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# concretepipenews

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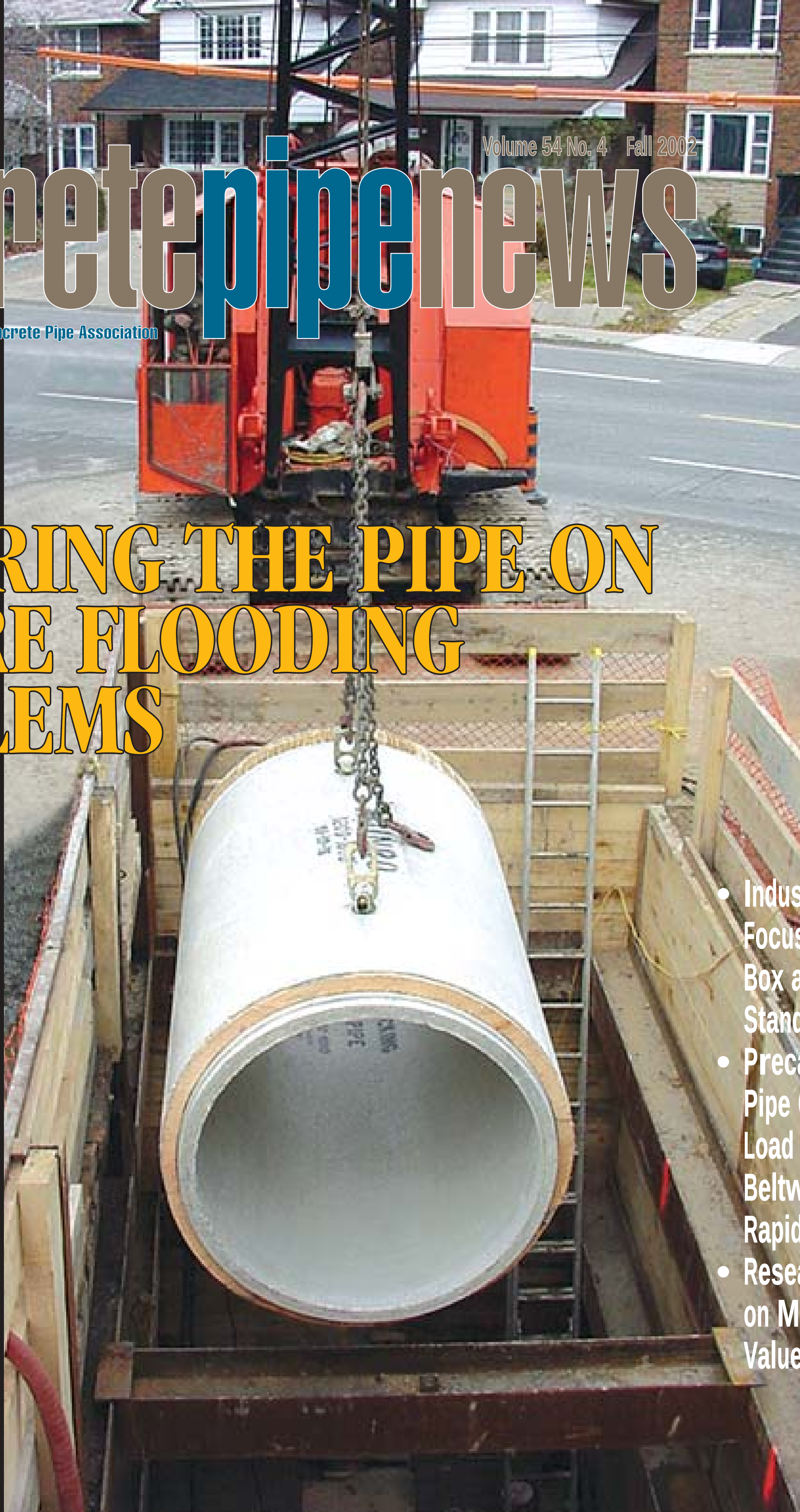

## PRECAST RCP TUNNELED & JACKED IN TORONTO

# LOWERING THE PIPE ON FUTURE FLOODING PROBLEMS

- Industry Spotlight: Focus on Precast Box and Pipe Standards
- Precast Concrete Pipe Carries the Load of New Beltway in Grand Rapids
- Research History on Manning's "*n*" Values

**This issue:**

Volume 54, Number 4
Fall 2002

*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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*Cover: Over 440 meters of 1200 mm, 100D (48-inch diameter Class IV) precast reinforced concrete pipe was jacked into position in the Toronto suburb of East York. The tunneled and jacked pipeline will help eliminate chronic flooding problems in the residential neighborhood.*

President's Report

*John J. Duffy*

# A WORLD FULL OF CHOICES

We live in a world full of choices. Each morning, most of us are able to enjoy our choice of breakfast juice, coffee, after shave lotion and what we wear to work. We selected our mode of transportation, or make and model of vehicle, from a list of suitable options. And we may even choose what we have for lunch. Our choices can range from the brand of toothpaste we prefer to our choice of profession, spouse/partner or religious faith. The best thing about this great country is that we have the freedom to make choices.

Designers of North America's water and wastewater pipeline infrastructures, and the contractors who have built them, have choices also. They want a drainage product that will perform according to their expectations. It is irresponsible to tell them one type of thermoplastic conduit "handles the gamut of installation needs and that with proper installation procedures followed – only one class of pipe is required." How presumptuous is such a claim! It is the responsibility of producers and their industry associations to provide properly tested products and verifiable information to designers and contractors so they can make informed choices about the products best suited for an application.

For years, the concrete pipe industry has pointed out the weakness of thermoplastic conduit standards. We have been diligent in our efforts to expose half-truths and misleading information from producers of competitive drainage products. Never has the concrete pipe industry claimed that concrete pipe – and its offerings of pipe class are the only choices to be considered by designers. Our message has been consistent. "Here are the products; here is the performance that you can expect under given environmental circumstances; here are the design tools that can be used to help build a system that will last a hundred years and more; and, volumes of scientific and promotional publications are available from our national, state and provincial concrete pipe associations that help you make an informed choice."

The concrete pipe industry does not make the assumption that designers and contractors cannot think for themselves and make informed choices of products to use within the paradigms of local environmental, economic and political values.

Yes, concrete pipe industry ads and promotional publications are hard-hitting. They have to be in an industry that can be easily overlooked, since once its products are installed they are out of sight and out of mind for generations. It is extremely costly and oftentimes dangerous to fix mistakes, if the wrong product has been installed and has to be replaced. The concrete pipe industry offers choices to people who use its products, and vigorously defends its products and technologies, as well as the rights of designers, engineers, contractors and public officials to make the right choice for our nation and its people.

Industry Spotlight

# Wallace J. Munden, P.E.

## Vice President, Scurlock Industries
## President, Scurlock Industries of Springfield

Known to his friends in the concrete pipe industry as "Wally", Munden has been an active member of the American Concrete Pipe Association since joining its Technical Committee in 1985. He served on that committee until March 2002, including two terms as Chair. Wally is a professional engineer who graduated from Vanderbilt University with a Bachelor of Engineering degree.

Munden supports the concrete pipe industry by serving on committees such as ASTM C-13, (where he was recently appointed Chair of C-13.07), ASCE Committee on Buried Concrete Structures, and the AASHTO Rigid Culvert Liaison Committee. He is a member of the National Society of Professional Engineers, and the American Public Works Association, serving as President of the Missouri chapter in 1982.

Wally began his career in the concrete pipe industry in 1982 as General Manager of Rose Con Pipe, after heading up the City of Springfield's engineering division of the Public Works Department for ten years. A subsidiary of Jonesboro Concrete Pipe, Rose Con Pipe changed its name to Scurlock Industries in 1999 in honor of company founder, Vance Scurlock. Characteristic of his service history to the concrete pipe industry, Munden did not hesitate when asked to participate in the Industry Spotlight. This is what he had to say on the subject of precast concrete pipe and boxes, and associated standards.

