# Concrete Pipe Information Booklet

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Introduction

The Ontario Concrete Pipe Association and the Ontario precast drainage producers are pleased to provide you with the Concrete Pipe Information Booklet. The OCPA and its member producers have long been recognized as leading sources of technical information on the precast concrete pipe, maintenance hole and box culvert industry. This booklet is a compilation of material assembled into a format designed for quick and easy reference to many of the issues that relate to the design, manufacture and installation of concrete pipe and products.

Within the gravity sewer market, many different pipe materials are available for use. This booklet will also touch on a few items for consideration when choosing a pipe material for infrastructure. The topics discussed in this booklet do not cover all issues that may be relevant in the design of an infrastructure project. Instead, the booklet highlights many of the commonly asked questions that relate to concrete pipe, maintenance holes and box culverts.

Since 1957 the Ontario Concrete Pipe Association has been the source of information relating to industry products. We hope this booklet will become a reference tool capable of providing useful insight into many of the issues that have been brought to the attention of our industry. We are and will continue to be committed to the improvement of the only product anchored, in an ever-changing marketplace, by its historical reliability as evidenced by the last one hundred years or more of dedicated service.
Ease of installation can be mistaken for ease of handling. Although lightweight pipe is easy to handle, it is far more installation sensitive than the heavier concrete pipe. The degree of dependence on the soil-pipe interaction is a measure of installation sensitivity and hence ease of installation. The ease of installation for concrete pipe together with powerful new tools for the design engineer lead to opportunities for saving time and non-renewable materials on underground infrastructure projects.

The strength of concrete pipe is determined by a three edge bearing test (3EB), establishing pipe strength under a severe point load condition. Traditional concrete pipe design uses a bedding factor of about 2 for granular bedding material as a means of equating the 3EB strength to a proposed installation. This means that the measured 3EB for 0.3-mm crack is equivalent to approximately double the design load. The conservative bedding factor has proven reliable for decades for a variety of installation conditions.

In contrast to the methodology for designing a concrete pipe installation, flexible pipe installation can be associated to the relationship between pipe stiffness and soil stiffness required in the soil envelope. The relatively low stiffness of flexible pipe must be compensated for by assuming that the installer can provide high soil stiffness through good installation techniques. An imported granular material is used in the installation of flexible pipe to attain the necessary soil stiffness. The granular envelope must provide uniform pressure around the circumference of the conduit to allow the tubing to maintain an approximation of the original circular cross-section. Thermoplastic pipe with a parallel plate test stiffness of 320 kPa is often used in design with a modulus of soil...
reaction of 7000 kPa. The soil stiffness must be about 22 times higher (7000/320) than the stiffness of the flexible pipe. The flexible pipe designer must be confident that realistic assumptions are used in his design and that the installer is aware of and capable of providing the assumed design parameters in what can be adverse field conditions.

New concrete bedding designs, developed by the American Concrete Pipe Association (ACPA) and subsequently adopted by the American Society of Civil Engineers (ASCE), American Society for Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO) and the Canadian Highway Bridge Design Code (CHBDC), have changed the way that concrete pipe installations are designed. SIDD, Standard Installation Direct Design, and a powerful new design tool, PipePac, provide new opportunities to optimize installations for the designer wanting to utilize the reliability and installation ease of concrete pipe. PipePac is a design package that permits the use of finite element analysis, on which SIDD is based, to determine the strength of pipe required for any installation. This is in addition to the traditional methods used for decades. The SIDD bedding design accounts for limitations not addressed in the traditional design method, such as:

- Loads considered to be acting only at the top of pipe;
- Axial thrust not considered;
- Difficulty in providing a ‘shaped bedding’;
- Bedding materials and compaction levels not adequately defined.
The finite element model prescribes definitive trench configurations (*refer to Figure 1*) and measurable levels of compaction (*refer to Table 1*).
### Table 1: Compaction Requirements

**STANDARD TRENCH INSTALLATION SOILS AND MINIMUM COMPACTION REQUIREMENTS**

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Bedding Thickness</th>
<th>Haunch and Outer Bedding</th>
<th>Lower Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dₒ/24 minimum, not less than 75mm. If rock foundation, use Dₒ/12 minimum, not less than 150mm.</td>
<td>95% SW</td>
<td>90% SW 95% ML, or 100% CL</td>
</tr>
<tr>
<td>2</td>
<td>Dₒ/24 minimum, not less than 75mm. If rock foundation, use Dₒ/12 minimum, not less than 150mm.</td>
<td>90% SW or 95% ML</td>
<td>85% SW or 90% ML or 95% CL</td>
</tr>
<tr>
<td>3</td>
<td>Dₒ/24 minimum, not less than 75mm. If rock foundation, use Dₒ/12 minimum, not less than 150mm.</td>
<td>85% SW, 90% ML or 95% CL</td>
<td>85% SW, 90% ML or 95% CL</td>
</tr>
<tr>
<td>4</td>
<td>No bedding required, except if rock foundation, use Dₒ/12 minimum, not less than 150mm.</td>
<td>No compaction required, except if CL, use 85%</td>
<td>No compaction required, except if CL, use 85% CL</td>
</tr>
</tbody>
</table>

- where Dₒ is the outer diameter of the pipe
- SW are well-graded material (sands, gravels etc.)
- ML are inorganic silts, fine sands or clayey silts with slight plasticity
- CL are inorganic clays of low to medium plasticity, gravelly clays, sandy clays etc.
SIDD bedding allows for a range of installation options from high quality granular bedding to the use of native materials. The bedding design is left to the designer, who is able to determine the most appropriate installation design for the project under consideration. This decision shall be based on a combination of issues, such as project location, ultimate use of infrastructure, site conditions, availability of materials and installation cost. The designer is given the ability to ‘design’ the project through the use of PipePac.
**Metric Conversions for Mass:**

1 kilogram (kg) = 2.205 pounds

1 pound = 0.4536 kilograms (kg)

1 metric tonne = 1000 kilograms (kg) = 2205 pounds = 1.1023 short tons

1 short ton = 2000 pounds = 907.2 kilograms (kg) = 0.9072 metric tonnes

**INSPECTION:**

- Concrete pipe should be inspected on the truck when it first arrives at the jobsite before it is unloaded to ensure that no damage has occurred during transit. Damaged or missing items must be reported at this time.

- It is important to check that the pipe is the correct size and class, and that it is supplied with the proper gasket.

- All components of any lifting assembly must comply with the requirements of the Regulations for Construction Projects (Ontario Regulation 213/91) made under the Occupational Health and Safety Act.

- A competent person designated by the contractor should inspect all lifting assemblies and attachment hardware prior to each use. Any damaged or defective equipment must be immediately removed from service.

- All other safety procedures and recommended operating practices by the manufacturer of the lifting equipment must be followed.
UNLOADING:

The work procedures for material handling, worker safety, and the modification of backhoes, loaders and fork lifts for use as cranes or similar hoisting devices must comply with the relevant sections of the Ontario Regulation 213/91 made under the Occupational Health and Safety Act.

- Pipe should be unloaded on a level site using the appropriate lifting equipment.

- Capacities of lift assemblies, devices, forklifts and cranes should be checked before unloading.

- Small diameter pipe up to and including 250mm diameter come palletized and require lift forks to properly support the pallet.

- Pipe up to and including 900 mm diameter can be unloaded using the automatic tailgate unloader, provided timber is placed under the pipe barrels to protect the bells from impact when unloading on hard ground or pavement.

- Wood planks should be placed between pipes as they are rolled off a tailgate to prevent impact damage with an adjacent pipe.

- When using forklift equipment, care must be taken to ensure the inside of the pipe is not gouged or damaged. Wooden planks should be used to ensure the forks do not come in direct contact with the pipe.
• Pipe 975 mm diameter and larger provided with an anchor or a lift hole, must be lifted off the truck deck using proper lifting devices with sufficient lifting capacity.

• Pipe should be unloaded as close to the trench as possible to reduce handling, and placed on the trench side away from the excavated material.

