

# concretepipe news

The Magazine of the American Concrete Pipe Association

## CALGARY USES SPECIALLY DESIGNED PRECAST CONCRETE BOXES FOR STORMWATER DUCT



- Lesson Learned About Making the Right Choice of Culvert Pipe
- A Study Into The Economic Costs of Culvert Failures



**This issue:**

Volume 56, Number 2  
Summer 2004

*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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**Published by:**

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



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## Oversight

The ACPA acknowledges that credit for the installation photos on the cover of the Fall/Winter Issue of *Concrete Pipe News*, Volume 55 No.4 and on page 7 of the article entitled, "RCP Drains Provide Immediate Health, Safety and Economic Benefits", by R. Woodbury should have been given to Sid Lockhart, The South-eastern Oakland County Sewer District System. We regret the oversight.

*On the cover:  
American 5299  
fifty-ton crane  
offloads box unit for  
immediate place-  
ment in the double-  
cell Rundle under-  
ground stormwater  
storage structure.*



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*John J. Duffy*

## **There's More to the Highway Bill than Meets the Eye**

Perhaps we have reached the point where the rubber has met the road, literally. Are the messages from all sectors of our industry getting through to our elected representatives in Washington about the state of our road and highway infrastructure? Our leaders know the numbers; they probably listen to delegations and their staffs almost daily where someone is pleading for passage of the highway bill. Although listening has been advanced to a great art in our governments, many representatives seem to be unresponsive.

The transportation bill under consideration started in 1991 as the Intermodal Surface Transportation Efficiency Act, also known as ISTEA. Then, TEA for the 21<sup>st</sup> Century (TEA-21) followed and was enacted in 1998 for six years. Although it expired September 30, 2003, it was extended with \$218 billion approved by Congress. Its successor, the transportation bill, is called the Transportation Equity Act: A legacy for Users (TEA-LU).

Many point to a 2002 Transportation department report that estimated that state and federal authorities would have to spend at least \$90.7 billion a year - \$544 billion over six years - simply to maintain traffic conditions. That same report said more than a third of major U.S. roads are in

poor or mediocre condition, and 28% of bridges are deficient or obsolete.

The state of the Nation's buried infrastructure is well known by industries involved in producing, installing and maintaining sanitary and storm sewers, and highway culverts. In March 2000, the Water Infrastructure Network (WIN) estimated the current annual cost for new investments, maintenance, operation, and financing of the U.S. national sewer system at \$27.5 billion per year. Data on highway culverts have been scarce until January 2004, when a paper prepared for the Transportation Research Board by Joseph Perrin, Jr. and Chintan S. Jhaveri reported that there have recently been a number of culvert failures in North America. It observes that sudden highway culvert failures cause road sections to collapse, thereby creating sinkholes. This poses a major safety risk, as well as tremendous disruption to traffic. The report places a cost on failing highway culverts and calls for incorporation of user delay costs in Life Cycle Cost Analysis when culverts are being planned or replaced. Knowing this information is important to wisely use the funds that will be approved in TEA-LU. The report is summarized in this issue of *Concrete Pipe News*.

The point has been made that dependable highway systems are essential to the growth of the Nation's economy, its security, and the prosperity of Americans. Knowing what we do about the health of our transportation and affiliated buried infrastructure, why the delays in releasing badly needed funds for new infrastructure and the replacement of works that are failing? We know that funds are available at a ceiling that would be acceptable to the White House. Does it have to be all or nothing, or can we not move ahead with what we can afford while our leaders find ways and means to bring forward the balance of the funds needed within the spirit of the pledges made by the White House?

Our lifelines are in need of funding now. If delays are protracted, more culverts and sewers will reach the end of their service life and the costs of replacement, maintenance and expansion will continue to escalate, while representatives talk about the problem. We are surely at a point where the rubber has met the road and there is no more time for idleness in Congress. ☺



## Peter Deem, Vice President, National and Regional Promotions Lakewood, Colorado

Peter Deem is an award-winning leader within the North American cement industry. He has received honors from his peers for his outstanding effort in promoting cement and concrete products. His commitment of time and energy, beyond regular responsibilities, has contributed significantly to the marketing of reinforced concrete pipe and boxes, and all associated products.

Peter has worked with the American Concrete Pipe Association (ACPA) for five years while implementing the Strategic Promotion Plan for North America, between PCA and ACPA, launched in 1999. The first phase of the program was very successful, due in large part to PCA involvement. Projects completed through the joint promotion strategy include three promotional videos, a research and development project identifying and documenting problems with high density polyethylene tubing used for sanitary and storm sewers, development of a small scale concrete pipe model for trade shows and displays, and the establishment of an email communications link (Focus ezine) among allies. Peter is a true champion of the concrete pipe industry.