**Q:** *Precast concrete boxes have proved to be a versatile product used for conveying storm water, sewage, and watercourses; access tunnels for animals, people, and vehicles; galleries for housing buried electronics, security structures, and retention structures. Please comment on the application of box units and the standards required to keep pace with their variety of uses.*

**Munden:** At Scurlock Industries, we supply boxes for all of the uses mentioned in the question as well as boxes for golf course structures, access and utility tunnels, and storm shelters. There is great potential for increased use of boxes for long-term retention facilities under parking lots and other facilities, especially where traffic loading is a design consideration.

The standards we have now for box design and materials are certainly adequate, and in many situations, may be too conservative. Looking ahead, we can expect designers and end users to work with concrete pipe and box producers to fine-tune our standards for special applications.

**Q:** *You are now Chair of the new ASTM C13.07 subcommittee on box culverts. What are the challenges facing the committee and what does your committee hope to achieve over the next three years?*

**Munden:** The new Load and Resistance Factor Design (LRFD) provisions coming out of AASHTO will require the development of new standards, including new reinforcing tables. In other areas, we will have to review existing standards to accommodate longer spans, work on new standards for 3-sided structures, and consider standards for new materials such as cementitious slag. For certain sizes of boxes, current standards include tables that are over designed in areas such as haunches and wall thickness. The Committee will look into unifying standards to provide common fill height tables and spans.

**Q:** *Designers and owners of precast concrete box systems are becoming more critical of joint tolerances and infiltration/exfiltration. Please comment on the design of jointing systems and gaskets for box culverts and sewers.*

**Munden:** This is an area that will require measured study. New standards would lead to the need for an upgrade or purchase of new equipment. Such a standard could be misused, as watertight joints are not necessary, or even desirable, for most applications. We have to be careful that the development of a new standard for tighter joint systems is not misinterpreted, or accepted as the norm for every application. Most producers already have the ability to provide a box culvert joint that will meet a specifier's or owner's special requirements.

**Q:** *BOXCAR is now widely used to calculate reinforcing steel areas for user-specified box geometry, material properties and loading data. What features of this program do you believe will require continuous review for future upgrades, and why?*

**Munden:** Since BOXCAR was first developed, the program has undergone periodic improvements, like bringing it into a Windows environment. It must be constantly upgraded to ensure that it is user friendly, and also to bring new and revised standards into the program. At the same time, we must be careful that it is not "misused" by persons who do not have sufficient knowledge of the design parameters associated with the program. Future upgrades will address longer spans, new designs, and materials standards. The program must always be compatible with standards accepted by AASHTO and ASTM.

**Q:** *As a long-time member of the American Concrete Pipe Association and past Chair of its Technical Committee, please comment on your most challenging issue related to the application of precast concrete products, and how the issue was resolved.*

**Munden:** I first became involved in ACPA's Technical Committee in the closing years of the Soil-Pipe Interaction Design Analysis (SPIDA) research and testing, which led to a fundamental change in the way we understand bedding factors and installation procedures. That was about 17 years ago. The biggest challenge and accomplishment has been the move from standard A, B, C, and D beddings to Type 1, 2, 3, and 4 beddings for precast concrete pipe. This issue was the most significant change in our industry for some time, and it led to the development of the PIPECAR and BOXCAR software. The research and ultimate changes spanned a period of more than 30 years from inception to where we are today with the new bedding standards and factors being accepted.

Another significant challenge has been the work we have done to explain the differences between rigid and flexible installations, and just what is required for a well-constructed installation.

**Q:** *The trenchless technology industry is building larger tunneling and jacking machines, and installations are using greater sizes of precast concrete products over greater distances. What are the issues that must be addressed by concrete pipe producers to meet the need for products used for tunneling and jacking projects?*

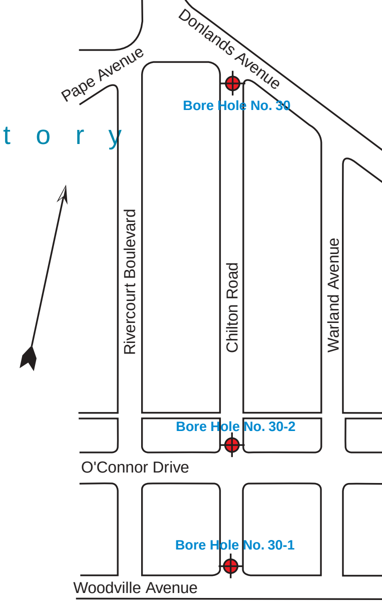
**Munden:** Bedding factors for jacking and tunneling are not yet standardized. As I mentioned before, our industry worked long and hard to develop new bedding factors based on SPIDA research, but loads are different for jacked and tunneled pipe than they are for trenched pipe.

Properly engineered joint designs for trenchless installations are crucial, and different manufacturers may have different designs. The ACPA's Technical Committee has been working with ASCE to develop a design procedure to appropriately evaluate a jacking pipe joint for jacking loads.

Concrete pipe producers want to provide sufficient information to designers regarding appropriate pipe strengths for jacking and tunneling. For example, designers often call for Class V pipe strength for trenchless applications. It is quite possible that a lower strength class pipe would suffice, but designers sometimes confuse pipe strength with jacking pressure resistance. Sufficient compressive strength of the pipe at the face of the joint is crucial but often has little relationship to the strength class, or load bearing capacity of the pipe. There is a need to explain the difference between compressive loads at the face compared to soil loads on the pipe.

# Fast-Paced Installation of RCP Spells Quick Relief for Canadian Residents

By Frank Mazza, C.E.T.
Munro Concrete Products Ltd., Barrie, Ontario • (705) 734-2892




*Sketch showing proposed borehole locations.*

A chronic flooding problem for residents along Chilton Road in East York, Toronto has been corrected with a 1200 mm (48-inch) diameter reinforced concrete storm sewer, installed by the jacking method. Munro Concrete Products of Barrie, Ontario, supplied the specially designed pipe to accommodate the installation challenges faced by the contractor. The new sewer is one of many ongoing projects by the City of Toronto to reduce surface and basement flooding in various neighborhoods of the city. Residents in some old neighborhoods in the Borough of East York have endured periodic flooding for decades.

The City of Toronto has been phasing in corrective measures for several years to mitigate the flooding. Historically, during wet weather conditions, stormwater was discharged along with sanitary sewage into combined sewers. Many of these old combined sewers were constructed over eighty years ago, and now have insufficient capacity to convey flows. Stormwater that once was absorbed in open fields is now carried from rooftops of buildings then overland by paved surfaces. The combined stormwater and sanitary sewage causes flooding and overcharging of Toronto's wastewater treatment plants. In some instances, the combined stormwater and wastewater flowed directly into Lake Ontario causing beach closures and increased levels of pollution.

*Two different jacking contractors, working from two locations, enabled Toronto's Works and Emergency Technical Services Department to complete the 1200 mm, 100 D (48-inch diameter Class IV) jacking project in only 90 days.*

In East York, part of the solution is construction of trunk storm sewers to collect flows from local storm sewers and discharge effluent to East York's existing Leaside trunk storm sewer. The Chilton Road trunk storm sewer is part of Toronto's Combined Sewer Overflow (CSO) management strategy.

*Swift Lift® lifting devices and steel bands around the pipe bells were integral components of the precast concrete pipe manufactured by Munro Concrete Products Ltd.*

*The reinforcing steel of each pipe was extended into the spigot to enhance jacking performance.*

Chilton Road services an environmentally sensitive, and mature residential neighborhood. Installation of the trunk sewer by open cut method would have been extremely disruptive to the daily routines of the residents, and would have adversely effected the natural environment. Residents and their local elected representative expressed concerns about any construction activity that would cause traffic delays and road closures. The decision was made by the City's Works & Emergency Technical Services Department to install the sewer by jacking reinforced concrete pipe below the road. Concrete pipe was the obvious choice for this project because of its inherent strength and durability.

Alsi Contracting Ltd. of Maple, Ontario was awarded the contract to install 440 meters (1,443 feet) of 1200 mm (48-inch) diameter jacking pipe. Because of the concerns of the residents, Alsi was given only ninety working days to complete this project. To meet the tight construction schedule, Alsi decided to tunnel from two locations, using two tunneling subcontractors.

