

concrete pipe news

The Magazine of the American Concrete Pipe Association

www.concrete-pipe.org

STORMWATER MANAGEMENT USING PRECAST CONCRETE BOXES



- Reinforced Concrete Pipe Seen As End-Of-Life Solution
- Exploring The Meaning Of Durability Of Reinforced Precast Concrete Pipe
- If It's Pipe Knowledge You Want, The Place To Go Is The ACPA Fall Short Course School



This issue:

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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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The capability of pipe to perform as expected for the design life of a project is a fundamental engineering consideration, especially in today's economic environment where life cycle cost analysis and asset management requirements have been set in place to ensure sustainable buried infrastructure. When specifiers and design engineers understand the properties of concrete and all factors affecting the performance of reinforced concrete structures, durability of reinforced concrete pipe becomes meaningful.

If It's Pipe Knowledge You Want, The Place To Go Is The ACPA Fall Short Course School 13

More than 250 concrete pipe industry professionals, including guests from DOTs, consulting engineering firms, construction companies, and governments convened in Las Vegas on November 8, 2004 to learn about rigid and flexible pipe. The 2005 Fall Short Course School promises to be even more popular, as its value continues to increase each year that it is held.

**On the Cover:
Precast concrete
boxes used for
stormwater
detention
conserve space
and reduce
potential
liability issues
associated with
stormwater
management
ponds.**





John J. Duffy

Implementation Of Standards And Specifications Is *Where The Rubber Meets The Road.*

Federal and state departments of transportation play a vital role in all aspects of the American way of life. The U.S. Department of Transportation (DOT) began in April 1967. Its mission is to “serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets our vital national interests and enhances the quality of life of the American people, today and into the future.” All state DOTs have similar missions that reference safe, efficient transportation systems comprised of highways, roads, bridges, railways, public transportation services, transportation safety programs, licensing and carrier regulations. In carrying out their missions, it is incumbent upon DOTs to adhere to nationally recognized standards and specifications for the good of the Nation’s infrastructure and its people.

Standards are material descriptions, manufacturing criteria or testing procedures developed by a voluntary consensus-based process by users (consumers), general interest parties (consultants), and producers/manufacturers of products. Standards specify how various technologies, products, and components must perform when used in combination or interchanged. Engineers use American Society for Testing and Materials (ASTM), American Association of State Highway and Transportation Officials (AASHTO), American Society of Civil Engineers (ASCE), or

other standards to ensure that the products specified will perform their intended function. It is important that specifiers understand the details and implications of various standards when preparing bid documents so that only products that will perform as expected for the design life of a project will be identified.

Lessons learned from the past need to be retold to avoid similar mistakes today. Business and commerce spurred by the industrial revolution of the 19th century led to the development of a network of railways for shipping products cross-country. In the beginning, the distance between two rails on a track was not standardized and product had to be offloaded and transferred to a second train to complete the journey. Only when the railroad gauge was standardized to 4 feet, 8 1/2 inches would inter-connectivity and inter-operability of the Nation’s railways become dependable and efficient. The 4 feet, 8 1/2 inches track width originated from rutted roadways in England derived from the original military specification for an Imperial Roman army war chariot. During the Civil War the United States government recognized the military and economic advantages to having a standardized track gauge. The 4 feet, 8 1/2 inches gauge was mandated for use in the Transcontinental Railroad in 1864 and by 1886 had become the United States standard.

The reliance on, or reference to accepted standards (DOT, AASHTO, ASTM, ASCE, municipality) does not relieve the design professional of liability should project expectations not be met. The American Concrete Pipe Association and its member firms participate fully on the various committees of ASTM, AASHTO, and ASCE to ensure that standards are developed that will work when applied to conditions in the field. The ACPA continually questions the specification of flexible pipe products under the Nation’s major highways and roads. The United States Army Corps of Engineers has determined that most studies estimate the product service life for concrete pipe to be between 70 and 100 years, aluminum pipe with properly applied coatings to at least 50 years in most environments, and a product service life of no greater

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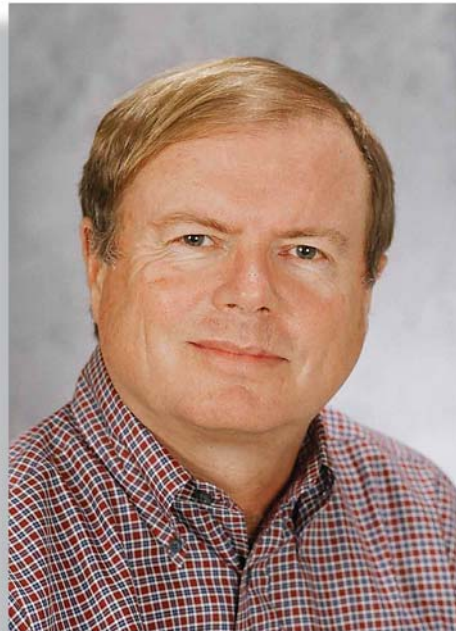


Duncan Gage

President, Hydro Conduit Division (Rinker Materials Corporation) West Palm Beach, Florida

The interests of Mr. Gage extend beyond the growth of business units within the Rinker Corporation. He understands that it is imperative that industry support learning institutions that build the level and quality of knowledge in the next generation that will inherit the concrete and precast concrete products industries. Recently, he became a member of the National Steering Committee for the Middle Tennessee State University B.S. degree program in Concrete Industry Management, to ensure that there is a place to archive precast concrete industry business knowledge.