Deem graduated from the University of Minnesota in 1966 with a BA, and then worked for Ryerson Steel Company, followed by service in the Air Force until 1970. His career with Holcim started in 1982 as a market manager in central Minnesota for Dundee Cement Company which became Holnam and later Holcim (US) Inc. He transferred to the corporate office in 1986 working in promotions and public relations until 1990 when he became Regional Manager of a newly formed region for Minnesota, Iowa and the Dakotas. In 1995, Deem



was made V.P. of Sales for Holcim's West Division located in Denver, then V.P. of National and Regional Promotions in 2002, working with various national associations and regional promotion groups. Peter has served as Vice Chair of the Portland Cement Association's Public Works Committee, Market Development Chairman for the American Concrete Paving Association, and is currently on the Government Affairs and Marketing Committees of the American Concrete Pipe Association.

Peter is no stranger to the concrete pipe industry and the American Concrete Pipe Association. This is what he had to say when we asked him to share his insight into our industry and the ACPA.

**Q:** *The concrete pipe industry is not a huge consumer of cement compared to others such as concrete highway pavements, concrete building components, and structures. Why did the cement producers decide to join forces with concrete pipe producers and their associations through the Portland Cement Association to develop and implement a strategic promotion plan for North America?*

**Deem:** The Portland Cement Association (PCA) maintains working relationships with many concrete allied industry groups. An organization known as the North American Concrete Alliance, which ACPA recently joined includes eleven trade associations with a common interest in promoting the use of concrete.

After seeing a noticeable drop in market share, the Pipe Association contacted PCA about working more closely together to reverse the negative trend that was developing. I believe they saw PCA as the logical group with whom to partner.

As a cement producer, I feel we have to look at all consumers of cement and promote all concrete products. We in the cement industry, are in a rather unique position where we really don't promote cement as such; we promote our customers' concrete products.

Certainly compared to highways and buildings, concrete pipe isn't a high consumer of cement; however, over the past five years we've been working together, cement usage in pipe products has increased 25% to 2.5 million tons. We're heading in the right direction.

**Q:** *You are involved in committee work with the ACPA and have witnessed first-hand how its members work with ACPA to promote the use of concrete pipe, raise standards, and constantly pursue research and development that opens new opportunities for concrete pipe applications. Please describe what makes ACPA and its members effective in car-*



*rying out their strategies?*

**Deem:** I've always been impressed with the involvement of the ACPA membership and the passion they have for their product. The members' functional expertise combined with their commitment to a common goal form the foundation for successfully executing the strategy. In the five years we've been working together, I've seen a change in many of the members who now realize that even though they produce the superior pipe product, they have come to understand we have to promote the product. We cannot rest on our laurels; we have to continue educating others on the benefits of concrete pipe. The Association's strategic plan has also reflected this shift by adopting a more marketing approach. For years the industry was technically oriented and now, we've seen a blend of technical and marketing in the promotion effort. It's been a real group effort with the national and state organizations making a more consolidated effort with their promotional efforts.

**Q:** *Of all the promotional tools that ACPA has created over the past five years, and all the initiatives that ACPA has recently completed in partnership with the Portland Cement Association and its members, what do you believe has been the most effective, and why?*

**Deem:** Understand that this is my opinion and I mean this in all sincerity, I think the most effective initiative which has resulted from the PCA/ACPA relationship has been the focus of everyone in the Association to make sure the message of the benefits of concrete pipe is communicated to all audiences. It's very gratifying to see what has been done by bringing everyone together with a solid strategic plan. We can develop really good brochures, technical bulletins, etc., but if you haven't got the buy-in and conviction of the members to work hard at spreading the word, the program will fall flat.

**Q:** *Please describe some of the benefits currently being received by other infrastructure products using the latest cement blends and admixture, that may also apply to concrete pipe.*

**Deem:** I think the use of admixtures in ordinary portland cement, including fly ash and slag along with other concrete additives, have provided a number of benefits to concrete products - as well as concrete pipe. There are economic benefits of course; however, benefits such as sulfate resistance, resistance to alkali silica activity, and finishability also come to mind. Also the trend has been toward replacing prescriptive with performance-based specifications. As this evolves, the use and understanding of admixtures to enhance the performance of our concrete products becomes a necessary part of the business.

Which, speaking of these additives, we must also consider

the sustainable development and environmental benefits realized when using these by-products from the power plants and steel mills. By using these materials our industry provides an environmentally preferable option and advantage by keeping these materials out of landfills. Blends also reduce CO<sub>2</sub> emissions per ton of cement and, subsequently, per cubic yard of concrete.