The jacking operation was complicated because of an existing sanitary sewer located three to four meters above the crown of the new storm sewer, and silty soil that resulted in wet jacking conditions. The soil in the area is saturated below three to five meters, to a depth of 6.5 meters (21.3 feet). The invert of the new trunk sewer is at 9 meters (29.5 feet).

All 1200 mm, 100D (48-inch diameter Class IV) jacking pipe supplied by Munro were manufactured with Swift Lift lifting devices and steel bands around the pipe bells. Every sixth pipe was manufactured with 50 mm (2-inch) diameter grout ports at 10 o'clock and at 2 o'clock positions on the barrel. These grout ports were required to feed bentonite around the barrel to lubricate the pipe as it was being jacked. In total, 187 pipe units were supplied including three pipes with no spigot, and 30 with the grout ports.

Munro produced 30 pipes each day to complete the order. Steel end rings were engineered into the structure to assist with keeping the line and grade of the installation. A 5 mm (.20 inch) thick x 203 mm (8-inch) high band was selected so that the band itself would remain stiff and in place at the bottom of the form while pipe units were being poured. The reinforcing steel of each pipe was extended into the spigot to enhance jacking performance. The only change required to the production equipment was the use of an O-ring header.

The two tunneling contractors were Peran Tunnelling Ltd. and Jimmy Mack. Jimmy Mack was assigned two pushes that started from a shaft at O'Connor Drive and Chilton Road, running north for 129 meters (423 feet) and south for 129 meters (423 feet). Peran was assigned a section that began at a shaft at Donlands Avenue and Chilton Road, pushing south for 182 meters (597 feet). This construction technique, supervised by Lou Di Sarra of Alsi, was quickly initiated despite encountering poor soil conditions when sinking one of the access shafts to install the jacking equipment. As the pipe was being jacked through the silty soil, water was pumped back to the shafts, along with the spoil, and then removed from the shafts. The line and grade of the trunk sewer was guided by laser instrumentation, and a City survey crew checked the accuracy of the pushes every second day. The City took responsibility for the geodetic control and line of the sewer.

Alsi Contracting has been in business for over 30 years, specializing in sewer and watermain construction and site servicing. According to Lou Di Sarra, Alsi's General Manager, "We use reinforced concrete pipe for all jobs requiring pipe over 375 mm (15-inch) diameter. The product is better than alternatives, and concrete pipe is more reliable."

With the new stormwater trunk sewer running the length of Chilton Road, residents have the flooding relief they have been seeking for many years. Because of the reliability of the concrete pipe installation, they will enjoy life in their neighborhood with little thought to a section of the City's lifeline deep below their street.

| | |
|---|---|
| **Project:** | Chilton Road Storm Sewer Construction<br>Contract 01D1-86WP |
| **Owner:** | Works and Emergency Services Department<br>City of Toronto |
| **Designer:** | Works and Emergency Services Department<br>City of Toronto |
| **Contractor:** | Alsi Contracting Ltd.<br>Lou Di Sarra, General Manager |
| **Tunneling Contractor:** | Peran Tunnelling Ltd.<br>Jimmy Mack |
| **Quantities:** | 440 meters (1,443 feet) of 1200 mm (48-inch) diameter Reinforced Concrete Jacking Pipe |
| **Producer:** | Munro Concrete Products Ltd.<br>Barrie, Ontario<br>John Munro, President |

Munro Concrete Products Ltd was established 40 years ago under the name Precast Tank and Vault Company. In 1989 Munro's Barrie operation was opened in a 1400 square meter (15,000 sq. ft.) facility that expanded to 3,800 square meters (40,900 sq. ft.) by 1996. A second expansion is now under construction. Pipe and manholes are produced using a dry cast - vibration under pressure process. The facility features the latest in computerized batching and wire reinforcing cage fabrication equipment. Manholes, catch basins and pipe laterals can be quickly cored on one of the company's three coring machines. The facility has an ongoing quality assurance program in which raw materials and the finished product are inspected and tested. Products shipped from the plant include manholes, catch basins and ditch inlets, reinforced concrete pipe and fittings and headwalls. See www.munroconcrete.com for details.

# Precast Concrete Pipe Carries the Load of New Beltway in Grand Rapids

*By Robin Woodbury, Director of Marketing*
*Premarc Corporation*
*Durand, Michigan*
*800-968-2662*

*The Michigan DOT's desire to achieve a long design life motivated them to specify precast concrete products for the $160 million M-6/US-131 Interchange project.*

In Michigan, products are built to last. The automotive industry helps drive the American economy, and its major city lives on with the "Motor City" moniker. Little wonder that the state is known for its heavy traffic and slow commutes when the weather turns nasty. Supporting the great highways and structures of Michigan is a fabric of buried concrete pipe that carries stormwater and snow melt to the rivers and streams that flow to the Great Lakes. Premarc Corporation's network of production facilities has been instrumental in building a modern precast concrete infrastructure that will last for generations.

When driving east or west through Grand Rapids on Interstate 196 during rush hour, traffic congestion and slowdowns are common. Combine the east-west volume with merging traffic from US-131, and you have a bottleneck of angry motorists.

Work is currently under way on a greatly anticipated east-west limited access freeway in the southern Grand Rapids area. The Michigan Department of Transportation (MDOT) has been working on development of the Paul B. Henry Freeway (M-6) for 20 years. Once completed, M-6 will provide improved travel service through southern Kent and Southeastern Ottawa counties. With its eight interchanges, this freeway will alleviate traffic and congestion on local roads. MDOT estimates the new freeway will reduce travel times by as much as 50 percent in the area.

M-6 is being completed in three phases. The first phase was started in 1998 and included construction of 5.7 miles of new road. This phase was opened to traffic in November 2001. The remaining two phases will open to traffic in 2005.

The M-6 project has been broken into several different contracts and awarded to numerous contractors. The $160 million M-6/US-131 Interchange is the largest of these contracts and also the largest single MDOT contract ever bid. In addition, it is the most challenging portion of the M-6 project. The scope of the project includes new construction of a freeway-to-freeway interchange, construction of M-6 from Clyde Park Avenue to Division Avenue, 28 new bridges, and 14 new ramps. Reconstruction and widening of 4.2 miles of US-131 from 76th street to 44th street is also included in this contract.

Kamminga & Roodvoets, Inc., (K & R) was awarded all of the underground utilities and earthwork for the M-6/US-131 Interchange. The M-6 project was ideal for K & R's level of expertise because the firm has a reputation for performing more difficult and "risky" projects as they relate to schedules and field conditions.

*The scope of the M-6/US-131 Interchange project includes over 4-1/2 miles of precast concrete pipe, 600 drainage structures, 28 new bridges and 14 new ramps.*

A joint venture between contractors was formed to handle the M-6/US-131 Interchange. According to Kurt Poll, Vice President of Engineering at K & R, "We formed a tri-venture on the project a few months prior to the bid. K & R is managing the underground and earthwork, C.A. Hull Company is building the 28 bridges and miscellaneous sound and retaining walls, and Ajax Paving Industries is constructing the concrete pavement". The Joint Venture partners have worked together in the past and knew they would bring the necessary skills to the project to win the contract.

MDOT's desire to achieve a long design life motivated them to specify concrete products for the drainage system. Quality products, competitive prices and a manufacturing plant located within 10 miles of the M-6/US-131 Interchange prompted K & R to select the Premarc Corporation as its preferred supplier for all of the reinforced concrete pipe (RCP) and associated drainage products. To date, Premarc has supplied 11,960 feet of 12-inch; 1,810 feet of 15-inch; 1,984 feet of 18-inch; 1,264 feet of 24-inch; 1,592 feet of 30-inch; and 3,448 feet of 36-inch diameter RCP. Road culverts accounted for 3,607 feet of the concrete pipe shipped. Pipe supplied in the 12-inch to 36-inch diameter range were manufactured to ASTM C-14 and ASTM C-76 standards. Large diameter RCP supplied to the project included 1,696 feet of 42-inch; 272 feet of 54-inch; and 312 feet of 72-inch diameter pipe. Pipes in these sizes were manufactured to ASTM C-76 standards.