He knows that to be successful, all organizations must have strategic plans with action items that can be implemented. The American Concrete Pipe Association has a strategic plan that benefited from the counsel of Duncan Gage. Our interview with Mr. Gage is focused on the academic needs of the precast concrete pipe industry, beliefs in our industry that keep it strong, key elements of the



ACPA’s strategic plan, and current hot topics that require immediate attention.

Gage holds a B.Sc. (Mechanical Engineering) from Queen’s University in Kingston Ontario, Canada. He has 30 years experience in the concrete, aggregate and cement industries in Canada, United States, South Africa, and South East Asia. He has been president of Hydro Conduit Division of Rinker Materials since 2002.

Q: *You are involved in the degree program at Middle Tennessee State University (MTSU) in Concrete Industry Management (CIM). Why did you get involved, and what are you hoping that the recent graduates will bring to the precast concrete pipe industry?*

Gage: I was asked to participate on the National Steering Committee of MTSU to broaden the support for the CIM program, and to raise the profile of our industry in the eyes of the graduates. All segments of our industry – cement, concrete block, precast and pipe are competing with other industries for talent. Programs, such as CIM, increase the talent pool. Our participation gives us better access to the program’s students and graduates.

Q: *Please describe your vision with regards to apprenticeships and diploma/degree programs in colleges and universities across America that prepare young people for concrete-related industries.*

Gage: Many university programs, like the Middle Tennessee State University CIM program insist on internships at companies working in related fields. This gives “hands on” learning

experience and provides sponsoring companies exposure to potential new hires.

Q: *What do you understand to be the core beliefs of men and women who have taken on leadership roles within the concrete pipe industry? Of these beliefs, which ones do you believe are most commonly shared and why?*

Gage: The concrete pipe industry, as well as the cement and concrete products industries has become much more aware of the necessity of creating shareholder value in recent years. An understanding has evolved of a more sophisticated approach to quality, service and safety. Large and small companies understand the necessity to act with integrity, while producing products and providing services which provide good value for the end user.

Q: *There is much industry chatter about continued consolidation of large precast concrete pipe producers and disassociation with small concrete precasters. Do you believe that this perception has any validity?*

Gage: I believe the American entrepreneur is alive and well. New businesses are launched daily. The concrete pipe industry will continue to see mergers, and at the same time creation of new businesses in the concrete pipe industry and related fields.

Q: *Precast concrete pipe producers are supported by several state associations and the ACPA. Please comment on how you might envision more efficient use of the concrete pipe industry's limited resources in knowledgeable staff and funds to drive programs through participation in these associations.*

Gage: When associations from related industries link up to promote a common goal, much can be accomplished. But to do this efficiently, these organizations need to be able to clearly articulate their own visions and strategies. Associations with unclear strategies and visions have a difficult time moving forward, so when

multiple organizations with unclear strategies try to work together the outcome is poor, at best.

The state associations and member companies are best positioned to contact a large number of state DOTs and local agencies. Therefore, it is critical that the actions of the state associations and member companies are aligned with ACPA's strategic plan.

Q: *At the conclusion of the current strategic plan, what direction do you think the industry should take in development of the next strategic plan?*

Gage: I could suggest we use the same process that we had for the current strategic plan. Get all the members together, survey the current situation, the opportunities and threats for the future, and then update and change the strategic plan as required.

Q: *Rinker Materials Corporation – Hydro Conduit Division is an industry leader in marketing to specifiers via its Technical Promotions Engineer (TPE) Program. How is marketing success measured over the short term and long term in technical marketing to engineers?*

Gage: Hydro Conduit has put considerable effort into marketing to specifiers, and we are proud of our TPEs. Our managers, sales teams, and engineers understand that concrete pipe provides superior value to the end user.

Marketing success is difficult to measure in the short and long term. However, we will continue to get our message out regarding the best value proposition. I am pleased that we do not market products which are “cheaper, and trust me, almost as good.”

The recent workshops executed by the American Concrete Pipe Association in Las Vegas clearly articulated the advantages of concrete pipe over metal or HDPE pipe. We, as an industry, must get this message to every specifier and end user. ☺

HOSPITAL BOARD GOES WITH PRECAST CONCRETE BOXES TO MANAGE STORMWATER

By James Loaney, Director of Marketing
Hancock Concrete Products Company, Inc.
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Expansion plans for the hospital in Faribault, Minnesota were challenging because there was a requirement by the Minnesota Pollution Control Agency (MPCA) to reduce pollution and damage caused by stormwater runoff on a project that had insufficient space to construct conventional stormwater management facilities. The Rice County District One Hospital Board (in consultation with their consulting engineer and City of Faribault engineering staff) determined that conventional on-site management of stormwater runoff would be very expensive, as land would have to be acquired from surrounding residential landowners to accommodate stormwater detention ponds. Subsequently, Michaela Oeltjen, Project Engineer with the consulting engineering firm Sunde Engineering, Inc., developed a best practice alternative using precast concrete box sections for an underground detention system. The detention structure would be located under a portion of the parking lot and adjacent lawn that may someday become

additional parking space. This alternative required significantly less land acquisition, and

held several inherent characteristics that appealed to the hospital board including safety, lower cost compared to the alternatives, and cost-effective maintenance.