**Q:** *We know you are very active in many associations representing industries that depend upon cement. What have you learned from those associations that may help the ACPA serve its members better?*

**Deem:** I've had the privilege of working with a number of national and regional promotion groups over the past few years, and several elements come to mind. One of the primary things I've observed is the skill set and dedication of the staffs to move their products and associations forward. These people are the firm foundation upon which the association builds and distributes its programs. Also, I've seen a focused effort to be more inclusive of the membership with regard to policy and product development. Third—and this is perhaps one of the tougher but equally important elements to implement—is generating local member action. We cover a very large area in the US, and while the products from area to area are basically the same, sometimes the regions are not. We have power in our constituency that needs to be utilized regularly. This is why it's very important to have a strong local presence with the national organization acting as an umbrella. The really good associations have this local presence to carry the messages from above. One of the major benefits I've seen from the partnership with PCA is a closer relationship being developed between ACPA and the various state pipe associations.

**Q:** *What do you believe is the greatest challenge to ACPA in promoting the wide range of precast concrete products marketed by its members?*

**Deem:** In my estimation, the greatest challenge to ACPA in promoting their concrete products is basically the same for all concrete products— education.

I can't think of a concrete product where we feel the new engineers coming out of our universities have a really sound background in cement or concrete products. Certainly, they will graduate with a basic understanding of concrete, but we really need to ensure a better working knowledge of concrete design whether in concrete pipe or highways for instance. I think some of our competitive products have gotten better play with the students, and we have to do a much better job in this area.

**Q:** *ACPA is a major voice and authority in the buried*

**continued on page 15**

# CALGARY USES SPECIALLY DESIGNED PRECAST CONCRETE BOXES FOR STORMWATER DUCT

By Michael Chau, P.Eng.  
Project Manager  
City of Calgary

Randy Giberson, P.Eng.  
Sales and Plant Engineer  
Lafarge Canada Inc., Greater Calgary Area • 403-292-9515

Construction of the *Rundle Underground Storage Duct* in Calgary, Alberta was far more than the installation of a unique underground stormwater management structure. Location of the construction site presented a significant challenge to the design engineers. The only space available for the installation was the 72-foot wide median of the east and west-bound lanes of 16 Avenue - a section of the TransCanada Highway. Along with the space limitations, the 21 to 30-foot depth-of-bury was a significant consideration for equipment access and material selection for the structure.

The project consisted of a two-cell precast concrete box system (each box unit measuring 8 feet wide x 10 feet high), 800 feet long with cover up to 18 feet over the duct. This required an excavation depth in excess of 30 feet. The project also included two 8-foot x 18-foot cast-in-place maintenance access manholes that connected the two-cell duct to an existing duct with 72-inch diameter concrete pipe. The maintenance access manholes were located about 1/4 the distance from each end of the duct. City of Calgary Wastewater completed the engineering, in collaboration with Mack, Slack and Associates Inc. and EBA Engineering Consultants Ltd., located in Calgary.

The 2 million gallon underground storage structure was built to relieve flooding in north-east Calgary due to severe rainstorm events. The duct, located in the community of Rundle will collect stormwater during major rainfalls, detain it, and then slowly release it back to the storm sewer system.



**Boxes designed to support weight of crane as well as backfill material.**

During the project bidding stage, Whissell Contracting asked Lafarge engineers if they could design precast boxes to support an American 5299 fifty-ton crane to place the two parallel lines of box units. The design to support the crane, as well as the final soil backfill, resulted with the precast box culvert option being lower cost than the cast-in-place option.

Consideration of a high-density polyethylene conduit had been rejected during the preliminary engineering phase because of a lack of approval for use in the City of Calgary. City engineers had concerns about life cycle costs of HDPE, and additional concerns about the engineering of an HDPE duct along with the experience to construct such a structure.

The production and installation schedules were very important considerations of the project since the City could not close 16 Avenue N.E., and had to keep lane restrictions to

a minimum so as not to disrupt traffic. There was no room for on-site storage, so just-in-time delivery from Lafarge's plant 10 miles away became critical to the cost of construction.

BoxCar, a software program developed by the U.S. Federal Highway Administration and American Concrete Pipe Association during the 1990s was used in the design stage of the



precast concrete boxes. Deriving its name from "box culvert analysis and reinforcing design," this popular interactive

program can be used to calculate reinforcing steel areas for user-specified box geometry, material properties, and loading area. The program was used to analyze the precast boxes that would support the crane, the backfill loads of the median and the structural elements of

the stormwater storage duct. It was particularly useful for the contractor during the bidding stage of the project to get speedy and accurate answers to critical questions. The analysis proved that the boxes could be designed with adequate strength for performance and durability without requiring stirrups for shear reinforcement.

Work began on March 20, 2003 with preparation of the site for the installation of the boxes. The first box was shipped to the site

on April 7 with the last of the 542 box sections arriving on June 13. The job was completed June 30, 102 days after start-up. In the plant, production of the specially designed box units started on February 19, and ended ninety-four days later on May 24.