• Section 6 of the OCPA Concrete Pipe Design Manual details the installation of pipe, including handling and stockpiling.

The preceding list of procedures may vary slightly for the precast manufacturers; therefore the contractor should confirm these methods or alternatives for unloading with their precast supplier. In addition, it is the responsibility of the contractor to ensure compliance with the Occupational Health and Safety Act and the construction project regulations.

STORAGE:

• Pipe should be stored as close to the trench as possible.

• Pipe should be placed on planks to prevent them from becoming frozen to the ground in winter, and to permit ease of handling in summer. Using planks, pipe can be easily rolled and the lift cable can slide under the pipe. In addition, for pipes that have protruding bells, the boards and not the bells carry the weight of the pipe.

• The bottom layer should be placed on a level base. Each layer of bell and spigot pipe should be arranged so that the bells are at the same end. The bells in the
next layer should be at the opposite end, and projecting beyond the spigot of the section in the lower layer. Where there is only one layer the bells and spigots should alternate between adjacent pipe.

- All flexible gasket materials, including joint lubricating compounds where applicable should be stored in a cool dry place in the summer, and prevented from freezing in the winter. Rubber gaskets and preformed mastics should be kept clean, away from oil, grease, excessive heat and out of direct sunlight.
Proprietary lifting systems are available in the Ontario concrete pipe market for pipe and maintenance holes and box culverts. They offer a positive lifting connection to the pipe for added safety and since the anchors are embedded, patching is not required, thus no leaks. In addition, anchors in pipe can be used to “home” or pull the product into its final position.

HANDLING PIPE

In pipe, anchors are placed laterally along the top of the pipe. These anchors can accommodate pipe diameters from 975mm to 3600mm. Because the pipe is lifted by two points, stability during lifting is established aiding in homing one pipe to the other. Once the pipe has been temporarily set for final placement, one of the anchors from the previously set pipe can be used to home the new piece into final alignment (refer to Illustration #1). Once again, since the anchors are embedded in the concrete wall, there is no need for patching.

HANDLING MAINTENANCE HOLES AND ACCESSORIES

In maintenance hole products, anchors are placed on the sides of the product. Unlike pipe where there are two anchors along the sides of the product, maintenance products have one or more anchors on either side of the product for stability during installation and stacking (refer to Illustration #2). Inserts in maintenance holes have been tested and provide a 50% increase in factor of safety as compared to conventional pin methods.
Illustration #1
Correct method for Homing Pipe Together

**Note:** All lifting hardware shall be fastened to all anchors to safely lift the product.

The pipe is first transported to the installation site with the symmetrical sling and lowered close to the already placed pipe.

**Note:** All anchor locations must be used at once to safely lift the product.

To pull the pipe into position the long leg of the pipe layer is coupled to the previously placed pipes. The short leg (Eye 2) is hung into the hook provided for this purpose.

It must be ensured that the top guide pulley of the crane is over the outer lifting anchor of the previously placed pipe so that the direction of pull is slightly inclined towards the placed pipe.

When moving the jib, the pipe is now pulled into position using the precision hoisting gear.

**Stop - Release - action complete**

Illustrations supplied by Dayton Richmond.
Illustration #2
How to Use Universal Lifting Eye for Maintenance Holes

Note: Load must be applied simultaneous to all anchors in order to safely lift product.

Correct Method for Placing Lifting Eye onto Anchor

Note: Direction of extended lip should be in the direction of lift.
Precast reinforced concrete box units are accepted throughout North America as a standard, high quality, and economical product. Common sizes range from 1800x900 mm up to 3600x3600 mm, but are not restricted to these. The successful application of these large precast structures is due, in large measure, to the development of welded wire reinforcement (WWR). WWR sheets can be bent into shape as an economical replacement for rebar. Use of WWR has significantly improved production efficiencies and the quality of the finished product.

Deformed WWR with its higher yield strength of 485 MPa allows for a reduction in steel area of 17% over conventional 400 MPa rebar. WWR is easily bendable into rectangular cages and is readily weldable (typical Carbon Equivalent = 0.20 vs. 0.46 for weldable rebar). The closely spaced welded intersections of WWR result in superior crack control. A weld shear strength of 240 MPa which contributes to bond and anchorage of WWR in concrete is assured by maintaining an adequate size differential of wires being welded together. The smaller wire cross sectional area must be a minimum 40% of the area of the larger wire.

Reinforced concrete box units are covered by the standard specification OPSS 1821. The sizes of box units in OPSS 1821 (Material Specification for Precast Reinforced Concrete Box Culverts and Box Sewers) range from 1800x900 mm to 3000x2400 mm.

OPSS 1821 lists the respective steel area requirements for a full inner and outer cage made up of ‘U-shaped’ fabric sections (refer to Table 1). Minimum perimeter steel areas listed range from 180 to 1163 mm²/m with longitudinal steel areas ranging from 63 to 79 mm²/m. A typ-
ical reinforcement fabric style for a 2400 x 1800 mm box size with 0.90 m of earth cover would be 51 x 203 – MD38.7 x MW 19.2 and 51 x 203 – MD25.8 x MW19.2, for inner and outer cages, respectively.

OPSS 1821 requires that WWR shall achieve a minimum 4% elongation at ultimate strength measured over a 100 mm gauge length including one cross wire. WWR manufacturers are obliged to issue a mill compliance notification to that effect. As well, OPSS 1821 recognizes that some precast producers may utilize plain WWR and therefore only allows for Fy=450 MPa. Other standards allow for Fy=485 MPa for deformed WWR.

Table 1 is very useful as a design aid by listing metric wire sizes and equivalent customary inch unit wire sizes along with steel areas per unit length of pipe or box for different wire spacings.

**Steel Reinforcement**

Reinforcing wire cages are fabricated from premanufactured WWR sheets that are bent into ‘U-shaped’ fabric sections and tack welded to form square or rectangular inner and outer cages (*refer to Figure 1*). The wire used in WWR is produced from controlled quality, low carbon (S1006 to C1012) hot rolled steel rods. These rods are cold worked through a series of dies to reduce the rod diameter to the specified wire diameter and to improve the yield strength of the steel. A deformation roll is used to produce deformed wire. Chemical composition is carefully selected to give proper welding characteristics in addition to desired mechanical properties. WWR is pro-
produced on automatic resistance welding machines that are designed for long, continuous operation. Longitudinal wires are straightened and fed continuously through the machine. Transverse wires, entering from the side or from above the welder, are individually welded to the longitudinal wires each time the longitudinal wires advance through the machine a distance equal to one transverse wire spacing.

**Wire Size Designation**

Individual wire (plain and deformed) size designations are based on the cross-sectional area of a given wire. The “W” prefix is for plain smooth wire and “D” for deformed. The number following the letter gives the cross-sectional area of the wire: for customary units in hundredths of an inch. For example, W4 would indicate a plain wire with a cross-sectional area of 0.04 in$^2$. D10 would indicate a deformed wire with an area of 0.10 in$^2$. When describing metric wire or fabric a prefix “M” is added with the number following the letters “MW” or “MD” denoting the steel area in metric units (mm$^2$). For example MW 25.9 refers to a plain wire with an area of 25.9 mm$^2$. Table 1 lists the standard W & D and equivalent MW and MD wire sizes along with steel areas per unit length of box for different wire spacing.
## Table 1: Sectional Areas of Welded Wire Reinforcement Fabric (Metric Units)

**Sectional Areas of Welded Wire Reinforcement**  
**IMPERIAL UNITS**  
**METRIC UNITS**  
**AREA - in² PER LINEAR FOOT / AREA - mm² PER LINEAR METRE**