The project that was eventually approved and contracted to Kraus-Anderson Construction Co. comprised 650 lineal feet of 12-foot x eight-foot precast concrete box sections (manufactured to Minnesota DOT/reference AASHTO Load-factor Design), placed in five parallel lines, each 130 feet long. Troy Stutz, Project Manager with Kraus-

Anderson, worked with the design team to determine that the precast box detention system could be constructed as designed. The lines were spaced approximately eight feet apart with connecting crossover ports of 36-inch diameter precast concrete pipe to equalize the volume of the system between lines during heavy runoff periods. One 15-inch and one 18-inch diameter concrete pipe storm sewer

provided the inlets into the detention structure, and one 36-inch diameter concrete pipe served as the outlet control from the structure that discharged into a nearby ravine. Each of the five lines were fitted with two access ports located in the top of the structure to provide inspection



Joint mastic ensures water tightness.



access and an orifice for inserting equipment to pump sediment from the detention system when required. Bulkheads were cast on the two end pieces of each line prior to shipment to the site to ensure a watertight seal. A double wrap of joint mastic was applied on all joint surfaces of the box sections to ensure water tightness along the line of boxes beyond the bulkheads. Hancock Concrete Products Company, Inc provided all products from its plant at Cannon Falls, Minnesota. Niles Excavating was sub-contracted by Kraus-Anderson to perform the utility work, including installation of the detention structure.

Installation of the boxes occurred in the early winter season when snow and freezing temperatures can impede construction. Although the project was a first of its kind for the contractor, its crews efficiently excavated the site, prepared the bedding for the detention system, and completed installation (including backfill with compaction) in approximately three weeks. Contractor Dan Niles said, “The project went extremely well, and the concept of not disturbing local property made a lot of sense.”

When entering the hospital grounds today, very few are aware that under the parking lot and the adjoining lawn area lies a very effective solution for managing stormwater. In addition, there are no places for the proliferation of mosquitoes, or the potential for liability issues possible with an open-pond system. The Rice County District One Hospital Board, and the City of Faribault, Minnesota were very pleased with the decision to go underground with precast concrete boxes. The residents of the area were also



Five parallel lines of 12-foot x 8-foot precast concrete box sections used for stormwater detention under parking lot and lawn.

very happy to have the project develop without a negative impact on their property. ☺

Project:	Hospital Stormwater Detention System Rice County, City of Faribault
Owner:	The Rice County District One Hospital Board
Design Approvals:	City of Faribault, Minnesota Tim Murray, City Engineer
Consulting Engineer and Surveyor:	Sunde Engineering, Inc. Bloomington, Minnesota Michealea Oeltjen, Project Engineer
Contractor: (Construction management General contractor)	Kraus-Anderson Construction Co. Minneapolis, Minnesota Troy Stutz, Project Manager
Installation Contractor: (site preparation, and box installation)	Niles Excavating Medford, Minnesota Dan Niles, Owner
Quantities:	650 lineal feet of 12-foot x eight-foot precast concrete box sections (manufactured to Minnesota DOT/reference AASHTO Load-factor Design)
Producer:	Hancock Concrete Products Co., Inc. Cannon Falls, Minnesota Gary Schmidgall, Plant Manager

Hancock Concrete Products Company, Inc. has been an industry leader in the production of precast concrete sewers and arches since 1917, supplying Minnesota, Iowa, Wisconsin and the Dakotas with concrete utility and road construction products. It has introduced large span arch pipe and long span arch into the market. For information see www.hancockconcrete.com.



REINFORCED CONCRETE PIPE SEEN AS END-OF-LIFE SOLUTION

By Robin Woodbury, Director of Marketing • Premarc Corporation • (800) 968-2662

When pipe was first used in America for sanitary sewers some 160 years ago, there was no provision for replacing the infrastructure at the end of its service life, nor much urban planning to determine how long a system needed to last. This attitude toward buried services (out of site and out of mind) carried well into the 1990s, and now presents itself as one of the major issues affecting the economy, and health and safety of Americans.

Throughout the country, concrete pipe installed more than a century ago continues to function - its service life meeting all expectations and more. As new materials entered the market to compete with concrete pipe, it did so, on the basis of lowest initial cost. It seems as if any consideration of life cycle costing was completely absent during specification of materials and products, as countless miles of alternate pipe or tubing products lie underground with no certain determination of service life, other than the claims of manufacturers. In the last decade of the 20th century, municipal and state officials began to see the enormous implications of failure to match service life of products to design life of projects. Corrugated metal pipe used for culverts and stormwater drains began to reach the end of its service life and sudden failures began to occur on a wide range of highways and roads. These failures often cost millions of dollars in construction, material, product, detours, and lost business attributed to repairing or replacing culverts.

A corrugated metal pipe (CMP) culvert collapse in the City of Muskegon, Michigan in June of 2004 underscores the failure of past governments to plan ahead for infrastructure replacement, and the emerging realization that precast concrete pipe meets the demand for durable products that adds value to the wealth of cities. A run of 60-inch diameter CMP collapsed and

caused the closure of West Hackley Avenue for five weeks.

Inspection by video camera determined that the collapse of the sidewalk on West Hackley Avenue was caused by the failure of one of two 60-inch-diameter CMP pipelines comprising the culvert at Ruddiman Creek. The two 60-inch diameter corrugated metal pipelines were approximately 68 years old and showed their age. The culvert should have been replaced long

before the pipelines failed, to avoid the socio-economic disruption of West Hackley Avenue, and the unexpected burden of a sudden failure on the capital works budget.

It was determined that the most economical and safest course to prevent future failures of the culvert would be to remove both 110-foot long runs of 60-inch diameter corrugated metal pipe and reconstruct the culvert with two runs of reinforced concrete pipe. Muskegon Public Works

Director Robert Kuhn said, "Replacing both pipelines, although the most costly repair option, was the safest course because a future failure could endanger a major water transmission line running along the east side of Hackley Avenue." This 48-inch diameter transmission line connects the city's water filtration plant with three above ground water storage tanks serving Muskegon water customers.