The design team used engineering principles, contemporary design software, and life cycle cost considerations to ensure an economic and safe project that will serve the people of the area for generations. Resources have to be used more wisely than ever before, considering the high costs of infrastructure rehabilitation and growth issues facing our cities. The Rundle underground storage duct may be considered a leading-edge project that employed engineering principles, currently being enhanced by university-based research (see inset) for tackling complex and costly infrastructure projects. Construction of the Rundle duct was estimated to cost \$CAD3.8 million. ☺

**It is critical to public safety that structures such as the Rundle stormwater duct not undergo brittle shear failures. If the shear reinforcement in these structures is excessive, however, it is a waste of resources and contrary to principles of sustainable development.**

**An investigation into shear behavior of concrete box culverts is being undertaken at the University of Toronto. When completed, the research is expected to have a significant impact on the cost of buried infrastructure and the use of resources for producing precast concrete boxes. But most significantly, the research will have a profound impact on design methodology and principles used in industry and academia for concrete structures.**

<b>Project:</b>	Rundle Underground Storage Duct
<b>Owner:</b>	City of Calgary
<b>Design Engineer:</b>	Michael Chau, P.Eng., City of Calgary
<b>Structural Consultant:</b>	Mack, Slack and Associates Inc. Calgary, AB
<b>Geotechnical &amp; Quality Control:</b>	EBA Engineering Consultants Ltd, Calgary, AB
<b>Contractor:</b>	Whissell Contracting Limited Calgary, AB
<b>Quantities:</b>	800 feet (8-foot wide x 10-foot high) two-cell concrete duct
<b>Producer:</b>	Lafarge Canada Inc., Greater Calgary Area Randy Giberson, P.Eng., Sales and Plant Engineer

The Calgary Plant of Lafarge Canada Inc. is a key component of Lafarge North America's concrete pipe operations in Canada. Products include reinforced concrete pipe ranging in size from 12-inch to 120-inch diameter, jacking and tunnel pipe, manholes, catch basins, precast concrete box units and associated drainage products. Lafarge plants in Calgary, Edmonton and Winnipeg provide precast concrete pipe and an assortment of drainage products throughout western Canada. See [www.lafargepipe.com](http://www.lafargepipe.com) for details.



# Lesson Learned About Making the Right Choice Of Culvert Pipe

*9-foot x 6-foot precast box sections were used for a new precast concrete culvert.*

Photos: Rinker Materials-Hydro Conduit

By Jeffery A. Hite, Rinker Materials-Hydro Conduit • Miami, Florida • 813-220-4076

Vigilant residents of the idyllic River's Edge Street Subdivision in Jupiter Florida had sufficient warning that a culvert under the only road entering their neighborhood was about to fail. They banded together to replace a failing high density polyethylene (HDPE) pipe installation with a reinforced concrete box culvert. A concrete culvert system was originally specified in 1996. Residents had taken the contractor's advice to install HDPE pipe instead of concrete because of a lower initial cost of the culvert material. The premature failure is a prime example of using the wrong material for an application, and not matching service life of a product to design life of a project.

A triple run of 48-inch HDPE pipe was installed under the access road to the subdivision in 1996. The road crosses a natural creek that drains into the Loxahatchee River. Within two years after the design engineer had originally specified a concrete culvert system, cracks formed on the HDPE pipe and extended through the wall. The cracks began at the pipe ends and grew to eventually join in the cen-

ter. Said Wallace B. McCall, local resident, "With complete failure and road collapse imminent, we were faced with the prospect of being stranded with no access to our homes and no



▲ Failed triple run of 48-inch HDPE pipe.

◀ Single access road closed for 4 days.

access to fire or medical emergency vehicles."

When the imminent failure was first identified, homeowners sought advice from the manufacturer of the HDPE product, only to



find that the manufacturer maintained the opinion that the culvert material was failing due to installation conditions, and initially offered no monetary assistance to alleviate the problem. When a lawsuit was filed against the manufacturer, supplier, and installer, the parties reached a settlement totaling \$27,500. This was only 61% of the original \$45,000 cost of the installation. Had a concrete culvert system been installed as specified, its service life of 75 to 100 years (depending upon local environmental conditions), would have matched the intended design life of the entrance roadway, and there would have been no need for the residents to assume a premature replacement charge. Low-cost alternatives to concrete drainage products do not always meet the long-term needs of projects.

Property owners contacted Rinker Materials-Hydro Conduit, Miami Florida in search of an economic solution. Hydro Conduit supplied 9-foot x 6-foot precast box sections for a new precast concrete culvert. The contractor excavated the failed HDPE pipe and replaced it with precast concrete sections within the four days that the road was closed in November 2003. A temporary footbridge was also built by the contractor for pedestrian traffic. During construction, residents also used boats to cross the river. They made arrangements with Martin County Fire Rescue to provide personnel and equipment to the island neighborhood in case of emergencies. Mr. McCall commented, "All things considered, the project was a huge success, and has totally resolved our concerns about an unplanned total road collapse."



