in the ditch that was once a trolley right-of-way, and relocating and upgrading utilities that service the campus. While as many large trees as possible were saved, extensive landscaping enhanced the project to provide an attractive entrance and buffered residential properties to the east and west.

Managing storm water runoff for the reconstruction of the hockey field was a major challenge, especially for Burroughs' neighbors. A drainage system was constructed around the perimeter of the field and a retention basin buried beneath the field to manage storm water and accommodate existing drainage.

During design of the buried storm water management structure, both pre-cast concrete boxes and corrugated metal were identified as possible construction materials. The specification was written to require precast concrete boxes because the service life of the concrete boxes far exceeded the service life of corrugated metal. The school was investing in a very expensive synthetic field. It made sense to match the design of the field and its ultra modern materials with a concrete retention structure that would last for the life of the field with minimal maintenance. In addition to the long service life, the structure could be precast to accommodate manhole risers, bulkheads and an overflow weir at the downstream end of the chamber.

Design of the retention chamber called for 204 feet of 10-foot x 10-foot box sections with gasketed joints. The chamber was designed to hold about 20,000 cubic feet of water before discharging over the weir during a major storm event. Under normal conditions, the chamber would hold runoff and discharge the water into the natural streambed at a controlled rate to alleviate downstream flooding of neighboring properties and associated erosion.

The length and straight-line alignment of the structure made the project an ideal application of just-in-time delivery of product. The contractor prepared the entire trench and bed-

ding to receive the box sections before bringing a 350 TN crane onto the site and ordering delivery of the box sections. The contractor was able to control construction activity and complete the installation safely, with the least impact on the campus and neighbors.

Once the trench was ready to receive the boxes, the contractor and producer, Independent Concrete Pipe Company, worked in harmony to ensure the arrival of the boxes in a timely manner. Seven trucks with low bed decks were scheduled to deliver a single box each for offloading and installation every 15 to 20 minutes, after the specially designed downstream bulkhead unit containing the weir was set in place. The trucks maneuvered into position adjacent to the crane, so that the lifting hooks could be quickly attached and the boxes lifted directly into position in the trench, as the crane moved methodically along the top of the trench. There was little unnecessary movement of heavy equipment and boxes on the construction site.

The precast concrete detention structure was constructed within one day, demonstrating the efficiency of building structures with precast boxes. ☺

Project:	Precast Concrete Retention Structure for Hockey Field
Owner:	John Burroughs School Ladue (St. Louis), Missouri
Consulting Engineer:	Volz, Incorporated St. Louis, Missouri
Contractor:	Fred M. Luth and Sons St. Louis, Missouri
Producer:	Independent Concrete Pipe Company St. Louis, Missouri
Quantities:	204 feet of 10-foot x 10-foot box sections with gasketed joints.

Independent Concrete Pipe Company has eight plants located in Kentucky, Indiana, Missouri, Ohio and Illinois. Established in 1912, the St. Louis, Missouri Plant supplies reinforced concrete pipe and manholes, precast concrete box units and Hy-Span® bridges to the growing metropolitan area of St. Louis.

editorial

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throughout the United States.

Joint technology for both pipe and boxes, along with connection devices will continue to evolve in concert with advances in robotic precast concrete plants. I foresee advances in ductile concrete to allow producers to market a wider range of drainage products for traditional drainage applications and those related to heating ventilation and air conditioning of concrete buildings. Self-consolidating concrete is likely to become routinely used for wet cast products due to its ability to reduce the water/cement ratio and increase workability. New discoveries in binders for concrete will advance the recipes for concrete mixes that open even more opportunities for pipe and boxes in aggressive environments.

Over the next ten years, climate change and extreme weather patterns will continue to shape the development of cities and major urban megalopolises. Hydraulic regimes of watersheds are changing, and some regions of the nation are becoming either arid or plagued by flooding. Controlling storm water and preserving it for household or industrial use will intensify. Precast concrete pipe and boxes will be increasingly in demand for underground storage tanks and irrigation systems, and some products will be improved for recharging aquifers. In ten years, demand for larger sized precast concrete products may affect regulations for transporting such products and the design of delivery vehicles.

Public focus on anything environmental will also impact our industry. Use of water, energy costs, and depleted natural resources in close proximity to plants will energize re-

search and development on using recycled materials for some precast concrete products. Don't think for a moment that we have heard the end of sustainable development. The next ten years will see rapid changes to regulations and standards related to sustainable development. LEED (Leadership in Energy and Environmental Design) - rated projects will extend to large tracts of private and public sector developments, placing concrete pipe and boxes in an arena of competition that may not necessarily be driven by standard specifications. Contractors and design engineers will have to select products based on points and not solely matching service life to design life or demonstrating long-term performance.

Finally, I foresee a gravity pipe industry where performance of both facilities and products will be heavily influenced by third party certification evolving from such programs as the ACPA's Q-Cast. Public agencies will demand higher performance from sewers to protect the health and safety of Americans. Culverts under major transportation systems will last several generations with minimal maintenance and safety concerns.

The pace of change in our industry will pick up significantly over the next decade. Few of us in the industry today are likely to live another fifty years to reflect upon what we did in the first two decades of this century. Unlike our forbearers of the first two decades of the 20th century, details of what we are doing are well documented and recorded. One constant, however, is the performance of precast concrete pipe that functioned as expected throughout the first 100 years of our history. That expectation will continue throughout this century because of the high quality pipe and boxes being installed today. ☺

PROFESSIONALS FINDING VALUE IN ACPA MEMBERSHIP

To mark its centenary, the American Concrete Pipe Association has introduced the category of Professional Membership to professionals who work within the precast concrete pipe and box industry. Professional membership is limited to any individual, firm, partnership or corporation which is actively engaged in specifying, designing or providing consulting or other professional services to the ACPA, its members, or the precast concrete pipe and box culvert industry, as defined by ASTM Committee C-13. Professional membership is not available to companies that would be included in Active, Associate or International Membership. In addition, acceptance as a Professional Member is at the sole discretion of ACPA's Board of Directors. Benefits of membership include:

- ✓ access to technical support
- ✓ access to marketing information and research
- ✓ access to experts in the concrete pipe industry
- ✓ opportunity to shape research projects of precast concrete pipe and box sections
- ✓ discounts on continuing education through Short Course Schools, Concrete Pipe University, and other training
- ✓ gaining insight into industry trends and issues
- ✓ discounts on ACPA marketing and technical resources from the ACPA Resource Catalog (member prices)
- ✓ subscription to *Concrete Pipe News* quarterly publication
- ✓ receipt of monthly electronic newsletter, *E-NewsCast*.

The ACPA has already processed several applications for membership. The ACPA is encouraging Professional Members to become involved in charting the future of the Association by participating on committees, and creating services and products that have even greater value for users of reinforced concrete pipe and boxes. The cost of Professional Membership is \$150 per year. Details of the new category and an application form are posted on the ACPA's website at www.concrete-pipe.org under "Become a Member."



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