The service life of precast reinforced concrete pipe is well beyond 100 years under conditions where the nature of above and below ground environments is well suited to concrete pipe, the product has been produced according to industry-wide standards and quality assurance programs, and where the pipe has been installed by experienced pipe-laying crews. Durability and proven performance were the reasons why reinforced concrete pipe was chosen to replace the failed corrugate metal culvert.

Jackson-Merkey Inc., of Muskegon, was selected to be the prime contractor for the project. Established in 1984, the con-



Failed 60-inch CMP culverts replaced with twin 60-inch concrete pipe culvert.

tractor specializes in underground construction and has completed numerous projects for the City of Muskegon. The company has earned a reputation in the industry for quality workmanship. Combining a highly skilled staff, technical expertise and extensive field experience, Jackson-Merkey, Inc was the logical choice for this project. The contractor began the project by installing a dewatering well point system consisting of 1-inch diameter pipes to draw down Ruddiman Creek.

The 48-inch diameter water transmission line which runs along the south side of West Hackley Avenue on top of the culvert was shut down for the duration of construction. To preserve the existing line, Jackson-Merkey attached the transmission line to a steel I-beam and suspended the line over the 20-foot deep excavation. A smaller 8-inch diameter waterline servicing the area runs along the north side of West Hackley Avenue on top of the culvert. This line was detoured to bypass the excavation and keep water flowing to residents during the reconstruction period.

Superior joints, competitive prices, as well as the ability to provide on-time deliveries prompted the contractor to choose The Premarc Corporation to supply the reinforced concrete pipe from its plant in Grand Rapids, Michigan. Premarc was able to supply the concrete pipe and associated flared end sections in a timely manner to keep the installation crew on schedule.

Installation of the twin 60-inch diameter concrete pipe culvert called for the diversion of Ruddiman Creek into one of the two failed CMP culverts while the twin 60-inch diameter concrete pipe culvert was installed by open cut method. Once installation of the twin culvert was complete, the flow was diverted from the remaining CMP culvert to the twin precast concrete pipe culvert. The contractor completed the project by filling the failed CMP culvert with grout.

Reconstruction of approximately 100-feet of road took five weeks to complete. During this time, traffic had to be re-routed approximately two miles to avoid the construction site. Replacement costs for the project were \$160,000.00. This cost did not include the social and economic costs of detours and lost time



Reinforced precast concrete pipe used as end-of-life solution for failed corrugated metal pipe culvert.

to commerce and residents.

The Hackley Avenue project clearly demonstrates the need for engineers to resist false economies of selecting, or allowing alternate materials with the lowest initial cost to be favored from the outset. There is another serious point highlighted by this culvert failure. That is that many projects originally designed for 50 years are expected to perform much longer. An original concrete pipe installation allows designers and owners of infrastructure to err on the conservative side. Engineers have a duty to specify materials and products that match service life to design life. Problems, such as very high post-construction maintenance costs, eventually arise when projects are designed without looking beyond lowest initial cost intended to reduce the cost of pipeline installation within the owner's construction budget. The costs borne by home and business owners through construction delays and detours far outweigh the initial savings brought to a project by using the wrong material and product in the wrong application. By specifying reinforced concrete pipe to replace corrugated metal culverts at the end of their service life, owners of buried infrastructure drainage systems may rest assured that the service life of the reinforced concrete pipe will equal and exceed the design life of most roadbeds. ☺

Project:	West Hackley Avenue Culvert Replacement City of Muskegon
Owner:	City of Muskegon
Engineering:	City of Muskegon Mohammed S. Al-Shatel, P.E.
Contractor:	Jackson-Merkey Inc., Muskegon, Michigan
Quantities:	220 feet of 60-inch diameter Class 3 RCP manufactured to ASTM C 76
Producer:	Premarc Corporation Durand, Michigan

The Premarc Corporation is a leading manufacturer of concrete products for the construction industry. Founded in 1927 in Durand, Michigan by the Marsh family, the company operated primarily in the Flint and Lansing area. In the past 15 years, it has expanded its sales territory with facilities in Cadillac, Grand Rapids, Clarkston, and Durand. Premarc's delivery fleet supplies the entire lower peninsula of Michigan and extends into Indiana.

Premarc's manufacturers product line includes all shapes and sizes of precast reinforced concrete sanitary and storm sewer pipes, manholes, catch basins, wet wells, and pump stations. Bridge products include concrete box culverts, prestressed bridge beams and CON/SPAN. For more information, see www.premarc.com.

EXPLORING THE MEANING OF DURABILITY OF REINFORCED PRECAST CONCRETE PIPE

Durability of a pipe material is equally important as the ability of products made from that material to perform structural and hydraulic functions. The capability of pipe to perform as expected for the design life of a project is a fundamental engineering consideration, especially in today's economic environment where life cycle cost analysis and asset management requirements have been set in place to ensure sustainable buried infrastructure. The challenge faced by many standard-development organizations, municipal officials, and department of transportation specifiers of sewer systems and culverts is a clear understanding of the term, durability. Durability is not defined as clearly as structural and hydraulic standards for drainage pipe systems, because it includes the performance of the components of concrete and reinforced concrete structures. Durability deals with life expectancy and the endurance characteristics of a material or structure. Among other considerations, the varying nature of climate, weathering, soils and geology, fluid chemistry, product installation techniques, in-plant production, material mixes and raw material quality cloud the development of a way to define durability and predict performance.