*During construction, residents also used boats to cross the river and a temporary footbridge was also built for pedestrian traffic.*



Cost of the replacement, including excavation of the failed pipes, was \$47,500. The River's Edge Street Subdivision homeowners paid for the work and material on a voluntary basis. They are relieved to have resolved the problem and are confident that the box culvert is a permanent solution. Many residents

agreed that they now have a structure in place that will not fail, as did the high density polyethylene system. The concrete culvert looks better, functions better, and is more durable. Residents fully realize that they would

have saved considerable money in the long run had they gone along with the original specification for a concrete culvert that

could withstand the loads of local traffic and service vehicles, as well as the demands of a maritime climate and aquatic environment. ☺

<b>Project:</b>	River's Edge Street Subdivision Culvert Replacement
<b>Owner:</b>	River's Edge Street Homeowners
<b>Quantities:</b>	Forty feet
<b>Producer:</b>	Rinker Materials-Hydro Conduit Miami, Florida Jeffery A. Hite, Regional Engineer

Rinker Materials has been a part of Florida's building and construction industry since 1926, when Marshall E. "Doc" Rinker, Sr. started the company. Rinker Materials is a major supplier of precast concrete pipe, boxes and manholes, construction materials, aggregates, and ready-mixed concrete throughout the United States. For more information on Rinker Materials-Hydro Conduit, visit [www.rinker.com](http://www.rinker.com).

# A Study Into The Economic Costs of Culvert Failures

By Joseph Perrin Jr., Research Assistant Professor,  
Civil Engineering Department, University of Utah  
and Chintan S. Jhaveri

As America's highway infrastructure ages, bridge corrosion, road degradation and utility decay are becoming an increasing concern for agencies across the Nation. Culvert pipes and boxes on major roads are also at risk, as recent catastrophic failures have resulted in sinkholes, road damage, and flooding. Such failures of culvert infrastructure are costly to:

- government agencies which must fix or replace the culvert at emergency rates;
- private land owners who often incur flood damage; and,
- the motoring public and industry due to delays in travel time.

When a section of culvert collapses, there are often issues of safety and liability that arise from the ensuing road failure.

Actual replacement cost and the cost of roadway user delays (due to road closures and detours) are often not considered in the Life Cycle Cost Analysis (LCCA). Since the Nation's highway infrastructure is in need of billions of dollars to simply maintain current assets, it is very important to include these costs in any LCCA. A survey of all 50 states and seven Canadian provincial transportation agencies regarding culvert failures and LCCA was incorporated into the study. Of the 25 responding agencies, only three reported that they apply some form of LCCA, while 15 reported that they document their failures to some extent, although most are cursory or memory based.

Several recent examples of failed culverts are documented in the final report to demonstrate the impact on LCCA. The study concludes that a national tracking of culvert failures would help state and provincial transportation agencies better understand the risk associated with culvert failures. Tracking failures would also help identify trends and quantify the costs. Based on the tracked information, a risk factor could be incorporated into LCCA calculations.

## Scope Of The Study

The scope of the study on the economic cost of culvert failures was:

- to quantify the economic implications of culvert failures, including related highway user delay costs;

- to find out if the risk of failures is being considered as a culvert material selection criteria; and,
- to identify the need to document culvert failures.

Various types of pipe material have different life expectancies. As more culverts fail, a major concern is whether government transportation agencies have, or do not have a plan to monitor and replace culverts based on inspection. Without a scheduled maintenance and replacement plan, failing culverts will continue to be replaced when unscheduled emergencies occur.

While the specification for the type of culvert pipe to be installed resides with the governing agency, many agencies have not distinguished the difference between flexible and rigid pipe. Installation costs vary by pipe material, and many agencies select the less expensive option. This approach may be a short-term decision that does not consider the long-term costs. LCCA, therefore, should be considered to determine the overall costs of the design life of the installation.

## Context

In typical LCCA, service life of a pipe material is a contentious topic because an exact service life for each pipe material has not been fully determined. Certain agencies such as the US Army Corps of Engineers, and American Association of State Highway and Transportation Officials (AASHTO) and ASTM have made recommendations to help states and cities select culvert pipe material, but each transportation agency also assumes their own life expectancy based on experience or literature.

The United States Army Corps of Engineers identified service life of pipe material in a March 1998 report. The following are quotes from that report:

- Service Life: "For major infrastructure projects, designers should use a minimum project service life of 100 years when considering life cycle design."
- Concrete: "Most studies estimated product service life for concrete pipe to be between 70 and 100 years."
- Steel: "Properly applied coatings can extend the product life to at least 50 years for most environments."
- Aluminum: "Long-term performance is difficult to predict because of a relatively short history of use, but the designer should not expect a



- product service life of greater than 50 years.”
- Plastic: “Performance history of plastic pipe is limited. A designer should not expect a product service life of greater than 50 years.”