Connecting the storm sewer involved the installation of 580 drainage structures ranging from 24-inch to 60-inches in diameter. Twenty structures were supplied in diameters of 72-inch through 96-inch.

High quality products and Premarc's network of production facilities were instrumental in the management of on-time deliveries. Contractors were able to install product and stay on schedule without incurring costly delays because of close proximity to production facilities in Grand Rapids, Durand and Cadillac. Premarc used its own self-unloading fleet to deliver over 200 shipments of product to job sites.

A crucial section of the M-6/US-131 Intersection included the US-131 crossing over Buck Creek. This bridge was specified as a concrete three-sided structure in accordance with MDOT specifications. Premarc was contracted to supply a CON/SPAN® bridge system. CON/SPAN is a precast three-sided bridge system. Premarc is a licensed manufacturer of CON/SPAN in

Michigan. Installation of the bridge included part-width construction, allowing partial installation of the structure.

Installation of the CON/SPAN bridge system was divided into two phases. Phase one, installed in July 2002, consisted of 106 feet of a 28-foot span x 11-foot rise system. Along

*The M-6/US-131 Interchange project included the use of a CON/SPAN® bridge system crossing over Buck Creek.*

with the spans, a permanent headwall was attached to one end of the system while a temporary headwall was attached to the other end. The temporary headwall had a significant slope across the face, which included a difference in elevation of 7 feet from one end to the other.

Phase two of the CON/SPAN structure will be installed in the spring of 2003. It will consist of 150 feet of the 28 foot x 11 foot system to be installed along with a permanent headwall containing the same slope as the temporary headwall. Units in both phases of the bridge sit on 6-foot high x 2-foot 9-inch wide pedestal walls. This creates the necessary hydraulic capacity to meet the peak storm flows. Since the CON/SPAN system does not require a bridge deck to be built, traffic will be quickly re-directed onto US-131.

When construction is completed in 2005, a much needed traffic artery will be in place to handle the continued growth in the Grand Rapids area. By having the foresight to specify concrete products, the Michigan Department of Transportation has guaranteed the life cycle, safety and quality of this new belt line that is built to last – just like the state's automotive industry, and its products.

| | |
|---|---|
| **Project:** | M-6/US-131 Interchange |
| **Owner:** | Michigan Department of Transportation |
| **Designer:** | Michigan Department of Transportation |
| **Contractors:** | Kamminga & Roodvoets, Inc., (underground utilities and earthwork) |
| | Kurt Poll, Vice President of Engineering |
| | C.A. Hull Company (bridges and sound/ retaining walls) |
| | Ajax Paving Industries (concrete pavement) |
| **Quantities:** | **ASTM C-14 Pipe** |
| | 11,680 feet – 12" diameter |
| | 1,674 feet – 15" diameter |
| | 1,208 feet – 18" diameter |
| | 432 feet – 24" diameter |
| | 864 feet – 30" diameter |
| | 1,768 feet – 36" diameter |
| | **ASTM C-76 Pipe** |
| | 280 feet – 12" diameter |
| | 136 feet – 15" diameter |
| | 776 feet – 18" diameter |
| | 832 feet – 24" diameter |
| | 728 feet – 30" diameter |
| | 1,680 feet – 36" diameter |
| | 1,696 feet – 42" diameter |
| | 272 feet – 54" diameter |
| | 312 feet – 72" diameter |
| **Other Structures** | 580 (24"-60" diameter) drainage structures |
| | 20 (72"-96" diameter) drainage structures |
| | 256 feet (28 foot x 11 foot) CON/SPAN bridge system |
| **Producer:** | Premarc Corporation |
| | Durand, Michigan |
| | Robin M. Woodbury, Director of Marketing |

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, Traverse City, Grand Rapids, and Clarkston. Premarc's delivery fleet supplies the entire lower peninsula of Michigan and extends into Indiana. Premarc's manufactured 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

# GO WITH THE FLOW! THE HISTORY OF RESEARCH ON MANNING'S *n* VALUES

*Adapted from ACPA's Design Data 10 by Matt Childs, P.E.,*
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## INTRODUCTION

Selection of the proper value for the coefficient of roughness of a pipe is essential in evaluating the flow through culverts and sewers. An excessive value is uneconomical and results in oversizing of pipe, while equally, a low value can result in hydraulically inadequate pipe.

Proper values for the coefficient of roughness of commercially available pipe has been the objective of periodic investigations and, as a result, extensive knowledge and data are available on this often-controversial subject.

## DESIGN VALUES

The difference between laboratory test values of Manning's *n* and accepted design values is significant. Numerous tests by public agencies and others have established Manning's *n* laboratory values. These laboratory results, however, were obtained utilizing clean water and straight pipe sections without bends, manholes, debris, or other obstructions. The laboratory results indicated the only differences were between smooth wall and rough wall pipes. Rough wall, such as unlined corrugated metal pipe have relatively high *n* values, which are approximately 2.5 to 3 times those of smooth wall pipe.

Smooth wall pipes were found to have *n* values ranging between 0.009 and 0.010 but, historically, engineers familiar with sewers have used 0.012 or 0.013. This "design factor" of 20-30 percent takes into account the difference between laboratory testing and actual installed conditions. The use of such design factors is good engineering practice and, to be consistent for all pipe materials, the applicable Manning's *n* laboratory value should be increased a similar amount in order to arrive at comparative design values. Recommended design values are shown in Table 1.

## FLOW FORMULAS

Manning's formula, in terms of flow, is expressed as follows:

$$Q = \frac{1.486}{n} AR^{2/3}S^{1/2} \quad \text{where:}$$

Q = flow in pipe, cubic feet per second

A = cross-sectional area of flow, square feet

R = hydraulic radius, equal to the cross-sectional area of flow divided by the wetted perimeter of pipe, feet

S = slope of pipe, foot per foot

*n* = coefficient of roughness appropriate to the type of pipe

**Table 1: Recommended Values of Manning's *n***

| Pipe Material | Values of Manning's *n* | | |
|---|---|---|---|
| | Lab Values | Promoted Values | ACPA Recommended Values |
| Concrete | 0.009-0.010[1] | 0.011-0.013[1] | storm sewer - 0.011-0.012[1]<br>sanitary sewer - 0.012-0.013[1] |
| HDPE lined | 0.009-0.015[2] | 0.009-0.013[3] | storm sewer - 0.012-0.020[2] |
| PVC solid wall | 0.009-0.011[4] | 0.009[4] | storm & sanitary sewer - 0.011-0.013[2] |
| Corrugated Pipe | 0.012-0.030[5] | 0.012-0.026[6] | 0.021-0.029[7] |

1 American Concrete Pipe Association's "Concrete Pipe Design Manual" - 2000
2 Tullis and Barfuss Study - 1989
3 CPPA Specifications
4 Uni-Bell's "Handbook of PVC Pipe" - 2001
5 University of Minnesota test on Culvert Pipes - 1950
6 NCSPA'S "Modern Sewer Design" - 1999
7 U.S. Department of Transportation Federal Highway Administration's "Hydraulic Design of Highway Culverts" - 2001

## MANNING *n* VALUE RESEARCH

### HDPE PIPE

Research by Tullis and Barfuss in 1989, presented to the American Society of Civil Engineers showed that tests on corrugated HDPE pipe with a liner has a laboratory Manning's *n* value in the range of 0.009 to 0.015, depending on the condition of the liners. The bonding of the liner to the corrugations, in many cases, made the pipe interior wavy, explaining the broad range in n values. This waviness causes the HDPE pipe to have hydraulic values similar to CMP. Manning's *n* concerns regarding HDPE pipe, however, are not widely understood because the pipe has never been tested under an external load, and further research is required. Because of the broad range of *n* values, an *n* value of 0.012 for HDPE pipe will not provide a 20 to 30 % design.

Frequently the inner liner of a double wall (profile wall) HDPE pipe undergoes a phenomenon called corrugation growth. After a short period of time, sometimes prior to installation, plastic deformation occurs in the liner creating waviness that makes the interior of HDPE pipe appear similar to corrugated metal pipe. The inner lining is intended to produce a smooth-walled pipe, however, a corrugated pattern results when stresses are transferred from the liner to the corrugation. The smooth liner is unable to resist the stresses in the field and corrugation growth appears. Designers of piping systems utilizing lined HDPE pipe should size the pipe using a Manning's *n* value similar to that of corrugated metal pipe.