<table>
<thead>
<tr>
<th>WIRE SIZE*</th>
<th>NOMINAL DIAM.</th>
<th>NOMINAL AREA</th>
<th>NOMINAL MASS</th>
<th>CENTRE TO CENTRE SPACING (in)</th>
<th>CENTRE TO CENTRE SPACING (mm)</th>
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<tbody>
<tr>
<td>W20</td>
<td>0.505</td>
<td>0.200</td>
<td>0.680</td>
<td>1.20</td>
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<td></td>
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<td></td>
<td></td>
<td>0.60</td>
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<tr>
<td>W129</td>
<td>12.83</td>
<td>129</td>
<td>1.01</td>
<td>2540</td>
<td>1693</td>
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<tr>
<td>W18</td>
<td>0.479</td>
<td>0.180</td>
<td>0.612</td>
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<td>116</td>
<td>0.911</td>
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<td>W16</td>
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<td>0.544</td>
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<td>W15.5</td>
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<td>0.465</td>
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<td>W100</td>
<td>11.3 (10M)</td>
<td>100</td>
<td>0.785</td>
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<td>W14</td>
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<td>0.42</td>
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<td>W90.3</td>
<td>10.72</td>
<td>90</td>
<td>0.708</td>
<td>1778</td>
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<td>W12</td>
<td>0.391</td>
<td>0.120</td>
<td>0.408</td>
<td>0.72</td>
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<td>W77.4</td>
<td>9.93</td>
<td>77</td>
<td>0.607</td>
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<td>W11</td>
<td>0.374</td>
<td>0.110</td>
<td>0.374</td>
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<td>71</td>
<td>0.556</td>
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<td>0.315</td>
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<td>9.3</td>
<td>68</td>
<td>0.531</td>
<td>1343</td>
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<td>W10</td>
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<td>0.100</td>
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<td>0.506</td>
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<td>W7.5</td>
<td>0.309</td>
<td>0.075</td>
<td>0.255</td>
<td>0.45</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.225</td>
<td>0.15</td>
</tr>
<tr>
<td>W48.4</td>
<td>7.85</td>
<td>48</td>
<td>0.379</td>
<td>953</td>
<td>635</td>
</tr>
<tr>
<td>W7</td>
<td>0.299</td>
<td>0.070</td>
<td>0.238</td>
<td>0.42</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>0.21</td>
<td>0.14</td>
</tr>
<tr>
<td>W45.2</td>
<td>7.6</td>
<td>45</td>
<td>0.354</td>
<td>889</td>
<td>593</td>
</tr>
<tr>
<td>W6.5</td>
<td>0.288</td>
<td>0.065</td>
<td>0.221</td>
<td>0.39</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.195</td>
<td>0.13</td>
</tr>
<tr>
<td>W42.1</td>
<td>7.32</td>
<td>42</td>
<td>0.329</td>
<td>826</td>
<td>550</td>
</tr>
<tr>
<td>W6</td>
<td>0.276</td>
<td>0.060</td>
<td>0.204</td>
<td>0.36</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.18</td>
<td>0.12</td>
</tr>
<tr>
<td>W38.7</td>
<td>7.01</td>
<td>39</td>
<td>0.304</td>
<td>762</td>
<td>508</td>
</tr>
<tr>
<td>W5.5</td>
<td>0.265</td>
<td>0.055</td>
<td>0.187</td>
<td>0.33</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.165</td>
<td>0.11</td>
</tr>
<tr>
<td>W35.5</td>
<td>6.73</td>
<td>36</td>
<td>0.278</td>
<td>699</td>
<td>466</td>
</tr>
<tr>
<td>W5</td>
<td>0.252</td>
<td>0.050</td>
<td>0.170</td>
<td>0.30</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.15</td>
<td>0.10</td>
</tr>
<tr>
<td>W32.3</td>
<td>6.4</td>
<td>32</td>
<td>0.253</td>
<td>635</td>
<td>423</td>
</tr>
<tr>
<td>W4.5</td>
<td>0.239</td>
<td>0.045</td>
<td>0.153</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.135</td>
<td>0.09</td>
</tr>
<tr>
<td>W28.9</td>
<td>6.07</td>
<td>29</td>
<td>0.228</td>
<td>572</td>
<td>381</td>
</tr>
<tr>
<td>W4 (4ga)</td>
<td>0.226</td>
<td>0.040</td>
<td>0.136</td>
<td>0.24</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.12</td>
<td>0.08</td>
</tr>
<tr>
<td>MW25.8</td>
<td>5.74</td>
<td>26</td>
<td>0.202</td>
<td>508</td>
<td>339</td>
</tr>
</tbody>
</table>
*Wire size:
Imperial wire sizes are designated by their sectional area in hundreths of a square inch.
Metric wire sizes are designated by their sectional area in mm²

*Ex. for W 8, Area = 0.08 in²*
*Ex. for MW51.6, Area = 51.6 mm²*
- W - denotes smooth wire ex.: W 1 8
- D - denotes deformed wire ex.: D 1 8
- M - denotes metric ex.: MW18 or MD18

**Rebar Sizes:**

<table>
<thead>
<tr>
<th>#</th>
<th>A</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.11</td>
<td>71 mm²</td>
</tr>
<tr>
<td>4</td>
<td>0.20</td>
<td>129 mm²</td>
</tr>
<tr>
<td>5</td>
<td>0.31</td>
<td>199 mm²</td>
</tr>
<tr>
<td>6</td>
<td>0.44</td>
<td>284 mm²</td>
</tr>
<tr>
<td>7</td>
<td>0.60</td>
<td>387 mm²</td>
</tr>
<tr>
<td>8</td>
<td>0.79</td>
<td>510 mm²</td>
</tr>
</tbody>
</table>

**Mesh conversion:**
Rebar Fy = 400 MPa: Deformed Mesh Fy = 485 MPa, available up to 550 MPa
Area reduction when converting Rebar Steel Area to Deformed Mesh
Multiply by x 400/485 = 0.825

**Minimum Mechanical Properties for WWR**

<table>
<thead>
<tr>
<th>Type of WWR</th>
<th>Minimum Tensile Strength</th>
<th>Minimum Yield Strength Fy</th>
<th>Minimum Weld Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Wire Mesh</td>
<td>515 MPa (75 000 psi)</td>
<td>450 MPa (65 000 psi)</td>
<td>240 MPa (35 000 psi)</td>
</tr>
<tr>
<td>Deformed Structural Wire Mesh</td>
<td>550 MPa (80 000 psi)</td>
<td>465 MPa (70 000 psi)</td>
<td>240 MPa (35 000 psi)</td>
</tr>
</tbody>
</table>

**Conversion Factors:**
1 in = 25.4 mm 1 lb = 0.4536 kg
1 ft = 0.3048 m 1 lb = 0.4536 kg
1000 psi = 6.895 MPa
1 in² = 645.2 mm²
1 in²/ft = 2116.7 mm²/m
1 lb/ft² = 4.882 kg/m²
Designating Style of Welded Wire Reinforcement Fabric

Spacing and sizes of wires in WWR are identified by “style”. A typical style designation is 152 mm x 305 mm – MD77.4xMW32.3. This denotes a unit of WWR in which:

- Spacing of longitudinal wires = 152 mm
- Size of longitudinal wires = 77.4 mm$^2$
- Spacing of transverse wires = 305 mm
- Size of transverse wires = 32.3 mm$^2$. A typical description of a fabric style and sheet size would be 152 mm x 305 mm – MD77.4xMW32.3 x 2337 mm + 13 mm + 13 mm x 7320 mm including 152 mm overhangs. This describes a sheet of the previous style which is 2337 mm wide plus 13 mm overhang on each side (i.e. 2363 mm overall width) with an overall length of 7320 mm, including 152 mm overhangs on each end. It is...
important to note that the terms of longitudinal and transverse are related to the manufacturing process and do not refer to the relative position of the wires in a concrete structure. Figure 2 provides a graphical representation of the nomenclature used for welded wire fabric.