AASHTO, in its 1991 Model Drainage Manual, also documents the recommended practice for culvert selection and design. While general hydraulic design criteria is recommended, the AASHTO Drainage Manual gives recommendations about the costs and risk analysis aspect of pipe material selection. These recommendations state:

- The chosen culvert shall meet the selected structural and hydraulic criteria and shall be based on:
  - construction and maintenance costs;
  - risk of failure or property damage;
  - traffic safety;
  - environmental or aesthetic considerations;
  - political or nuisance considerations; and
  - land use requirements.
- Culverts shall be located and designed to present a minimum hazard to traffic and people.
- Culverts shall be regularly inspected and maintained.
- The material selection shall consider replacement cost and difficulty of construction as well as traffic delay.
- The selection shall not be made using first cost as the only criteria.

The AASHTO Drainage Manual documentation supports the need to consider all aspects of costs, including traffic user delays and risk of failure. Field results are the primary measure in a risk assessment as it includes the pipe performance regardless of pipe material or installation abnormalities. If the installation procedures are improper this produces an inherent risk that can be accounted for by historic performance records. As construction inspection funding by government agencies is scarce, reliance upon contractor’s quality control procedures greatly impacts installation quality. Therefore, there is an inherent need to track failures and document pipe performance on a national level to identify the performance by pipe material.

A typical consideration in cost analysis for culvert selection is material cost. Other costs include excavation, backfill, compaction, labor, traffic control, and road repair. When only pipe material costs are considered for an initial installation, the future implications for replacing the pipe are often neglected.

### A New LCCA Equation To Include Total Cost of Installation

Supported by a literature review and the survey,

the study team developed a new equation for LCCA that includes total cost of installation. The new method computes the total cost (T) of installing a culvert for a given time (H), usually 100 years. The total cost (T) in Equation 1 is the sum of the culvert’s installation costs ( $I_{H(L)}$ ) for all installation within the horizon year, and the cost of associated user delay (D).

**Total Cost (T) = Installation/Replacement Cost ( $I_{H(L)}$ ) + User Delay (D).....(Equation 1)**

#### Installation/replacement cost

An explanation for installation/replacement costs is given below and shown in equation 1a. The installation/replacement cost ( $I_H$ ) is computed from the initial installation cost ( $I_i$ ) based on the present value, and then projected at a discount rate (r) for any replacements during the time horizon H depending on the assumed life of the culvert (L). The discount rate is the differential between inflation and interest rates. Therefore,

$I_{H(L)} = \sum_{k=0}^n I_i (1+r)^{kL}$  where,  $n = (H/L)-1$ ..(Equation 1a)

For example, the cost of installation for a 100-year horizon for culvert material having different service lives is shown in Table 1. This cost is for material with assumed lives of 25, 50, and 100 years, based on a 4% discount rate. Furthermore, it is assumed that initial installation cost for each pipe culvert crossing is approximately the same.

#### User Delay Costs

The cost of delay (D) experienced by the user during the culvert’s installation is computed based on the following: (Typical assumptions are shown in italics)

- the roadway Annual Average Daily Traffic (AADT) on which the culvert is being installed;
- the average increase in delay or congestion the installation is causing to each vehicle per day (‘t’ in hours);
- the number of days the project will take (d);
- the average rate of person-delay in dollars per hour ( $c_v$ ); (*\$17.18 per person-hour of delay*)
- the average rate of freight-delay in dollars per hour ( $c_f$ ); (*\$50 per freight-hour of delay*)
- the percentage of passenger vehicles traffic ( $v_v$ ); (*97% vehicle passenger traffic*)
- the vehicle occupancy factor ( $v_{of}$ ); and (*1.2 persons per vehicle*)
- the percentage of truck traffic ( $v_t$ ); (*3% truck traffic*)

**TABLE 1: Cost (in dollars) of Culvert Installation over a 100 Year Horizon**

Horizon (H)		100 years			
Assumed life of culvert (L)		25 years	50 years	100 years	
# of Replacements in 100 years (n=(H/L)-1)		3	1	0	
Costs	Initial Installation I <sub>i</sub>	I <sub>H</sub> (25)	I <sub>H</sub> (50)	I <sub>H</sub> (100)	
		\$5,000	\$148,589	\$40,533	\$5,000
		\$10,000	\$297,178	\$81,087	\$10,000
		\$25,000	\$742,944	\$202,667	\$25,000
		\$50,000	\$1,485,889	\$405,334	\$50,000
		\$75,000	\$2,228,833	\$608,001	\$75,000
		\$100,000	\$2,971,777	\$810,668	\$100,000

**TABLE 2: User Delay Per Day for a Range of AADTs**

AADT Level	Increased Delay Level				
	10 min	20 min	30 min	1-hour	2-hour
5,000	\$17,915	\$35,829	\$53,744	\$107,488	\$214,975
10,000	\$35,829	\$71,658	\$107,488	\$214,975	\$429,950
20,000	\$71,658	\$143,317	\$214,975	\$429,950	\$859,901
30,000	\$107,488	\$214,975	\$322,463	\$644,926	\$1,289,851
50,000	\$179,146	\$358,292	\$537,438	\$1,074,876	\$2,149,752
75,000	\$268,719	\$537,438	\$806,157	\$1,612,314	\$3,224,628
100,000	\$358,292	\$716,584	\$1,074,876	\$2,149,752	\$4,299,504

The k factor allows each user delay cost to be tied to the specific period of the failure year where the variables may change in the future.

$$D = \sum_{k=0}^n [AADT_k * t_k * d_k * (c_{vk} * v_{vk} * v_{ofk} + c_{fk} * v_{fk})] \quad \text{(Equation 1b)}$$

Table 2 shows a sample of annual average daily traffic and the cost of increased delay.