## COMPARATIVE TESTS FOR CONCRETE AND CORRUGATED METAL PIPE

Originally, designers used the same *n* factor in Manning's equations as its predecessor, the Kutter equation. As the Manning formula came into more common use, the direct interchange of *n* values with Kutter's was questioned. A series of studies, prior to 1924, at the University of Iowa provided the first extensive data on this disputed point. These were cooperative studies sponsored by the Bureau of Public Roads, U.S. Department of Agriculture, and the University of Iowa. The test program consisted of 1,480 hydraulic experiments on 12, 18, 24 and 30-inch concrete pipe, corrugated metal pipe, and clay pipe. Results of these tests were published in 1926 by the University of Iowa in Bulletin No. 1, "The Flow of Water Through Culverts," by David L. Yarnell, Floyd A. Nagler and Sherman M. Woodward. Values obtained from the test results for Manning and Kutter roughness coefficients, are given in Table 2. After the Iowa test results were published, many

**Table 2 University of Iowa Tests on Culvert Pipes – 1926. Average Values for the Coefficient of Roughness in Concrete, Vitrified-clay, and Corrugated Metal, Culvert Pipe**

| Diameter of Pipe Inches | Kutter Coefficient | | | Manning Coefficient | | |
|---|---|---|---|---|---|---|
| | Concrete | Clay | Metal | Concrete | Clay | Metal |
| 12 | 0.0117 | 0.0101 | 0.0194 | 0.0119 | 0.0098 | 0.0228 |
| 18 | .0121 | .0119 | .0217 | .0121 | .0118 | .0248 |
| 24 | .0130 | .0127 | .0216 | .0130 | .0125 | .0239 |
| 30 | .0127 | .0131 | .0232 | .0125 | .0131 | .0254 |

Notes on pipe used in the Iowa tests: The 12" and 18" concrete pipe were in 2-foot lengths. The 24" and 30" concrete pipes were in 3-foot lengths. The vitrified-clay pipes were all in 30-inch lengths. Corrugated metal pipes were supplied in 6 and 8-foot lengths. Corrugated metal pipe had a 1/2 x 2-3/4 inch corrugation pattern. Joints in the concrete pipe where made with cement mortar. Joints in the vitrified-clay pipe made with oakum and cement mortar.

**Table 3 University of Minnesota Test on Culvert Pipes – 1950. Summary of Test Results**

| Type and Size of Pipe | Pipes Flowing Full | | | | Pipes Flowing Partly Full | | | |
|---|---|---|---|---|---|---|---|---|
| | No. Tests | of Manning Maximum | Roughness Minimum | Coefficient Average | No. of Tests | Manning Maximum | Roughness Minimum | Coefficient Average |
| 18-inch corrugated | 11 | 0.0251 | 0.0222 | 0.0242 | 8 | 0.0258 | 0.0248 | 0.0252 |
| 24-inch corrugated | 13 | 0.0252 | 0.0228 | 0.0242 | 10 | 0.0244 | 0.0232 | 0.0240 |
| 36-inch corrugated | 12 | 0.0247 | 0.0216 | 0.0232 | 14 | 0.0243 | 0.0228 | 0.0236 |
| Group | 36 | 0.0252 | 0.0216 | 0.0239 | 32 | 0.0258 | 0.0228 | 0.0242 |
| 18-inch corrugated arch | 23 | 0.0255 | 0.0210 | 0.0239 | 10 | 0.0233 | 0.0216 | 0.0223 |
| 24-inch corrugated arch | 7 | 0.0245 | 0.0217 | 0.0236 | 3 | 0.0228 | 0.0213 | 0.0220 |
| 36-inch corrugated arch | 9 | 0.0240 | 0.0216 | 0.0232 | 13 | 0.0230 | 0.0221 | 0.0226 |
| Group | 39 | 0.0255 | 0.0210 | 0.0237 | 26 | 0.0233 | 0.0213 | 0.0224 |
| 18-inch concrete | 12 | 0.0108 | 0.0091 | 0.0097 | 10 | 0.0110 | 0.0102 | 0.0107 |
| 24-inch concrete | 9 | 0.0104 | 0.0093 | 0.0100 | 6 | 0.0108 | 0.0102 | 0.0104 |
| 36-inch concrete | 11 | 0.0108 | 0.010 | 0.0106 | | | | |
| Group | 32 | 0.0108 | 0.0091 | 0.0101 | 16 | 0.0110 | 0.0102 | 0.0106 |

NOTE: From Technical Paper No. 3, Series B designers re-evaluated the *n* values for Manning's formula and used 0.013 for smooth wall pipe and 0.024 for corrugated pipe. These values were not universally accepted, however, and other designers used 0.015 for concrete and clay pipe. Metal pipe manufacturers were advocating an *n* of 0.021 for corrugated metal pipe, and some designers still erroneously use this comparatively low value for corrugated pipe today.

The next significant investigation of Manning *n* values for pipe began in 1946 and continued over a four-year period at St. Anthony Falls Hydraulic Laboratory, University of Minnesota. A primary purpose of these large scale tests was to obtain pipe friction coefficients which would be more accurate and dependable. A total of 181 hydraulic tests were run on 18, 24, and 36-inch circular concrete pipe, corrugated metal pipe, and corrugated metal pipe arches for the full flow and partly full flow conditions. Many of the shortcomings of previous hydraulic tests were eliminated in the Minnesota tests. Culvert test lengths were 193 feet, which were longer and more representative of actual installation conditions. Pipe section lengths were closer to actual commercial lengths, particularly for concrete pipe, with six-foot sections being used instead of the two-foot and three-foot lengths used in the 1926 Iowa test. The test results were published in 1950 by the University of Minnesota in Technical Paper No. 3, Series B, "Hydraulic Data Comparison of Concrete and Corrugated Metal Pipes" by Lorenz G. Straub and Henry M. Morris and are as shown in Table 3. These results indicate a significantly lower value of Manning's n for concrete pipe than the 1926 Iowa tests. Technical Paper No. 3 also included recommended design values for *n* for both corrugated metal and concrete pipe as reproduced in Table 4. Comparing the values from Tables 2, 3 and 4, it is readily apparent that no safety factors were applied to the laboratory values when converting them to design values. The footnote beneath Table 4, however, qualifies the application of the recommended values to such an extent that they could not be used for realistic pipe installation. As previously discussed, laboratory values should not be used for design purposes without appropriate safety factors.

During the period 1960-1962, research was conducted in Canada to determine design values of *n* for pipe used in culvert construction. The research was under the auspices of the Co-operative Highway Research Program in Alberta, which included the provincial Department of

Highways, the Research Council of Alberta, and the Faculty of Engineering of the University of Alberta as participating bodies. Tests were made on field installations of 60-inch structural plate corrugated metal pipe culverts 70 and 150-feet long with various inlet shapes and slopes from 1 to 3 percent, and on a 48-inch concrete pipe culvert 78-feet long on a slope of 0.5 percent. Laboratory tests were conducted on 15-inch diameter standard corrugated metal pipe 36 and 724-feet long with slopes from 0 to 8 percent. Test results were published by the Research Council of Alberta in the 1962 Alberta Highway Research Report 62-1 titled "Hydraulic Tests on Pipe Culverts" by C. R. Neill. Summaries of the Manning *n* values computed for the 60-inch structural plate pipe are quoted as follows:

"The *n* values computed from 33 tests showed a normal type of statistical scatter, with a mean of 0.0357 and a standard deviation of 0.0025. Pending further tests, the value of 0.035 was adopted for structural plate corrugated metal pipe."

Manning *n* values determined for the 15-inch standard corrugated metal pipe, are quoted as follows:

**Table 4 University of Minnesota Tests on Culvert Pipe – 1950. Recommended Design Coefficients of Corrugated Metal and Concrete Culverts**

| Items | Corrugated Metal* | Concrete* |
|---|---|---|
| Manning coefficient of roughness, n, full flow | 0.0250 | 0.0100 |
| Manning coefficient of roughness, n, partly full flow | 0.0240 | 0.0110 |

NOTE: From Technical Paper No. 3, Series B - Table III, Page 5.