Figure 2: Nomenclature

Specifications

Welded Wire Reinforcement and wire for the manufacture of WWR is produced in accordance to CSA specifications as listed in Table 2. Table 3 lists the minimum required mechanical properties. You will note that smooth and deformed WWR have a yield strength equal to 450 MPa and 485 MPa, respectively. Higher yield strengths, improved weldability, premanufactured quality control and fabricating efficiencies are the primary advantages of WWR over rebar.
Table 2: Specifications Covering Welded Wire Fabric

<table>
<thead>
<tr>
<th>Canadian Standards</th>
<th>U.S. Specifications</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSA G 30.3</td>
<td>ASTM A 82</td>
<td>Cold-Drawn Steel Wire for Concrete Reinforcement</td>
</tr>
<tr>
<td>CSA G 30.5</td>
<td>ASTM A 185</td>
<td>Welded Steel Wire Fabric for Concrete Reinforcement</td>
</tr>
<tr>
<td>CSA G 30.14</td>
<td>ASTM A 496</td>
<td>Deformed Steel Wire for Concrete Reinforcement</td>
</tr>
<tr>
<td>CSA G 30.15</td>
<td>ASTM A 497</td>
<td>Welded Deformed Steel Wire Fabric for Concrete Reinforcement</td>
</tr>
</tbody>
</table>

Table 3

Welded Smooth Wire Fabric
CSA G30.5 / ASTM A 185

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Tensile Strength (MPa)</th>
<th>Yield Strength (MPa)</th>
<th>Weld Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW7.8 (W1.2)</td>
<td>515</td>
<td>450</td>
<td>140</td>
</tr>
<tr>
<td>&amp; Over</td>
<td>75 000 psi</td>
<td>65 000 psi</td>
<td>20 000 psi</td>
</tr>
<tr>
<td>Under</td>
<td>485</td>
<td>385</td>
<td></td>
</tr>
<tr>
<td>MW7.8 (W1.2)</td>
<td>70 000 psi</td>
<td>56 000 psi</td>
<td></td>
</tr>
</tbody>
</table>

Welded Deformed Wire Fabric
CSA G30.15 / ASTM A 497

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Tensile Strength (MPa)</th>
<th>Yield Strength (MPa)</th>
<th>Weld Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW7.8 (W1.2)</td>
<td>550</td>
<td>485</td>
<td>140</td>
</tr>
<tr>
<td>&amp; Over</td>
<td>75 000 psi</td>
<td>70 000 psi</td>
<td>20 000 psi</td>
</tr>
<tr>
<td>Under</td>
<td>550</td>
<td>485</td>
<td></td>
</tr>
<tr>
<td>MW7.8 (W1.2)</td>
<td>70 000 psi</td>
<td>56 000 psi</td>
<td></td>
</tr>
</tbody>
</table>

For ASTM equivalent designs, please contact your local box culvert producer.
New Construction

Concrete pipe fittings, which are manufactured in accordance with CAN/CSA A257, are recommended for new construction. Fittings, such as tees and wyes can be used for service connections, catchbasin leads and secondary lines. Pipe tees and wyes for secondary lines are manufactured by matching the springline of both the mainline pipe with the lateral pipe. Standard catchbasin and service connections are detailed below (refer to Figure 2). For maximum wye sizes please contact your local supplier.

As an alternative, maintenance hole tees and bends can be used on mainlines with a diameter greater than 1200 mm. Maintenance hole tees are manufactured by connecting a riser section directly into the mainline pipe. A pipe tee to a secondary line or a pipe bend can be installed directly downstream of the maintenance hole tee, allowing access for maintenance and operation (refer to Figure 1.1 & 1.2).

<table>
<thead>
<tr>
<th>Main Line Size</th>
<th>Max Tee Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>375</td>
<td>375</td>
</tr>
<tr>
<td>450</td>
<td>450</td>
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<td>525</td>
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<td>600</td>
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<tr>
<td>825</td>
<td>825</td>
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<tr>
<td>900</td>
<td>900</td>
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</tr>
<tr>
<td>2250</td>
<td>1200</td>
</tr>
<tr>
<td>2400</td>
<td>1200</td>
</tr>
<tr>
<td>2550</td>
<td>1200</td>
</tr>
</tbody>
</table>
Existing Line

Concrete pipe is versatile in that additional connections can be made on site by the contractor. For smaller diameter pipe, the connection is made by coring a hole in the mainline pipe, then connecting the lateral pipe using an approved pipe adaptor or flexible boot. Such adaptors will provide a watertight flexible connection when properly installed. For larger diameter pipe, the traditional method involves cutting the existing pipe, placing a new pipe (lateral) and then pouring a concrete collar and cradle around the connection to the first lateral joint. Care should be taken to protect the connection from possible differential loading.
Since sewers in Ontario have sufficient slope to maintain solids contained in the sewer stream in suspension, hydrogen sulfide generation is usually not a significant problem here. In Ontario, the average ambient temperature is low enough during most of the year to prevent sulphide development. Industrial chemicals, that could facilitate sulphide production, or cause corrosion directly, are monitored and controlled at source. In addition, sewer use bylaws contain restrictions on the discharge of deleterious substances and the discharge of wastewater with elevated temperatures to the sewer system. The goal of design engineers is to minimize the potential for the development of hydrogen sulfide in sewers. Concrete pipe can resist intermittent attacks of corrosive agents due to the manner in which it is manufactured (usually with a minimum cover of 25mm of concrete over the reinforcing steel).

When there are problems in drainage systems caused by $\text{H}_2\text{S}$, the following factors are usually the primary influences that may lead to the formation of sulphuric acid in sewers.

**Dissolved Sulphide:**

The sulphide concentration is the limiting factor in the release of hydrogen sulphide to the sewer walls whereby corrosion may result. If metals are present in the sewage stream, a small amount of sulphide is immobilized to form insoluble metal salts. The amount varies from 0.1 to 0.3 mg/L.
**pH:**

The pH influences dissociation of the sulphide ion species in the sewer. At a pH of 6, more than 90% of the dissolved sulphide is hydrogen sulphide. At a pH of 8, less than 10% is in the form of hydrogen sulfide.

**Biological Oxygen Demand (BOD) and Temperature:**

Temperatures above 15° Celsius may contribute to the generation of hydrogen sulphide if all other conditions of sulphide generation are present.

BOD is a measure of the oxygen depletion by the decomposition and mineralization of organic matter. In a sewer system, the conversion of sulphates to sulphide requires energy. The BOD determination is a measure of the energy within the system that will facilitate this conversion. The BOD usually occurs over a 5 day period and has thus become known as the 5-day BOD.

**Velocity:**

Velocity affects the rate of oxygen absorption, the release of hydrogen sulphide to the atmosphere, and the build up of solids. The minimum velocity of the sewer stream should be between 0.61 and 1.07 m/s to keep solids in suspension. If the velocity causes turbulent flow conditions, increased oxygen may be absorbed into the wastewater, but hydrogen sulphide in wastewater will also be released to the atmosphere. The released hydrogen sulphide may cause corrosion to the wall of the concrete pipe.
Time:

The continuous flow of sanitary sewage is the best defense in the fight against hydrogen sulphide production. Delay in the flow decreases the velocity, thus increasing the risk of production of $\text{H}_2\text{S}$.

Designers must guard against these risks when considering the design of sanitary sewage facilities.

Junctions:

Junctions are important because the wastewater from the tributaries may contain high concentrations of sulphide, lower pH, high BODs and higher temperatures. All of these factors may affect the hydrogen sulphide production in the main sewer line. Junctions may also affect the type of flow wherever they enter the main. If the flow is turbulent, more oxygen may be absorbed into the wastewater, or more hydrogen sulphide may be released into the atmosphere. Since the effects of corrosion outweigh the increase in oxygen absorption, the junctions should enter the main in a manner that reduces turbulence.

Forcemains and Siphons:

Special junctions like forcemains and siphons, have a similar effect on the wastewater stream, as do regular junctions. Forcemains and siphons may flow at low velocities, or intermittently, allowing the increase of sulphide. Forcemains usually flow full, which also facilitates the build-up of sulphides due to the anaerobic conditions in the forcemain. When forcemains and siphons enter the main sewer, the higher concentration of sulphide may cause problems further downstream.
Ventilation:

Ventilation is not an effective measure to reduce the corrosion of concrete pipe because it is difficult to prevent condensation on the walls of pipe due to temperature variations. The hydrogen sulphide is oxidized in the aerobic layer on the wall of the pipe to form sulphuric acid which may corrode the pipe as it trickles down the wall of the pipe.