**The New Equation**

By developing a national database where a “culvert failure report” could be compiled, data could be made available to other agencies, and experiences across the nation could be shared. Culvert tracking data could lead to development of a risk factor and emergency replacement factor. Both of these could be included in the cost analysis methodology, along with the installation/replacement and user costs. Equation

1 would then include a new factor as shown in Equation 2.

$$\text{Total Cost (T)}_t = \text{Installation/Replacement Cost } (I_{H(L)})_t + \text{User Delay (D)}_t + RF_t * (ERF * I_t + EUD)_t \quad \text{(Equation 2)}$$

Where:

- T = total life cycle cost for the given pipe type t
- I<sub>H(L)t</sub> = installation costs and replacement costs for an H horizon year with L expected pipe life for pipe type t.
- D<sub>t</sub> = user delay during construction and replacements during the horizon analysis period (usually 100 years)
- RF = risk factor for pipe type t (some probability of failure)
- ERF = emergency replacement factor for pipe type t  

$$= \frac{\text{Cost of emergency replacement}}{\text{normal replacement costs}}$$



EUD = emergency user delay = Cost of user delay during emergency replacement

A number of recent culvert failures were identified as part of the study. Table 3 identifies the costs of the failures related to emergency costs and how a longer life pipe used during initial installation would have saved long-term costs. It also identifies the associated cost-benefit ratio.

**Implications of The Study**

User traffic delay costs in LCCA cannot continue to be overlooked. Most often, user delay costs far exceed the actual construction costs. Any initial savings that occur by installing a culvert material with a lower service life expectancy is quickly exceeded by subsequent replacement installations and user delays. By

quantifying the additional costs of emergency replacement, it is clear that an inspection/maintenance program provides an attractive cost benefit. It also shows that culvert materials with a longer service life are more cost-effective than materials with lower service life expectancy – even if initial installation is more expensive.

The Nation’s infrastructure is aging more rapidly than it can be maintained and replaced. An example is the interstate system that is now approaching 45 years. Many culverts on this system have 30 to 50-year service life material and there is no immediate prospect to replace the thousands of culverts that are at, or have exceeded, their service life. It is important to consider whether culvert material with longer service life is more cost-effective simply based on the likelihood that the culvert may not be replaced at the end of its service life. ☺

**TABLE 3: Summary of Failure Case Study Information**

Location	I-70 east of Vail, CO	I-480 near Maple Heights, OH	SR-79, near Buckeye Lake, OH	SR 173, West Jordan, UT	I-70 Eisenhower Tunnel, CO	I-75 near Prudenville, MI	Highway 401, near Milton, Ontario Canada
Pipe Size / Type	66" CMP	60" CMP	30" CMP	72" CMP	60" CMP	73"x55" ellipse, CMP	30" CMP
Costs of Replacement (\$)	\$4,200,000	\$384,000	N/A	\$48,000	\$45,000	\$95,000	N/A
Length (ft)	85-100'	N/A	50'	50'	40'	50'	40'
Time to Replace (Days)	49	8	6	5	7	6	1
Impacted AADT	20,950	16,760	4,920	19,338	1,257	5,100	45,000
Detour Delay	120 min	60 min	20 min	20 min	30 min	20 min	240 min
User Cost (\$)	\$4,046,000	\$3,079,000	\$290,000	\$693,000	\$220,000	\$249,000	\$5,033,000
Total Costs (\$)	\$8,246,000	\$3,463,000	N/A	\$741,000	\$265,000	\$344,000	
Pipe Age (yrs)	35-60	60	30+	20	30	30	25
Number of Replacements (Compared to 100 year design life)	1	1	3	4	2	2	3
Total Costs for 100 yr Horizon (2003 \$)	8,046,000	3,463,000	NA	2,964,000	530,000	688,000	NA
Estimated Cost to change to 100 year pipe (2003 \$)	12,000	13,000	NA	6,200	4,500	6,200	NA
Benefit/ Cost Ratio	671	266	NA	478	118	111	NA

All cost rounded to nearest \$1,000

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Costs: \$175 for guests when sponsored by ACPA member company. Includes course materials, group functions, continental breakfast, lunch and refreshments. Does not include hotel or travel expenses.