*The above recommended values apply to new, straight pipe with no obstructions, side openings, or other flow-disturbing features. The Manning coefficients for corrugated metal apply to corrugations with 1/2-inch height and 2-2/3 inch spacing. The Manning coefficients for concrete apply to pipe manufactured by the cast-and-vibrated process in 6-foot lengths of pipe and with non-pressure rubber ring joints.

"Values ranged from 0.021 at very low velocities to 0.025 at high velocities. It appeared that 0.026 was probably a peak value and that 0.025 was reasonable for design purposes."

Additional quotes as to values of Manning's *n* for concrete pipe are as follows:

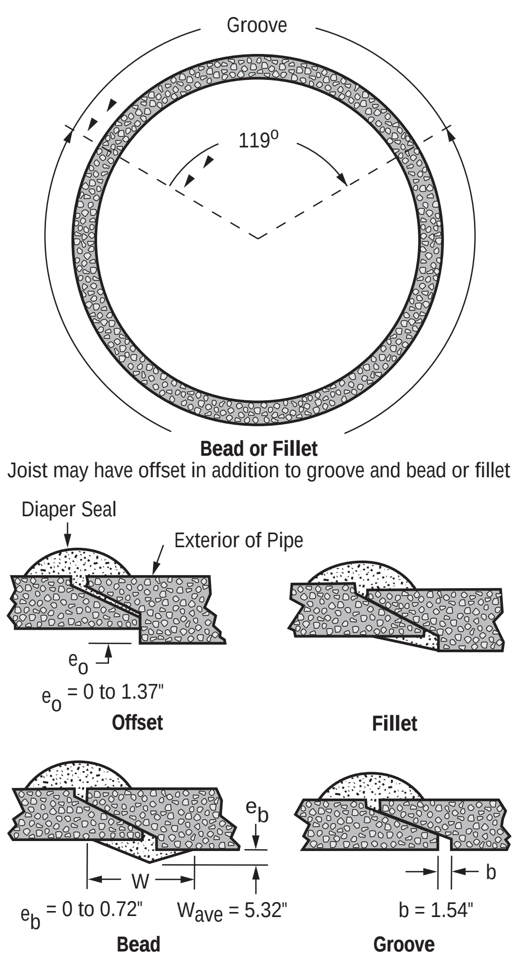
"No determination was made of roughness coefficients, since the pipe was too short and smooth to show appreciable friction losses."

As one purpose of the experiments was to determine the possible hydraulic advantages of using concrete pipe instead of corrugated metal pipe, the following statements from the test report are significant:

"By comparison, it can be seen that the capacity of the 48-inch concrete culvert was approximately the same as that of the 60-inch structural plate corrugated metal one, of approximately the same length. At the upper end of the test range, the concrete culvert showed rather better performance."

"The tests on concrete pipe culvert showed that a concrete culvert of given diameter was considerably more efficient than a corrugated metal one in most design situations especially when subjected to high headwater depths, the main reason being the much smaller friction losses in the concrete pipe. It appeared that concrete culverts prime readily when their inlets are slightly submerged, and may then be assumed to flow full throughout, and also that the standard type of grooved inlet is quite efficient."

**Figure 1 Cross-Section of Concrete Pipe Test Joints**




## CONCRETE PIPE TESTS

In June 1956, experimental studies on 24 and 36-inch concrete pipe were initiated by the State Road Department of Florida to determine the effect of interior surface finishes and joint irregularities on the pipe coefficient of friction. The test program and studies were performed at St. Anthony Falls Hydraulic Laboratory, University of Minnesota. This series of tests is significant in that field laying conditions were simulated, a condition designers found lacking in other hydraulic studies. Laboratory test installations were 240-feet long for the 36-inch pipe and 192-feet for the 24-inch pipe. Tests were made on pipe installed in two ways: (1) pipe laid with normal construction practices and closely simulating field measurements of joint irregularities, and (2) pipe laid with extreme care to eliminate, as far as possible, all flow interference at the joints. The first condition was referred to as "average" joints and the second as "good" joints. Figure 1 illustrates the irregularities noted in field joints. Joint irregularities were of three basic types:

- offsets-due to misalignment or variation in diameter of pipe.
- grooves-formed by annular openings between tongue and groove ends of pipe.
- beads and fillets-formed by mortar smoothed over the interior surface of the joint.

Results of this series of tests were published in December 1960, by St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Technical Paper No. 22, Series B, titled "Resistance to Flow in Two Types of Concrete Pipe" by Lorenz G. Straub, Charles E. Bowers and Meir Pilch. A comparison of the test data for pipe with "good" and "average" field irregularities indicates a difference in Manning's n on the order of 1.9 percent. Numerical values of n for 36-inch and 24-inch pipe with "average" joints were 0.0111 and 0.0110, respectively.

In the mid-1980's, laboratory tests of concrete and plastic pipe were conducted at the T. Blench Hydraulics Laboratory, Department of Civil Engineering, The University of Alberta. A report by D.K. May, A.W. Peterson and N. Rajaratnam, "A Study of Manning's Roughness Coefficient for Commercial Concrete and Plastic Pipe", was published in January, 1986. Commercially available concrete pipe in 8, 10 and 15-inch diameters and PVC plastic pipe in 8, 10 and 18-inch diameters were tested with clean water and straight alignment. The average Manning's *n* values were found to be 0.010 for concrete pipe and 0.009 for PVC pipe as presented in Table 5.

**Table 5 University of Alberta – 1986. Summary of Test Results**

| Type & Size Pipe | Number of Tests | Manning's n Values | | |
|---|---|---|---|---|
| | | Maximum | Minimum | Average |
| 8-inch PVC | 63 | 0.0115 | 0.0080 | 0.0088 |
| 10-inch PVC | 60 | 0.0104 | 0.0077 | 0.0089 |
| 18-inch PVC | 62 | 0.0096 | 0.0073 | 0.0091 |
| Group | 185 | 0.011 | 0.0073 | 0.0089 |
| 8-inch Concrete | 58 | 0.0138 | 0.0092 | 0.0101 |
| 10-inch Concrete | 61 | 0.0136 | 0.0087 | 0.0098 |
| 15-inch Concrete | 60 | 0.0116 | 0.0076 | 0.0097 |
| Group | 179 | 0.0138 | 0.0076 | 0.0099 |

To reconfirm the results of the Alberta and previous studies, the American Concrete Pipe Association commissioned additional tests on 8, 12 and 18-inch diameter precast concrete pipe at the Utah Water Research Laboratory, Utah State University, Logan, Utah. Results were published in Hydraulics Report Number 157, J. Paul Tullis, October, 1986. Laboratory values of Manning's *n* for precast concrete pipe were reconfirmed as 0.010. Results are shown in Table 6.

**Table 6 Utah State University – 1986. Summary of Test Results**

| Type & Size Pipe | Number of Tests | Manning's *n* Values | | |
|---|---|---|---|---|
| | | Maximum | Minimum | Average |
| 8-inch PVC | 21 | 0.0100 | 0.0097 | 0.0098 |
| 10-inch PVC | 20 | 0.0102 | 0.0098 | 0.0100 |
| 18-inch PVC | 23 | 0.0103 | 0.0097 | 0.0100 |
| Group | 64 | 0.0103 | 0.0097 | 0.0099 |

## CORRUGATED METAL PIPE TESTS

Prior to 1950, comparatively few tests had been made on large size corrugated metal pipe. For this reason, the U.S. Army Chief of Engineers Office, in 1951, authorized tests on 3, 5, and 7-foot diameter corrugated metal pipe at the Bonneville Hydraulic Laboratory, Bonneville, Oregon. Length of the test installations was 350 feet for all diameters. All pipe had a corrugation pattern of 1/2-inch x 2-2/3- inch. The experimental conditions, as far as size and length of pipe tested, exceeded any previously used. Results of these tests were published in 1959, in the Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, "Friction Factors in Corrugated Metal Pipe" by Marvin J. Webster and Laurence R. Metcalf. Recommended Manning's *n* values are presented graphically in the report. As a conclusion, the report states that for 3, 5 and 7-foot nominal diameter corrugated pipe with a 1/2-inch x 2-2/3-inch corrugations and flowing full, a Manning's *n* = 0.024 was obtained.