If velocities of 0.61 metres per second and oxygen levels of 1 milligram per litre and temperatures less than 15°C Celsius can be achieved, corrosion in sanitary sewers will not be problem at any time.

Accumulation of solids could be a problem during the three warmest months of the year. During these months, temperature is sufficiently high to have sewer water temperatures above 15°C. The elevated temperatures would also decrease the dissolved oxygen. Dissolved oxygen is inversely proportional to temperature of the water. If effective BOD levels are less than 600 milligrams per litre and the effective slope is 0.2% and flow is 0.085 cubic metres per second, sulphide concentrations will not increase sufficiently to become a problem.
Today, with emphasis being placed on pipeline rehabilitation, many government agencies are evaluating the service life performance of their systems. Sometimes these evaluations key in on obvious design flaws relating to inherent problems such as leaking joints. To properly evaluate old pipe, consideration should be given to the standard specifications and manufacturing techniques in existence at the time the pipe was made. Today, concrete pipe manufactured in Ontario uses rubber gasketed joints with very close tolerances. Concrete pipe should not be viewed as inferior to any modern pipe materials based on observation of old mortar joint pipe. In fact, investigations of many old concrete pipe installations have demonstrated excellent durability with increased strength and superior abrasion resistance in adverse environments.

Modern pipe is made from two basic types of material – organic material and inorganic material. Organic materials were first used for pipe during the 1800’s. Wooden barrel stave pipe has been discovered during reconstruction in some Ontario cities. Today plastic replaces wood as the organic pipe material most commonly used. Unlike wood, plastic pipe contains preservatives, anti-oxidants and stabilizers, to slow down the natural gradual loss in strength that occurs with organic materials. However, the combination of stress and environment conditions may accelerate these natural changes in plastic materials. Also the use of fillers in PVC pipe can reduce the tensile strength which is critical to a flexible pipe material. Currently there is no known test to establish the service life of a PVC pipe containing filler. However, tests done on mainly small diameter tubing made of PVC without fillers, indicate statistical data that has been extrapolated to predict potential 50 year service life.
Inorganic materials such as clay and concrete have historically demonstrated good durability. Samples of concrete pipe made by the Romans is an example often cited to demonstrate the claim that modern concrete pipe has proven potential to last for at least 100 years. Many tests done on old pipe discovered during reconstruction projects have repeatedly confirmed that concrete pipe does increase in strength over time. Concrete pipe is unique in that it has a record of proven durability, an important feature required by today’s pipe specifiers.
Sanitary sewer systems are expensive, and once installed should have a service life of 100 years or more. Sanitary sewers carry substances that can be very damaging to public health and the environment. Therefore, their structural integrity should not be compromised by the substances they are designed to carry. The chemical resistance of concrete pipe makes it suitable for industrial sanitary applications. Thermoplastic pipe materials are not recommended for this type of use. Their structural integrity is limited by effluent temperatures, and their thin walls can be damaged by commonly found substances, such as detergents, vegetable oils, cleaning fluids and solvents.

Concrete pipe benefits from heavy walls and neutralizing materials such as limestone aggregate, which may prove advantageous for industrial sanitary sewers. It is acknowledged that acids with pH below 5.5 can damage concrete. Sewer Use Bylaw’s generally limit the discharge of substances to a range of pH 5 to pH 9, however, substances outside of this range have found their way into sewer systems. If there is a one-time-only situation, the surface paste of the concrete pipe is affected and the exposed limestone aggregate will effectively limit damage. If this is an ongoing condition, damage will occur, but, due to concrete pipe’s thick walls, full penetration rarely occurs and steel reinforcement will delay any possibility of structural failure. According to a 10-year study conducted by the Ohio Department of Transportation (1982), in an aggressive environment with a pH of 4, concrete pipe will last 100 years. This quality provides a measure of assurance that service will not be suddenly interrupted, and give maintenance crews time to plan and finance any remedial work necessary.
References:

(1) CSA B182.2-99: PVC Sewer Pipe and Fittings (PSM Type) & CSA B182.6-02: Profile Polyethylene Sewer Pipe & Fittings

“Industrial waste disposal lines should be installed only with specific approval of the regulatory authority, since chemicals not commonly found in drains and sewers and temperatures in excess of 60 degrees Celsius (140 degrees Fahrenheit).”

(2) CSA B182.6-02: Profile Polyethylene Sewer Pipe and Fittings

“Industrial waste disposal lines should be installed only with specific approval of the regulatory authority, since chemicals not commonly found in drains and sewers may be encountered and temperatures in excess of 60 °C.”

(3) Transportation Research Board NCHRP 225, page 118

“Some of the chemicals or common materials that can attack, degrade or destroy plastic used in pipe are given below. Exposures which may accelerate stress cracking are designated by ‘+’.”

PVC Ketones, esters, aromatic and chlorinated hydrocarbons+ and vegetable oils+.

PE Strong oxidizing acids, oils, polar reagents such as detergents+, alcohols+, esters+, ketones+, and silicones+.
Physical Properties of Reinforcement

Reinforcing areas required for concrete pipe, as determined by pipe design methods like SIDD (Standard Installations – Direct Design), SAMM (Spangler & Marston Method) and PipeCar vary according to design factors like depth of bury, bedding types, pipe geometry, and material properties of the concrete and steel.

Areas of steel are achieved through a grid pattern of longitudinal and circumferential wires. Longitudinal wires run the length of the pipe, while circumferential wires follow the perimeter of the pipe. For the most part, longitudinal wires maintain the position and shape of the circumferential reinforcement wires at designed spacing within the formwork. It is by varying the wire diameter and/or the wire spacing, along with concrete strength, that a pipe achieves its design strength. Reinforcing cages can be manufactured with welded wire mesh or fabricated using cage machines or mandrels.

Principles of Reinforcement

In a loaded application, the concrete pipe wall must resist the combined effects of moment and thrust known as flexural stress. The resultant of this stress is circumferential tension and compression forces within the pipe wall. Taking a closer look on how the pipe performs, it is actually the cross-sectional shape of the pipe that changes from round to a slightly elliptical shape. Although the movement is small, the vertical dimension decreases and the horizontal dimension increases. This change in shape produces tensile stresses at the invert and obvert of the
pipe, and on the outside of the pipe at the springline. While this is occurring, compressive stresses are developing in areas opposite to the tensile stresses. Flexural stress is maximized in the tensile areas of the pipe (refer to Figure 1).

Since concrete is weak in tension, steel reinforcement must be placed in these areas to control cracking. Reinforcement in areas of compression is not required, however, methods of reinforcing and ease of placement result in it being used.

Shear stresses (or diagonal tension) should also be checked when considering the supporting strength of the concrete pipe. Once again, it is the tensile zones within the pipe wall where shear strength of the pipe is reduced. For a given pipe diameter with a fixed wall thickness, varying reinforcement areas (within limits) and reinforcement placement provide the additional shear strength to the pipe.

Four cage con-
figurations are common use: single circular cage, double circular cage, single elliptical cage, and a combination of an elliptical cage and one or more circular cages. Alternatively, quadrant reinforcement can be used to provide increased steel areas in the tensile zones of the pipe. When necessary, stirrups provide the additional shear strength or radial tension strength. *Figure 2* illustrates a typical reinforcement pattern for large diameter pipe combining an inner and outer cage with an elliptical cage for optimum positioning of tensile steel.

**D-Load Requirements & Manufacturing Specifications**

Reinforced concrete pipe is manufactured in accordance with CSA standard CAN/CSA- A257.2-Series M92. The concrete pipe is tested and classified with a D-load using the Three-Edge Bearing (3EB) method. The D-load is the supporting strength of a pipe for an applied load expressed in Newtons per linear metre per millimetre of inside diameter (N/m/mm). There are two pipe strengths determined by this method; $D_{0.3}$ is a calculated pipe strength for an applied load which will produce a crack width of 0.3 mm over a 300 mm length, while $D_{ult}$ is a calculated ultimate pipe strength which will result in failure. The D-load strength concept and the statistical evaluation of test results are the basis for the CSA Standards that govern the manufacture of concrete pipe. CAN/CSA- A257.2 lists design tables for five classes of reinforced concrete pipe (ie. 40-D through 140-D) showing the pipe diameter, wall thickness, compressive strength of concrete and the amount of circumferential reinforcement required for each class. The steel areas listed are used as a guide, however, the overriding acceptance factor is the 3EB test. For some larger pipe sizes where the CSA Standard does not list
steel areas, the pipe manufacturer may employ the design methods referenced above as a guide to selecting steel areas.