Concrete is the world's most commonly used building material. In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed of portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Within this process lies the key to a remarkable trait of concrete. It is plastic and malleable when newly mixed, and strong and durable when hardened. These qualities explain why concrete is used to build skyscrapers, bridges, sidewalks, superhighways, houses, dams and buried precast concrete pipe infrastructure.

Concrete Pipe Properties

There are certain concrete properties that influence performance. These properties include concrete compres-

sive strength, density, absorption, water/cement ratio, cementitious content and type, and aggregates.

Compressive strengths for concrete pipe normally range from 4000 psi to 6000 psi. It is a function of many factors including aggregates, cementitious material, manufacturing, curing process and mix design. Most concrete design strengths refer to 28 day compressive strengths. It is not uncommon for 28 day tests to substantially exceed the specified design strengths.

Quality concrete pipe **densities** typically range from 145-155 pounds per cubic foot. Usually the higher the density, the greater the concrete "durability."

Absorption is primarily used to check the density and imperviousness of the concrete. As with compressive strength, the absorption can be greatly influenced by both the aggregates and the manufacturing process used. ASTM C 76 specifies a maximum allowable absorption of 8.5 percent or 9 percent, depending on the test method used, for concrete pipe.

Low water/cement (W/C) ratios are one of the trademarks of quality concrete pipe with corresponding high compressive strength as a function of the low W/C ratio. Typical precast concrete pipe have W/C ratios that range from 0.33 to 0.45 with 0.53 being the maximum allowed by ASTM C 76.

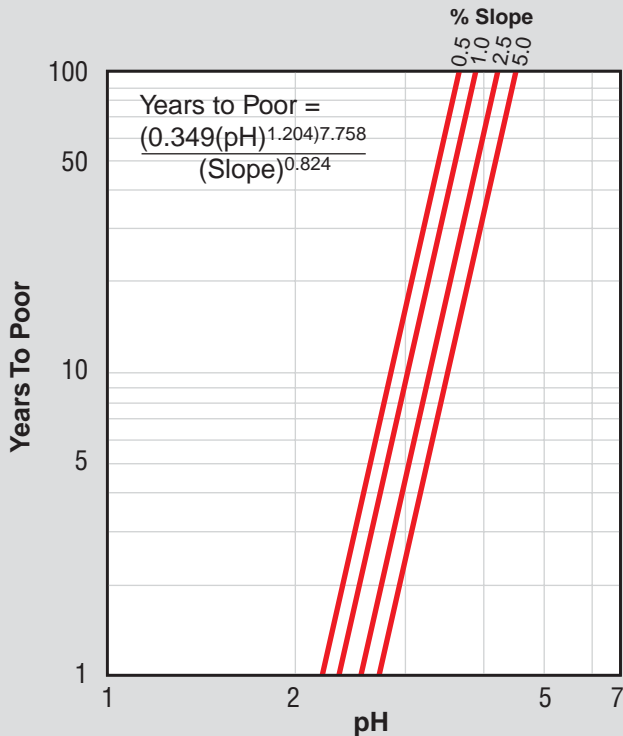
Cementitious content which has always been a topic of concern with engineers and manufacturers includes both cement and fly ash. The key to proper cementitious content is proper design of the mix, with consideration of all material properties, manufacturing and curing processes. All types of cement have been used in the manufacture of concrete pipe but generally Type II cement is used. Typical minimum cementitious content allowed by ASTM C 76 is 5 sacks (470 lbs) per cubic yard of concrete.

Concrete pipe aggregates, both coarse and fine, meet the requirements of ASTM C 33 except for gradation. Both natural and manufactured aggregates are suitable for use in concrete pipe. Aggregates are a key element in producing quality concrete and in turn, quality pipe. With regards to strength, durability and performance, all aspects of the aggregates should be considered. These include gradation, absorption, specific gravity, hardness, and in some cases alkalinity.

Concrete Durability

Durable is defined in Webster's New Collegiate Dictionary as, "able to exist for a long time without significant deterioration." Durability is defined by CSA (Canadian Standards Association) as, "The ability of a building or any of

its components to perform its required function over an intended period of time.” And, the ACI (American Concrete Institute) Committee 201 Durability of Concrete defines durability of portland cement concrete as, “The ability to resist weathering action, chemical attack, abrasion, or any



This graph was generated by the Ohio Durability Study. It shows the service life of precast concrete pipe based on the pH and the slope of the pipe. It shows that even when the pH is around 4, which is an extreme condition for a storm drain, concrete pipe can last up to 100 years.

other process of deterioration.”

Concrete is inherently a very durable material that will last indefinitely when designed properly for its intended environment and use, produced with good quality control, placed with sufficient care and expertise, and cured properly and thoroughly. Concrete is, however, potentially vulnerable to a variety of different deterioration mechanisms caused by adverse performance of paste, aggregates and steel.

Generally, surface attack of concrete is an extremely slow deterioration process. In most cases, aggressive agents must enter the concrete to cause significant damage. Permeability, diffusivity and absorption are the transport mechanism that allows such penetration. Permeability is the movement of gases or liquids through a porous medium due to a pressure head. Diffusivity is the transfer of mass by random motion of free molecules or ions in the pore solution due to a concentration gradient. Absorption is the transport of liquids in porous solids due to surface

tension acting in capillaries.

The single parameter that has the largest influence on durability is the water/cement ratio (low water/cement ratios result in reduced permeability and increased strength).