In 1958, a program of hydraulic tests was initiated by the U. S. Army Corps of Engineers, and the Bureau of Public Roads at the U. S. Army Waterways Experiment Station, for the purpose of determining roughness factors for structural plate corrugated metal pipe. The results were presented in a paper at the 44th Annual Meeting of the Highway Research Board, January 1965, and published in Highway Record No. 116. The paper is titled "Friction Factors for Hydraulic Design of Corrugated Metal Pipe," by John L. Grace, Jr. A major highlight of this research report was the preparation of graphs showing the relationship of Manning's *n* with pipe size for three commercially available corrugation patterns. A summary of the range of n values and the applicable equations relating Manning's *n* to pipe diameters are presented in Table 7.

**Table 7 Friction Factors for Hydraulic Design of Corrugated Metal Pipe**

| Equation | Corrugated Pattern | Pipe Size Range | *n* Value Range |
|---|---|---|---|
| $n = \frac{0.0259}{D^{0.044}}$ | $2\ ^{2}/_{3}" \times ^{1}/_{2}"$ | 12" - 96" | 0.0259 to 0.0237 |
| $n = \frac{0.0360}{D^{0.075}}$ | 3" x 1" | 36" - 96" | 0.0282 to 0.0262 |
| $n = \frac{0.0377}{D^{0.0775}}$ | 6" x 2" | 36" - 96" | 0.0333 to 0.0298 |

The corrugated metal pipe industry has formally recognized the higher laboratory values of Manning's *n*, which research has proven for available corrugation patterns.

The values of *n* recommended for unpaved corrugated metal pipe in the May 1999 "Modern Sewer Design," published by the National Corrugated Steel Pipe Association and the American Iron and Steel Institute, are presented in Table 8.

**Table 8 Values of Coefficient of Roughness n for corrugated Steel Pipe (Manning Formula)**

| Corrugations (Annular) | $2\ ^{2}/_{3} \times ^{1}/_{2}$ in. | 3 x 1 in. | Structural Plate 6 x 2 in. |
|---|---|---|---|
| Diameter | 1 to 8 ft. | 3 to 8 ft. | 5 to 20 ft. |
| Unpaved | 0.024 | 0.027 | 0.031* |

*BPR Circ. 10, Mar. 1965, p. 78. Based on 108-in. diam.

To date, limited testing has been conducted on helically corrugated metal pipe. Tests were conducted on helically corrugated metal pipe by A. R. Chamberlain and the results were published in 1955 at Colorado State University in a report titled "Effect of Boundary on Fine Sand Transport in Twelve Inch Pipes." Charles E. Rice conducted flow tests at the Stillwater Outdoor Hydraulic Laboratory, Stillwater, Oklahoma, on 8-inch and 12-inch pipe. His report titled "Friction Factors for Helical Corrugated Pipe," was published by the U. S. Department of Agricultural Research Service in 1966.

In 1970, the Federal Highway Administration, Offices of Research and Development published a report "Hydraulic Flow Resistance Factors for Corrugated Metal Conduits" by J. M. Norman and H. G. Bossy. The observations by the authors were that, "as the pipe diameters increases, the helix angle also increases, and as the helix angle approaches 90 degrees the pipe must behave as a corrugated pipe with annular corrugations. For a partly full flow condition in a helically corrugated metal pipe in which the spiral flow cannot be maintained, it is presumed that even a small helix angle would cause little reduction in resistance and that the same resistance coefficient as that for standard corrugated metal pipe should be used. There is a need to further test helically corrugated metal pipe, especially the larger sizes. At present, the use of a reduced resistance coefficient is indicated only for small diameters, 2 feet or less, and then only under full flow conditions. The best course for conservative design, pending further test results, is to use annular corrugated metal pipe resistance coefficients for helically corrugated pipe."

An updated "Hydraulic Flow Resistance Factors for Corrugated Metal Conduits" was published by the Federal Highway Administration in January, 1980. In 2001, the Federal Highway Administration published "Hydraulic Design of Highway Culverts, Hydraulic Design Series No. 5" by J.M. Norman, R.J. Houghtalen and W.J. Johnston. Both publications recommend annular flow resistance factors be used for helically corrugated metal pipe installations unless all the following conditions are meet:

- The conduit flows full.
- The conduit is circular in shape.
- There is no erosion resistant sediment build-up in the conduit.
- The conduit is greater than 20 diameters long.
- The conduit is unpaved.
- There are no manholes, wyes and tees.
- There are no changes in grade and alignment.

## CORRUGATED ALUMINUM PIPE TESTS

In April 1971, a report was published titled "Further Studies of Friction Factors for Corrugated Aluminum Pipe Flowing Full" by Edward Silberman and Warren 0. Dahlin, St. Anthony Falls Hydraulic Laboratory, University of Minnesota. Laboratory tests were conducted on pipe which ranged in diameter from 12 inches to 66 inches and lengths from 100 feet to 220 feet using both annular and helical corrugated aluminum pipe. The tests were conducted with a head of 20 feet so that the pipe would flow full.

The conclusions reached by the authors are "The experiments described in this report have been conducted using corrugated aluminum pipes flowing full. The measurements were made following an entry region of 20 or more pipe diameters, and although this distance appears to be sufficient, it is not known whether this is a minimum distance for fully developed flow. Measurements were made under laboratory conditions with pipe carefully aligned and joints carefully made so as to avoid introducing additional roughness. The water used in the tests carried a light load of sand, mostly as suspended load, from the Mississippi River. No significant amount of sand was found in the pipes after the flow was shut down; it is not believed that the sand affected the results."

Values of Manning's *n* ranged from 0.0107 for 12-inch helical pipe to 0.0222 for 48-inch helical pipe. Use by designers of such low *n* values is not recommended as these are based on laboratory tests for full flow conditions, a 20- foot head,

**Table 9 Policy Statements**

| Agency | Year | Publication | Values of Manning's Roughness Cofficients | | |
|---|---|---|---|---|---|
| Headquarters Department of the Army Office of Chief of Engineers | 1978 | Technical Manual – TM 5-820-3 Drainage and Erosion-Control Structures for Airfields and Heliports | Type of Pipe | | *n* |
| | | | All smooth wall | | 0.012 |
| | | | Corrugated metal pipe | | |
| | | | 2 2/3 by 1/2 inch | | 0.024 |
| | | | 3 by 1 inch | | 0.027 |
| | | | 6 by 2 inch | | 0.028-0.033 |
| | | | 9 by 2 1/2 inch | | 0.033 |
| Headquarters Department of the Army Office of Chief of Engineers | 1983 | Technical Manual – TM 5-820-4 Drainage for Areas Other Than Airfields | Type of Pipe | | ***n*** |
| | | | All smooth wall | | 0.012 |
| | | | Corrugated metal pipe | | |
| | | | 2 2/3 by 1/2 inch | | 0.024 |
| | | | 3 by 1 inch | | 0.027 |
| | | | 6 by 2 inch | | 0.028-0.033 |
| | | | 9 by 2 1/2 inch | | 0.033 |
| US Department of Transportation Federal Highway Administration | 1980 | Hydraulic Flow Resistance Factors for Corrugated Metal Conduits | Corrugation | Diameter Range (ft.) | n |
| | | | 2 2/3" x 1/2" | 1 - 8 | .0263 to .0235 |
| | | | 3" x 1" | 3 - 8 | .0281 to .0260 |
| | | | 6" x 1" | 3 - 8 | .0260 to .0270 |
| | | | 6" x 2" struct. plate | 3 - 21 | .0330 to .0300 |
| | | | 9" x 2 1/2 struct. plate | 7 - 15 | .0338 to .0318 |
| | | | For helically corrugated pipe - use the same values as an annular corrugated pipe | | |
| US Department of Transportation Federal Highway Administration | 2001 | Hydraulic Design Series Number 5, Hydraulic Design of Highway Culverts | Type of Pipe | | *n* |
| | | | Concrete Pipe | | 0.010 - 0.011 |
| | | | Concrete Box Culverts | | 0.012 - 0.015 |
| | | | Spiral Rib Metal Pipe | | 0.012 - 0.013 |
| | | | Corrugated Metal Pipe | | |
| | | | 2 2/3" x 1/2" | | 0.022 - 0.027 |
| | | | 6" x 1" | | 0.022 - 0.025 |
| | | | 5" x 1" | | 0.025 - 0.026 |
| | | | 3" x 1" | | 0.027 - 0.028 |
| | | | 6" x 2" | | 0.033 - 0.035 |
| | | | 9" x 2 1/2" | | 0.033 - 0.037 |
| | | | Corrugated Metal Pipes, Helical Corrugations, Full Circular Flow | | |
| | | | 2 2/3" x 1/2 | | 0.012 - 0.024 |
| | | | HDPE | | |
| | | | Lined | | 0.009 - 0.015 |
| | | | Corrugated | | 0.018 - 0.025 |
| | | | The Manning's *n* value ranges indicated in this table are laboratory values. In general, it is recommended that the annular resistance factors be used for corrugated metal pipes with helical corrugations. | | |