Reinforced Pipe Cage
Key Factor in the Determination of Loads on Rigid Pipe

When setting out to determine the loads on rigid pipe, and hence an appropriate pipe strength selection for a given job, designers should focus on three key areas to arrive at a safe, well engineered and cost effective design:

- Site soil conditions
- Installation type
- Bedding type

Site Soil Conditions

For many years designers have been referring to the Ontario Provincial Standard Drawings (OPSD) "Specified Minimum Class of Pipe" tables, also known as fill height tables (807.01, 807.03 and 807.04). These tables provide a useful guideline for design in terms of rigid pipe strength selection. They have been developed based on certain assumed values, which are listed in the 'NOTES' section at the bottom of each table.

The assumed values include:

- Soil density (w)
- Soil Lateral Pressure/Friction Term (kµ)
- Positive projection ratio (p)
- Settlement ratio (rd)

There are also implied values for live load type and lateral pressure fraction. Most importantly, note 'F' of OPSD 807.03 states that: "Conditions other than this should be calculated from first principles".

It is important that designers endeavor to use soils data relevant to their particular site. Failure to do so may lead to either over or under classifying of the pipe strength required on site.
Installation Type

There are six common installation types:

- **Negative Projecting**
- **Positive Projecting**
- **Confined Trench**
- **Jacked or Tunneled**
- **Wide Trench acting as Positive Projecting**
- **Zero Projecting**
The selection of an installation type will be determined, in part, by the type and condition of soils encountered on site as well as the proximity of existing services and structures to a proposed sewer line.

The classification of soils as per section 226 of Ontario Regulation 213/91 of the Occupation Health and Safety Act may promote or negate the use of a certain installation type. Further, due to uncontrolled site conditions and the installation on ancillary drainage facilities, i.e. maintenance holes, service connections, catchbasins, etc., and the level of effort provided in the construction of said facilities, the OCPA recommend the use of Positive Projecting design be used for concrete pipe installations.

**Bedding Type**

The selection of an appropriate bedding type, generally as per OPSD 802.03 series or one of the 4 SIDD types, will influence the load supported by an installed pipe as well as the cost of bedding material and the frequency of inspection required. The designer should weigh the cost of upgrading the strength of pipe to any offset in the total cost of bedding material resulting from a change in bedding type specification. This will yield the most cost effective pipe envelope design for a given site.

**Design Aids**

The OCPA offers free software to aid in the design and cost calculations for pipe selection. PipePac incorporates the new SIDD method as well as the traditional SAMM (Spangler and Marston Method) to determine the loads on pipe, and CAPE (Cost Analysis of Pipe Envelope) to compare the cost of the entire pipe installation.
This guideline is to assist designers in the proper sizing and selection of precast concrete maintenance holes (MH). These maintenance holes are manufactured according to the provisions of CAN/CSA A257.

After specifying sewer sizes, designers must consider the overall efficiency of the system by selecting the appropriate MH. Choosing the right maintenance hole assures proper hydraulic efficiency at intersections, grade changes and elevation changes. The pipe orientation (straight through, right angle, etc.) determines the diameter of the MH required for safe handling and installation.

**Maintenance Hole Selection Table**

Through the continued efforts of precast concrete manufacturer's, contractors and consulting engineers in Ontario, Table 1 was created. This table should be used to determine maximum pipe sizes entering MH and for pipe opening configurations.

*Table 1* shows some considerations for a MH including area required to accommodate the pipe openings and the benching.

**Other Considerations**

There are several other sizing considerations:

- the vertical location of pipes (*Figure 1*);
- safety landings (*Figure 2*);
- access for workers during the installation.
Significant Advancements in Maintenance Holes

For many years, concrete MH producers in Ontario have supplied pre-benched MH’s. Previously, benching was completed in the field to the OPSD construction standard. There are significant benefits of pre-benching including:

- the exacting standards in a manufacturing environment (to OPSD 706.010) - pre-benched MH's come to the site ready to drop into place thus installation is quick and easy.
- less time and effort on site - no wasted benching materials.
- worker safety - there's no need to enter a confined space.
- little disruption to traffic and no added costs in labour and equipment.

For further information on any of these selection guidelines, go to www.ocpa.com
### Table 1: Maximum Pipe Sizes

<table>
<thead>
<tr>
<th>Maintenance Hole Inside Diameter (mm)</th>
<th>Max. Pipe Size for Straight Through Installation (mm)</th>
<th>Max. Pipe Size for Right Angle Installation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td><img src="#" alt="Diagram of 1200mm pipe sizes" /></td>
<td><img src="#" alt="Diagram of 1200mm pipe sizes" /></td>
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<tr>
<td>1500</td>
<td><img src="#" alt="Diagram of 1500mm pipe sizes" /></td>
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</tr>
<tr>
<td>1800</td>
<td><img src="#" alt="Diagram of 1800mm pipe sizes" /></td>
<td><img src="#" alt="Diagram of 1800mm pipe sizes" /></td>
</tr>
<tr>
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<td><img src="#" alt="Diagram of 2400mm pipe sizes" /></td>
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</tr>
<tr>
<td>3000</td>
<td><img src="#" alt="Diagram of 3000mm pipe sizes" /></td>
<td><img src="#" alt="Diagram of 3000mm pipe sizes" /></td>
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<tr>
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<td><img src="#" alt="Diagram of 3000x2400mm pipe sizes" /></td>
</tr>
<tr>
<td>3600 x 2400</td>
<td><img src="#" alt="Diagram of 3600x2400mm pipe sizes" /></td>
<td><img src="#" alt="Diagram of 3600x2400mm pipe sizes" /></td>
</tr>
</tbody>
</table>
Maintenance Hole Selection Guidelines

Drop Structures

Drop structures are used where there may be a change in grade, pipe size, wet site conditions or to prevent water scouring of the MH. Currently, drop structures are created using an assembly of pipe junctions and fittings attached externally to the MH using steel reinforcing and encased in concrete. There is, however, a better way. The internal drop has been used primarily as an alternative to rehabilitating existing MH’s for new connections (refer to Figure 3). The major difference is the upsizing of the MH structure in order to accommodate the diameter of the drop pipe. The advantages? Ease and safety of installation and the ability to inspect and clean out the drop pipe after installation. See information provided in this guide for more details on internal drop structures.

Maintenance Hole Tees

In large pipe runs (1200 mm diameter or greater), it is possible to gain access to main line through a riser section teed directly into the mainline pipe called a maintenance hole tee (MH tee). Small incoming pipes can also be teed directly into the mainline pipe just downstream from the MH tee. This replaces a standard MH installation with a combination of tees for access and operation. Figure 4 illustrates, in plan view, the spacing for lateral and the MH feed riser section.
Figure 3

1200 Sections

1200 min

1500 min

Figure 4 (Plan View)

Lateral Line

Main Line
Background

Precast Reinforced Concrete Pipe is the most commonly used pipe material for jacking operations. Concrete Pipe is frequently installed by the jacking method where deep installations are necessary or where conventional open-cut excavation and backfill methods may not be feasible.

Concrete pipe for jacking installations first became evident in the North America in 1896 when Northern Pacific Railroad utilized this procedure for installing drainage systems under their rail lines. In more recent years, this technique has been applied to sewer construction where intermediate shafts along the line of the sewer are used as jacking stations. Reinforced bell and spigot concrete pipe as large as 3350mm diameter has been successfully installed by the jacking method.