Permeability can be reduced by supplementary cementing materials, or chemical admixtures. Permeability will be increased by imperfect consolidation, excessive segregation, excessive bleeding, or drying cycles during curing. The single biggest factor causing increased permeability is cracking of the concrete.

Reinforced concrete pipe is a composite structure and specially designed to use the best features of both concrete and reinforcement. The concrete is designed for the compressive force and the reinforcement for the tensile force. Unless the concrete cracks, the reinforcement is not being used to its design capacity. As more tensile forces are carried by the reinforcement, hairline cracks become visible, but these occur at loads well below the design loading of the reinforced member. Hairline cracks are not an indication of danger, distress, or loss of structural integrity. Concrete pipe is generally designed to carry loads well within the engineered load bearing capacity of a pipeline, and hairline cracks do not occur. If hairline cracks do occur, they tend to seal themselves through a process known as autogenous healing. Autogenous healing is the ability of concrete to repair itself in the presence of moisture. Reinforced concrete pipe, unlike reinforced concrete beams and slabs, are buried where moisture conditions are present for autogenous healing to take place.

Corrosion of reinforcement involves an electrochemical attack mechanism on the reinforcing steel which results in a volume increase, thus inducing tensile stresses in the concrete. Structural concrete requires steel reinforcement to carry the applied tensile stresses. Concrete is normally capable of providing excellent protection to the steel and prevents it from corroding. This protection is both physical and chemical in nature. Physically, concrete restricts ingress of basic components required to initiate corrosion (water, oxygen, chlorides). Chemically, the pore solution in concrete typically has a very high pH, which leads to the formation of a protective iron oxide film around the steel reinforcement.

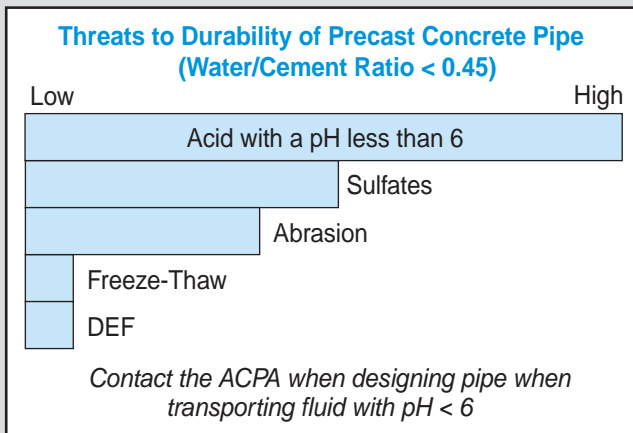
The primary physical reasons for lack or loss of protection by the concrete are insufficient cover over reinforcement, the presence of high permeability concrete, failure to protect concrete from chloride sources, and damage to concrete (cracking, spalling, scaling). Primary chemical reasons include penetration of chlorides into concrete,

destruction of the passivation layer when chloride ion content reaches 0.2 percent to 0.4 percent in the region adjacent to steel. In addition, carbonation of concrete leads to a reduction in pH, then depassivation occurs as pH approaches 11.

Sulfate attack on concrete is a chemical reaction between an external source of sulfate ions and certain components of hexagonal close packing (hcp) at the molecular level. Detection of sulfate attack is very difficult due to its internal nature and minimal amount of visual damage. Though high levels of sulfates are present in seawater, sulfate attack is mitigated to some extent. Magnesium hydroxide chemically protects against sulfate attack, and gypsum and ettringite are more soluble in solutions containing chloride ions.

Delayed Ettringite Formation (DEF) occurs when curing at elevated temperatures destroys ettringite, with the sulfate and aluminate being absorbed by the calcium silicate hydrate. After cooling, the sulfate is again available to form ettringite, resulting in expansion and cracking. This only occurs with certain cement chemistries and when moisture is readily available. It is a non-existing occurrence in the production of concrete pipe.

Acid attack is a chemical reaction between an external source of acidic liquid and hcp and, in some cases, aggregates. The attack is normally limited to the surface of concrete only, but may progress inward. Dissolution of compounds soluble in the given acid takes place virtually instantaneously. In most cases, this reaction forms insoluble calcium salts which build up and protect the concrete from further attack.



Freeze/thaw damage is induced by internal tensile stresses which are a direct result of repetitive cycles of freezing and thawing. Freeze/thaw damage is through at-

trition - one cycle does very little damage. It takes many cycles before the damage adds up to significant levels. Contributing factors include expansion of water upon freezing (when volume increases nine percent), and hydraulic pressure. Freezing of water in concrete begins in larger cavities and progresses to successively smaller ones. This produces a hydrostatic pressure as the expansion forces unfrozen water ahead of the freezing front. The magnitude of hydrostatic pressure is a function of concrete permeability, distance to the void boundary, and the rate of freezing.

Surface wear is the progressive mass loss from a concrete surface due to repetitive attrition cycles. Abrasion is the dry attrition as another solid object moves along or rubs against the concrete surface. Erosion is surface wear caused by the abrasive action of solid particles suspended in fluids. It can occur on canal linings, spillways and pipes for water or sewage transport. Cavitation is the loss of mass caused by the formation of vapor bubbles and their subsequent collapse due to sudden changes of direction in rapidly flowing water.

Alkali-aggregate reaction is a chemical reaction between the soluble alkalis in hcp and certain forms of silica found in some aggregates. The time elapsed between concrete casting and the appearance of damage can vary significantly, depending upon the type of aggregate involved.