## Industry Spotlight

continued from page 5

infrastructure industry. Please comment on the needs of the buried infrastructure industry and the way you see the concrete pipe industry evolving over the next few years.

**Deem:** I believe the needs of the buried infrastructure industry will center on our national security and that will affect all infrastructure needs of the country. Along with that, I think we'll also be looking at sustainability and environmental issues which make the selection of concrete pipe a natural.

As far as the concrete pipe industry, I think we will see some continued consolidation of companies, but at the same

time, new niche-market precast companies will also enter the marketplace. I see a stronger, healthier industry. These past five years have gone by quickly because the ACPA and the industry have put a lot of really hard work, thought, and ideas into what is needed to grow the industry. We have the most durable, long-lasting pipe system made, and it's now a matter of getting that message across. The interesting thing about promotion efforts is that we don't get immediate results; we plant seeds and help them grow. The seeds we've planted for the concrete pipe industry encourage me. ACPA has developed a strong strategic plan; they have a dedicated staff and very enthusiastic members to carry out that plan. I have a lot of optimism for the future. ☺

## “Quality Cast” Certified Plants

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

### Storm Sewer and Culvert Pipe

- Atlantic Corp. Pipe, San Juan, PR - Miguel Ruiz
- Boughton's Precast, Inc., Pueblo, CO - Rodney Boughton
- California Concrete Pipe (Oldcastle), Stockton, CA - Qing Lian Gao
- Carder Concrete Products, Littleton, CO - Bruce Spatz
- Carder Concrete Products, Colorado Springs, CO - Tom Walters
- Cayuga Concrete Pipe Company (Oldcastle), Croydon, PA - Allen Reed
- Cayuga Concrete Pipe Company (Oldcastle), Montrose, PA - Joe Diana
- Cayuga Concrete Pipe Company (Oldcastle), New Britain, PA - Kim Venable
- Cretex Concrete Products West, Inc., Billings, MT - Bill Cooper
- Cretex Concrete Products West, Inc., Mitchell, SD - Corey Haeder
- Cretex Concrete Products West, Inc., Rapid City, SD - Jeff Ullrich
- Cretex Concrete Products West, Inc., Riverton, WY - Butch Miller
- Foothills Concrete Pipe & Products, Platteville, CO - Frank Barnes
- Grand Junction Concrete Pipe, Grand Junction, CO - Ben Burton
- Hanson Pipe & Products, Inc., West Memphis, AR - Don Powell
- Kerr Concrete Pipe Company (Oldcastle), Hammonton, NJ - Bob Berger
- Kerr Concrete Pipe Company (Oldcastle), Farmingdale, NJ - Scott McVicker
- NC Products (Oldcastle), Raleigh, NC - Mark Sawyer
- Oldcastle Precast, Inc., Lebanon, TN - Jeff Masters
- Permatile Concrete Products, Bristol, VA - Charles Rainero
- Rinker Materials-Hydro Conduit, Denver, CO - Mike Leathers
- Rinker Materials-Hydro Conduit, Oakdale, PA - Ken Souffrant
- Rose Concrete Products, Inc., Scott City, MO - Laura Woldtvedt
- Sherman-Dixie Concrete Industries, Inc., Chattanooga, TN - Chris Mears
- Sherman-Dixie Concrete Industries, Inc., Franklin, TN - Tony Jackson
- Sherman-Dixie Concrete Industries, Inc., Lexington, KY - Marcus Barnett
- Sherman Concrete Pipe, Huntsville, AL - Billy Fagan

### Sanitary Sewer, Storm Sewer and Culvert Pipe

- Amcor Precast (Oldcastle), Nampa, ID - Mike Burke
- Amcor Precast (Oldcastle), Ogden, UT (12<sup>th</sup> Street) - Bob Jolley
- Amcor Precast (Oldcastle), Ogden, UT (Wall Avenue) - J. P. Connoley
- Cretex Concrete Products North, Inc., Elk River, MN - Bryan Olson
- Cretex Concrete Products Midwest, Inc., Shawnee, KS - Lynn Schuler
- Cretex Concrete Products Midwest, Inc., Waukesha, WI - Jay Rhyner
- Geneva Pipe Company, Orem, UT - Fred Klug
- Langley Concrete & Tile, Ltd., Langley, BC (Canada) - Mark Omelianiec
- NC Products (Oldcastle), Fayetteville, NC - Preston McIntosh
- Ocean Construction Supplies Limited (Inland Pipe), Vancouver, BC (Canada) - Ron Boyes

### Box Culvert

- Carder Concrete Products, Littleton, CO - Bruce Spatz
- Cretex Concrete Products West, Inc., Mitchell, SD - Corey Haeder
- Cretex Concrete Products West, Inc., Rapid City, SD - Jeff Ullrich
- Grand Junction Concrete, Grand Junction, CO - Ben Burton
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