Jacking Procedure

The initial procedure in jacking concrete pipe is to equip the leading edge of the pipe with a shield to protect the miners. This method is known as hand mining, a process where a person physically removes soil from in front of the pipe being jacked. As the material is removed on a small rail and trolley system installed in the bottom of the pipe, the pipe is jacked forward filling the void of the removed material. Material is trimmed with care and the excavation does not precede the jacking operation more than is necessary. Such procedures usually result in minimum disturbance of the natural soils adjacent to the pipe.

This method of pipe installation is very reliant on stable native soils and therefore soil data for the proposed project is critical. (Projects with loose native soils or soils
affected by ground water should not consider hand mining for pipe installation. This type of installation may be more suited to a directional drilling method for pipe installation.

Contractors occasionally find it desirable to coat the outside of the pipe with a lubricant, such as bentonite, to reduce the frictional resistance between the pipe and the soil. In most instances, this lubricant is pumped through special fittings installed in the wall of the pipe. It is desirable to continue jacking operations 24 hours per day until completed, because of the tendency of jacked pipe to set when forward movement is interrupted, for as little as a few hours, resulting in significantly increased frictional resistance to subsequent movement. If continuous jacking cannot be accomplished, then the additional forces necessary to move a pipe at rest must be taken into consideration when designing the jacking pipe installation.

It is important that the direction of jacking be carefully established prior to beginning the operation. This requires the installation of guide rails in the bottom of the jacking pit or shaft. In the case of large pipe it is desirable to have such rails carefully set in a concrete slab as the weight of the large pipe may induce some settlement into native soil. The number and capacity of the jacks used depend primarily upon the size and length of the pipe to be jacked and the type of soil encountered. The shaft thrust walls must be strong enough and large enough to distribute the maximum capacity of the jacks against the soil behind the thrust wall.

**Loads on Jacked Pipe**

Two types of loads are imposed on reinforced concrete pipe installed by the jacking method. The axial load due to
the jacking pressures applied during jacking process and the bearing load due to the earth cover. Live loading may also be a consideration depending on the project site and the depth of the pipe installation.

**Axial Loads:** For axial loads normally encountered, it is necessary to provide uniform distribution of the load around the periphery of the pipe to prevent localized stress concentrations. This is accomplished by assuring that the pipe ends are parallel and within the tolerances prescribed by CSA A257.2. Furthermore, utilization of a cushion material such as solid core plywood or hardboard in conjunction with an experienced contractor will ensure that the jacking force is properly distributed through the jacking frame and parallel to the axis of the pipe. The cross-sectional area of the concrete pipe is more than adequate to resist pressures encountered in any normal jacking operation.

It is always a good idea to meet with the jacking contractor to ascertain the jacking forces he expects to apply to the pipe. For projects where extreme jacking pressures are anticipated, due to long jacking distances or excessive unit frictional forces, concrete compressive strength higher than standard may be required, along with greater care in avoiding bearing stress concentrations. A factor of safety on axial load capacity shall be 3.20 based on the ultimate strength of the concrete. The effect of eccentric or concentrated loads on the pipe joints should also be evaluated.

The magnitude of the anticipated axial loads is a function of many factors including installation technique, total length of jack, pipe skin friction, and pipe diameter. The total jacking force \( F_{js} \) of concrete pipe is dependent on several primary factors.
• Cross sectional area of pipe at weakest point: \((A_j)\)
• Compressive strength of concrete: \((f'_c)\)
• Appropriate factor of safety: \((S.F.)\)

The rated jacking pipe force, (direct compression force), \((R_{js})\) conforms to the following equation:

\[
R_{js} = A_j \times f'_c / S.F.
\]

Additionally, longitudinal bending due to the eccentricity of the load on the joint face should be evaluated. In general the complete pipe remains in compression, despite minor bending due to eccentricity between the center of the joint face and the gross wall section beyond the joint. With some joint designs, the resultant force is acting considerably off the centerline of the wall, creating a net tensile stress. In such cases, this stress should be limited to \(3 \times f_{c1/2}\).

**Lateral Loads:** These loads can be a result of jacking force being applied to the pipe, if the jacking frame is not square to the end of the concrete jacking pipe. Another area where lateral pressure occurs is if the pipe is off line and/or grade, and the contractor adjusts the direction of the pipe to realign to the proper line and grade. This action subjects the bell and spigot ends of the pipe to extreme shear loads.

**Earth and Live Loads:** The calculation of the required pipe strength is determined by: the soil depth, soil mass, and the live load, if applicable. The Ontario Concrete Pipe Association’s software program PipePac, can assist in determining the load bearing capacity required of the pipe.
Two other factors need to be addressed; the dimension of the overcut on the outside of the reinforced concrete jacking pipe, and whether this area is grouted or not grouted after pipe installation. Once the overcut is determined the PipePac program allows for load calculations based on grouted or non-grouted conditions.

**Pipe Characteristics**

**Materials:** Requirements for cement, aggregates, reinforcing steel, and other additives shall be as specified in the appropriate CSA material standards.

**Manufacture:** Reinforced concrete pipe shall be manufactured according to CSA A257.2 Reinforced Circular Concrete Culvert, Storm Drain, Sewer Pipe, and Fittings, with attention being given to: nominal dimensions, pipe lengths, and the compressive strength of the concrete. At no time shall the compressive strength of the concrete be less than 40 Mpa.

Jacking pipe shall contain two cages of circular reinforcement in the barrel of the pipe. The outer cage shall extend into the groove of the pipe, and the inner cage shall extend into the tongue of the pipe. (refer to OPSS 1820 Material Specifications for Concrete Pipe).

The pipe will be manufactured with circular reinforcing cages only. At no time is elliptical steel reinforcement allowed in jacking pipe.

Should conditions warrant, the owner may request the groove end to be strengthened by the use of an external band of hot rolled steel, (12 gauge thick, and 203 mm in
height). The steel band is welded to the outside reinforcing cage with the use of appropriate spacers.

Lubrication (bentonite) ports are generally installed at the time of manufacture, and may or may not involve the use of a one way valve. It is best to check with the jacking contractor to locate these ports where they will work best for him.

Joints in the pipe should be as symmetrical as possible; that is, the thickness of the tongue should be as close as possible to the thickness of the groove end. Gasket options for jacking pipe include ‘O’ Ring or single offset since these gasket types are not affected by small movements in the joint area expected as jacking pressure is applied and relaxed.

Subaqueous lubricant should also be supplied with the pipe.

**Permissible Variation**

CSA A257.2 Reinforced Circular Concrete Culvert, Storm Drain, Sewer Pipe, and Fittings provides the user with minimum requirements for pipe variations. Users should contact the concrete pipe supplier to determine how the manufacturer ensures the dimensional limitations are met.

**Internal Diameter:** The internal diameter of 1200 mm to 3000 mm reinforced concrete pipe shall not vary more from the design diameter than +/- 1% or +/- 10 mm, whichever is less.

**Outside Diameter:** The external diameter of 1200 mm to 3000 mm reinforced concrete pipe shall not vary more from the design diameter than +/- 1% or +/- 10 mm, whichever is less.
Wall Thickness: At any location along the length of the pipe, or at any point around its circumference, the wall thickness shall not vary by more than +/- 5% or 5 mm, whichever is greater.

Roundness: The outside diameter of the pipe shall not vary from a true circle by more than 1%. The out of round dimensions shall be one half the difference between the maximum and minimum diameter of the pipe at any one location along the barrel.

Taper: The outside barrel of the pipe shall not vary in taper from the spigot end to the bell end by more than 3 mm.

Pipe Length: Finished pipe length shall not deviate from the design length by more than +/- 5 mm/m; with a maximum variance of +/- 10 mm in any length of pipe.

Length of Two Opposite Sides: Variations in the laying length of two opposite sides of the pipe shall not be more than 5 mm for any size of pipe.

End Squareness: End squareness across outside diameters shall govern over lengths of two opposite sides.

<table>
<thead>
<tr>
<th>Length Range</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 – 1500 mm</td>
<td>4.4 mm variation</td>
</tr>
<tr>
<td>1650 - 2250 mm</td>
<td>5.5 mm variation</td>
</tr>
<tr>
<td>2400 – 3000 mm</td>
<td>7.0 mm variation</td>
</tr>
</tbody>
</table>
WHY IS IT IMPORTANT TO ESTABLISH AN ENTRY PERMIT PROTOCOL FOR CONFINED SPACES?