no appreciable bed loads, carefully aligned joints, and a 20 diameter length of flow development region. Therefore, the conclusions and recommendations of the Federal Highway Administration in the 2001 updated report Hydraulic Design Series No. 5 regarding flow resistance factors for helical corrugations are applicable whether the pipe is made of aluminum or steel.

### AGENCY POLICIES ON $n$

Beginning in 1953, many governmental agencies made policy statements relating to the Manning $n$ values for use on work under their jurisdictions. Policy statements are listed in Table 9. Since these policy statements were so similar, the selection of the proper $n$ value for different pipe types appeared to be settled. In the FHWA's Hydraulic Design Series Number 5, all $n$ values are lab values. In all other policy statements, the fact that the $n$ values for concrete pipe have a built in safety factor, however, was not considered and a corresponding safety factor is not applied to the laboratory values for some other smooth wall pipe nor for corrugated metal pipe.

## "Quality Cast" Certified Plants

In an effort 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**

- Cayuga Concrete Pipe Company (Oldcastle, Inc.), Croydon, Pa. - Allen Reed
- Cayuga Concrete Pipe Company (Oldcastle, Inc.), New Britain, Pa. - Jim Savana
- Elk River Concrete Products (Cretex), Billings, Mont. - Milton Tollefsrud
- Elk River Concrete Products (Cretex) Helena, Mont. - Robert Ganter
- Kerr Concrete Pipe Company (Oldcastle, Inc.), Hammonton, N.J. - Bob Berger
- Kerr Concrete Pipe Company (Oldcastle, Inc.), Farmingdale, N.J. - Scott McVicker
- South Dakota Concrete Products (Cretex), Rapid City, S.Dak. - Jeff Ulrich
- Riverton Concrete Products Company (Cretex), Riverton, Wyo. - Butch Miller
- Sherman-Dixie Concrete Industries, Inc., Chattanooga, Tenn. - Earl Knox
- Sherman-Dixie Concrete Industries, Inc., Franklin, Tenn. - Roy Webb
- Sherman-Dixie Concrete Industries, Inc., - Lexington, Kentucky - Darrel Boone
- Americast-Pipe Division, Inc., Charleston, S.C. - Bill Gary
- Amcor-White Company (Oldcastle, Inc.), Hurricane, Utah - Brent Field
- Carder Concrete Products, Littleton, Colo. - Tom Walters
- Carder Concrete Products, Colorado Springs, Colo. - Bruce Spatz
- Grand Junction Concrete, Grand Junction, Colo. - Ben Burton
- California Concrete Pipe (Oldcastle), Stockton, Calif. - Qing Lian Gao
- Boughton's Precast, Inc., Pueblo, Colo. - Rodney Boughton

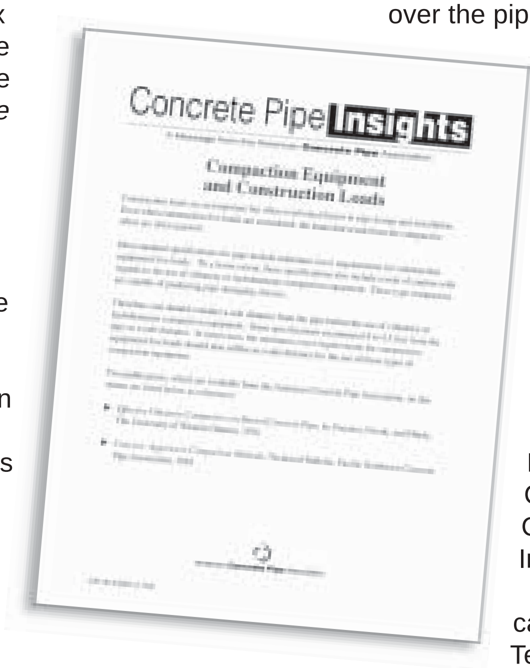
**Sanitary Sewer, Storm Sewer and Culvert Pipe**

- Advanced Pipes & Cast Company, Abu Dhabi, United Arab Emirates - Nasser Kammar
- Amcor Precast (Oldcastle, Inc.), Nampa, Idaho - Mike Burke
- Amcor Precast (Oldcastle, Inc.) Ogden, Utah - Tim Wayment
- Atlantic Concrete Pipe, San Juan, P.R. - Miguel Ruiz
- Elk River Concrete Products (Cretex), Elk River, Minn. - Bryan Olson
- Elk River Concrete Products (Cretex), Shakopee, Minn. - Steve Forslund
- Geneva Pipe Company, Ore, Utah - Fred Klug
- Kansas City Concrete Pipe Co. (Cretex), Shawnee, Kans. - Rich Allison
- NC Products (Oldcastle, Inc.), Fayetteville, N.C. - Preston McIntosh
- NC Products (Oldcastle, Inc.), Raleigh, N.C. - Mark Sawyer
- Ocean Construction Supplies Limited (Inland Pipe), Vancouver, B.C., Canada - Ron Boyes
- Amcor-White Company (Oldcastle, Inc.), Ogden, Utah - J. P. Connoley
- Rinker Materials-Hydro Conduit Division, Denver, Colo. - Ed Anderson
- Waukesha Concrete Products Company (Cretex), Waukesha, Wis. - Jay Rhyner

ACPA CERTIFIED PLANT Q CAST™

# Concrete Pipe Insights Bulletins Provide Simple Answers to Complex Questions

The American Concrete Pipe Association *Concrete Pipe Insights* bulletins provide easy-to-understand answers to complex technical issues. They get to the point and give direction for more information. The latest *Concrete Pipe Insights*, "Compaction Equipment and Construction Loads", notes that the loads resulting from the compactive effort are often ignored, even when construction live loads are considered. Compaction loads are an important, but frequently overlooked factor, in pipe design and installation.



Concrete Pipe Insights

Compaction Equipment and Construction Loads

Most standard specifications for pipe include minimum cover requirements for construction equipment live loads. To a lesser extent, these specifications also include a note of caution with regards to the use of vibratory or hydrohammer compaction equipment. These types of compactors are capable of producing pipe-damaging stresses.

Therefore, one should consider a safe distance over the pipe before the use of vibratory or hydrohammer compaction equipment. Some specifications recommend 4 to 4.5 feet from the pipe as a safe distance. In most cases, the minimum cover requirements for construction equipment live loads should also suffice as a safe distance for the use of these types of compactors.

Other *Concrete Pipe Insights* bulletins include: Concrete Pipe Joints - Your Best Choice; Concrete or HDPE: Strength versus Stiffness; Handling and Installation Comparisons; Hydraulics: Check the Comparisons; and Durability: Too Important to Ignore.

*Concrete Pipe Insights* bulletins can be downloaded from the Technical Section of the ACPA Website at www.concrete-pipe.org., or requested through ACPA offices in Irving, Texas.

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