There are many factors that influence the durability and performance of reinforced concrete structures that are well understood and managed to produce great structures that serve the Nation. Reinforced concrete pipe lasts for generations when it is designed properly for its intended environment and use, produced with good quality control, placed with expertise, and cured properly and thoroughly. When specifiers and design engineers understand the properties of concrete and all factors affecting the performance of reinforced concrete structures, durability of reinforced concrete pipe becomes meaningful. Only then can wise decision follow about matching service life of products to design life of projects. ☺

References:

- 1.) *Durability Issues for Concrete Pipe*, presentation at ACPA Fall Short Course School by Dr. Andrew J. Boyd, Department of Civil and Coastal Engineering, University of Florida, November 9, 2004.
- 2.) *Precast Concrete Pipe Durability*, CP Info No. 02-710, publication by the ACPA, September, 1991.
- 3.) *Cement and Concrete Basics*, www.cement.org/basics, Portland Cement Association, December, 2004.
- 4.) *Concrete Pipe Properties*, Info Brief No. 1010, www.rinker.com/hydroconduit/techlibrary/hs_briefs.htm, Rinker Materials, Hydro Conduit, March 1996.

If it's pipe knowledge you want, the place to go is the **ACPA Fall Short Course School**

Lights dimmed and the immortal words of Irving Berlin's *God Bless America* filled the hall through the enchanting voice of Celine Dion. This reflection marked the beginning of the ACPA's Fall Short Course School branded **RCP – Raise Your Concrete Potential** – and indeed the promise was fulfilled.

More than 250 concrete pipe industry professionals, including guests from DOTs, consulting engineering firms, construction companies, and governments convened in Las Vegas on November 8 to learn about reinforced concrete pipe production, durability and advantages, specifications, flexible pipe attributes, software development, and emerging pipe materials. Presentations were riveting using all available audiovisual technology, and knowledge was exchanged as liberally as coins in the casinos.

The "Panel Discussion" has become the main drawing card. This year, as well as last, representatives of the ACPA's producer members opened their minds to differing and sometimes challenging points of view held by speci-

fiers, contractors and purchasers of concrete pipe and alternate flexible products. For more than two hours, delegates and panelists explored issues such as engineers' liability, product performance, product and material failures and quality assurance, pipe installation and failure costs, new pipe installation inspections, and relationships with state and federal government elected representatives. There was no limit to the range of questions posed to the panelists.

University and industry researchers always hold a special place at ACPA functions. This admiration was reinforced at the Fall Short Course School as no less

than three esteemed academics presented information.

Dr. Joseph Perrin of the University of Utah reviewed his ongoing work on costs of culvert failures and development of a revised formula for calculating life cycle costs. His work addresses what sudden culvert failures actually cost, and that total cost in a life cycle cost analysis should really consider installation and replacement cost as well as the cost of the road user delay.

Dr. Manuel Uy of John Hopkins University heads a completely equipped and modern analytical chemistry and materials laboratory in-



Dr. Andrew J. Boyd gives meaning to the term "Durability".

"I was honored to have participated in the ACPA 2004 Fall Short Course School and serve as a presenter on the panel. The ACPA 2004 Fall Short Course was a very informative conference, one which I would highly recommend to anyone in the industry. I found a diverse group of people covering all aspects of the industry, which led to a very stimulating learning environment. Thanks for the opportunity."

**Senator David McBride, P.E.
State of Delaware**



Attendees engage in an animated discussion with industry experts.

“Over the last several years, my job duties have included the difficult issues related to alternative piping products. I believe that the ACPA Short Course was an excellent general overview of issues related to piping products for the design engineer. I found the courses related to durability of concrete pipe and concrete pipe hydraulics extremely useful. Classes discussing life cycle cost analysis and the true cost of culvert failures showed that a lowest cost may not always be the best way to go.”

*Ray Waters,
Assistant - Quality Assurance Supervisor
Clark County Nevada*

“I was very pleased with the overall conference. It was well organized, and effectively addressed timely technical, marketing and business matters. As a member of a panel charged with responding to a wide range of questions from the audience, I gained a better understanding of issues facing not only the concrete pipe industry, but also consulting engineers, regulators, contractors and developers. The questions were tough, timely, and thought provoking, and indicative of the high caliber of the conference attendees. I also gained a greater appreciation for the professionalism of the leaders in the concrete pipe industry. Thank you again for the opportunity to participate on the panel. As usual in situations like this, the ‘teacher’ learns more than the ‘class’.”

*William A. Luce, P.E.
Hansen, Allen & Luce, Inc.*

“I enjoyed the opportunity to provide a DOT perspective as a participant in the panel discussion. It was enlightening for me to hear the diverse opinions and concerns of the panel. The level of audience participation in the discussion indicated to me that the panel discussion was a learning experience for all involved.”

*Lon Ingram,
Chief of Materials and Research
Kansas D.O.T.*

“This course was informative and helpful. I found the information presented for structural backfill of HDPE, an area often overlooked, to be very informative.”

*Troy L. Peterson, P.E.
Quality Assurance Engineer
Materials Division
Utah D.O.T.*

volving many Ph.D. level chemists and engineers. He guided the delegates through a hard look at HDPE service life and concluded that current standards and specifications do not properly differentiate between HDPE products with varying chemistry and the purely empirical extrapolations currently being proposed is highly



Attendees listen intently to several industry specialists and guest lecturers.

speculative and most probably unreliable.

Dr. Andrew Boyd has established a successful research program at the University of Florida focused on concrete materials including durability, mechanical properties, nanostructural modification, structural rehabilitation, and nondestructive evaluation. He detailed all that is required to put meaning into the phrase, “durability of concrete.” He was able to explain how concrete is inherently a very durable material that will last for many decades if designed properly for its intended environment, produced with good quality control, placed with sufficient care and expertise, and cured properly and thoroughly.

Delegates were highly pleased with the value they received in exchange for investing their time and resources. The 2005 Fall Short Course School promises to be even more popular, as its value continues to increase each year that it is held. For information on next year’s training, visit www.concrete-pipe.org in the coming months. ☺



President's Message

continued from page 2

than 50 years for plastic pipe. America's major arteries are too important an asset to be constructed with questionable products written into loose specifications.

When designers are preparing specifications, risk assessment of products and services has become a challenging exercise. Designers faced with specifying culverts or sewers need to consider all angles of possible failures to call for the most reliable product. Failure of buried flexible systems are associated with buckling due to poor installation, corrosion, combustion, dis-jointing, flotation, wash-out, abrasion, thermal expansion, and ultra violet degradation. The track record of materials and products as well as similar case histories should also be included in any risk assessment. Condition investigations of HDPE (in-service) in six states with locations provided by Departments of Transportation, revealed that of the 39 HDPE pipes examined that were installed from 1989 to 1999 in diameters ranging from 30-inch to 60-inch, 26 pipes had deflections greater than 5%, 26 pipes had joint separation, and 29 pipes had buckling, cracking, or bulging.

Quality pipe installations require engineering, quality product manufacturing, and proper installation. To properly specify thermoplastic pipe on DOT projects, AASHTO and ASTM standards are recommended.

ASTM D 2321 (Standard Practice For Underground Installation of Flexible Thermoplastic Sewer Pipe)

Recognizes "numerous flexible pipe products" and "inherent variability of natural ground conditions:"

- Minimum densities 85% to 95%
- Install and compact in 6-inch maximum layers
- Use hand tampers or vibratory compactors
- Haunching: Work in around pipe by hand to ensure uniform support
- Do not permit compaction equipment to contact and damage the pipe

AASHTO Section 30- Thermoplastic Pipe

30.5.4. Structural Backfill

- 200mm (8-inch) loose lift thickness
- 90% compaction required
- Compact both sides simultaneously
- Structural fill 300 mm (1 foot) above pipe
- "...shall be worked into haunch area and compacted by hand"
- Compaction equipment within 1000 mm (3 feet) of the pipe shall be approved by the engineer
- Minimum cover for construction loads

When considering standards that have to be used, you have to wonder:

- How many contractors know the difference between how a rigid pipe and a flexible pipe perform?
- How many contractors know that less than 10% of the design strength comes from the flexible pipe itself?
- Do all contractors know that backfill techniques for flexible pipe are more demanding than those for rigid pipe? How many contractors have read ASTM D 2321 or AASHTO Section 30?
- How many contractors monitor the shape of a flexible pipe during backfill?

Specifiers working with DOT's must realize that the most technical and critical portion of their design will fall upon the lowest paid individual to carry it out. In addition, that person is also employed by the lowest bidder! Because the level of risk and liability to the design engineer rises once the contract is awarded, drafting of the specification becomes a task that is most serious. The designer must be assured that the specification is adequate and what his or her design actually requires. The specifier or design engineer must know the relevant standards and what they mean. Specifications must be written in a manner that will ensure the desired result, and they must be enforceable.

It all comes down to standards and specifications that meet the missions of Departments of Transportation to ensure a fast, safe, efficient, accessible and convenient transportation system. This is where the rubber meets the road. This is where the specifier and design engineer must be most vigilant. ☺

PIPECAR® 4.0 – NEWLY RELEASED VERSION

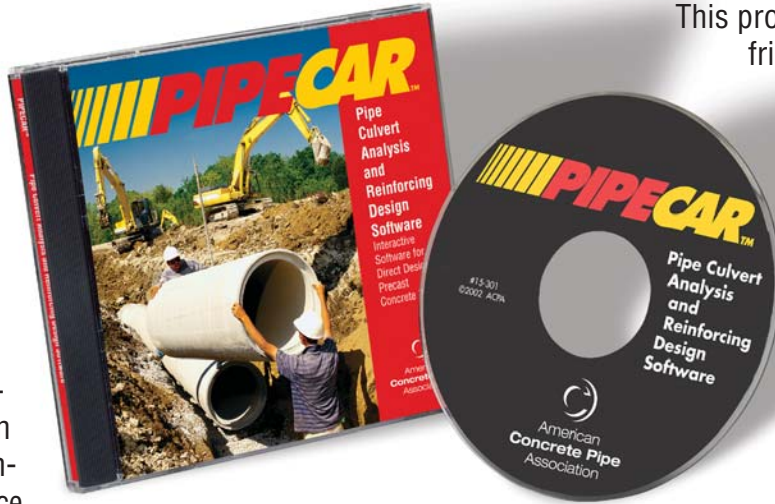
PIPECAR (Pipe Culvert Analysis and Reinforcing Design) software is a program developed by the Federal Highway Administration (FHWA) in conjunction with the American Concrete Pipe Association as a direct method of structural analysis and design of concrete pipe sections.

The latest version of the software, developed by ACPA, will allow users to design buried reinforced concrete pipe in accordance with the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway

Bridges or the AASHTO LRFD Bridge Design Specifications. The Canadian Highway Bridge Design Code has also been included.

This program is written in user-friendly input routines requiring minimal computer experience. You can obtain a copy through a concrete pipe member (membership locator is provided at www.concrete-pipe.org) or order a copy from the ACPA's Resource Center by calling 800-290-2272. Cost:

\$50.00 for members or non-members, plus shipping and handling. ☺



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