The law requires that confined spaces be identified and certain action taken before anyone may enter a confined space.

What is Confined Space?

The Ontario Occupational Health & Safety Act Regulations for Industrial establishments define confined space as a space in which, because of its construction, location, contents or work activity therein, the accumulation of a hazardous gas, vapour, dust or fume or the creation of an oxygen-deficient atmosphere may occur. Examples of confined spaces include the following:

- Completely enclosed structures with limited access, such as maintenance holes, storage tanks, tank cars and other vessels and chambers entered through a maintenance hole;
- Deep structures that may have an open top but require special means of entry and provision for emergency exits, such as tanks, lopping pits, bins, excavations, etc.;
- Other enclosed spaces include boilers, furnace flues, ducts, sewers, tunnels, pipelines, etc.

There are four main dangers in confined spaces: oxygen deficiency and oxygen enrichment; fire or explosion; toxicity; and, drowning in liquids or free flowing solids. If there is a chance that hazardous vapours, dust, gas, or fumes exist in the confined spaces, the air must be tested and the area ventilated.
Section 60 states:

(1) No worker shall be present in a confined space on a project unless,

(a) there is a means of egress from the parts of the confined space that are accessible to workers;

(b) all mechanical equipment in the confined space is disconnected from its power source and locked out;

(c) all pipes and other supply lines in the confined space whose contents are likely to create a hazard are blanked off; and

(d) the confined space is certified in accordance with subsection (3) to be safe for workers. O. Reg. 213/91, s. 60 (1).

(2) A competent worker shall test and evaluate a confined space before a worker enters it to determine whether it is free from hazard to a worker while the worker is present in it and as often as necessary to ensure that it remains free from hazard. O. Reg. 213/91, s. 60 (2).

(3) The worker who performs the tests shall certify in writing whether the confined space may endanger a worker. O. Reg. 213/91, s. 60 (3).
(4) The employer shall keep a permanent record of the results of all tests performed on a confined space. O. Reg. 213/91, s. 60 (4).

**Section 61 states:**

(1) No worker shall be present in a confined space in which there is or is likely to be a hazardous gas, vapour, dust, mist, smoke or fume or an oxygen content of less than 18 per cent or more than 23 per cent, measured at atmospheric pressure, unless this section is complied with. O. Reg. 213/91, s. 61 (1).

(2) The confined space shall be purged and ventilated to provide an atmosphere which does not endanger workers and measures necessary to maintain the atmosphere shall be taken. O. Reg. 213/91, s. 61 (2).

(3) Suitable arrangements shall be made to remove a worker from the confined space should assistance be required. O. Reg. 213/91, s. 61 (3).

(4) When a worker is present in the confined space, another worker shall be stationed outside it. O. Reg. 213/91, s. 61 (4).

(5) If the person stationed outside the confined space is not adequately trained in artificial respiration, a person so trained shall be conveniently available. O. Reg. 213/91, s. 61 (5).

**Section 62 states:**

(1) Despite subsections 60 (1) and 61 (1), a worker may be present in a confined space that is not purged and ventilated and for which no certificate under subsection 60 (3) has been given if this section is complied with. O. Reg. 213/91, s. 62 (1).
(2) A worker in a confined space shall use suitable protective breathing apparatus and a full body harness securely attached to a rope,

(a) whose free end is attached securely to a fixed support located outside the confined space; and

(b) that is being held by a worker outside the confined space who is equipped with an alarm. O. Reg. 213/91, s. 62 (2).

(3) A means of communication between a worker in the confined space and the worker outside it shall be provided. O. Reg. 213/91, s. 62 (3).

(4) A person trained in artificial respiration and equipped and able to perform rescue operations shall be readily available outside the confined space while a worker is inside it. O. Reg. 213/91, s. 62 (4).

(5) A competent worker shall inspect all equipment mentioned in subsection (2) as often as is necessary to ensure that it is in working order. O. Reg. 213/91, s. 62 (5).

Section 63 states:

(1) No worker shall be present in a confined space that contains or is likely to contain explosive or flammable gas, dust, mist or vapour except as provided in this section. O. Reg. 213/91, s. 63 (1).

(2) A worker may engage in cleaning or inspecting activities that do not create a source of ignition in a confined space in which the concentration of explosive or flammable gas or vapour is not likely to exceed 50 per cent of the lower explosive limit of the gas or
vapour. O. Reg. 213/91, s. 63 (2).

(3) A worker may engage in cold work in a confined space in which the concentration of explosive or flammable gas or vapour is not likely to exceed 10 per cent of the lower explosive limit of the gas or vapour. O. Reg. 213/91, s. 63 (3).

(4) In this section, "cold work" means a work procedure that does not generate heat and does not cause sparks or open flame, explosions or flash fires. O. Reg. 213/91, s. 63 (4).

References

(1) Occupational Health & Safety Act, R.R.O. Regulation 213/91, Amended to O.Reg. 527/00 Industrial Establishments.

(2) List prepared by Ontario Safety & Health Association.
REINFORCED CONCRETE PIPE 0.3 mm CRACK DESIGN

Reinforced concrete pipe is designed to have a 0.3 mm crack when it reaches its design load. These cracks are visible evidence that the concrete pipe has deflected, therefore placing the steel reinforcement into tension as it was designed to do. A reinforced concrete structural element may crack when it meets the design criteria. These hairline cracks do not provide a source for future corrosion and do not cause leakage as they do not extend through the pipe wall. The crack is V-shaped and is widest at the surface. The fact that the 0.3 mm crack criterion is conservative is demonstrated by more than 70 years of experience in the United States and Canada. There has never been a report of deleterious corrosion of reinforcement in a concrete pipe due to the existence of cracks of a 0.3 mm magnitude.
THE WEIGHT OF CONCRETE PIPE IS ADVANTAGEOUS

Concrete pipe is a heavy product and this mass is an advantage in a number of cases.

An example is when the ground water table is at an elevation higher than the invert of the pipe. Although the trench is dewatered during the installation of the pipe, the trench area downstream, after initial backfill, may become saturated. This would cause a buoyant effect on the pipe. The mass of the concrete pipe would counteract this buoyant force, ensuring an installation true to line and grade.

During the backfill operation, where the fill is placed in the trench from the side, the fill may accumulate more on the one side of the pipe than the other. The mass of the concrete pipe resists the lateral forces involved and the sewer remains true to line and grade.
All pipe materials are considered to be strong and durable by those marketing their product. Strength is measured in terms of either tensile strength or compressive strength. Modulus of elasticity is a measure of the stiffness of a material with stiffness defined as the ability to resist deformation. Modulus of elasticity is the ratio of stress divided by strain. By plotting a stress-strain diagram, the stress strain relationship of various materials can be illustrated (refer to Figure 1).

![Stress-strain diagram](image)

**Figure 1**

The definition of synergy is “the combined or co-operative action of two or more agents, groups or parts, etc. that together increase each other’s effectiveness”. The combination of the tensile strength of steel with the compressive strength of concrete has obvious benefits. Reinforced concrete pipe has the synergy of concrete and steel working together to provide a pipe material of superior strength and durability. In addition, concrete strength increases with time.
Economics and experience have taught the pipe industry that overbuilding a pipe is as unacceptable from an economic point of view, as underbuilding a pipe is from a structural point of view. The concrete pipe industry follows the basic engineering principle that pipe strength must be matched with pipe diameter. That is why concrete pipe D-load requirements were developed for CSA and ASTM Standards.

The ASTM Standard test requirements to establish the strength of some thermoplastic materials by cell classification does not require tests performed on actual pipe samples, but rather on compression moulded specimens that are often quite different from the actual pipe products (ASTM 1784 Sec. 3 & 9). The cell classification values listed are not necessarily suitable for direct application in design partly for this reason. This is in direct contrast to the established tests performed on actual concrete pipe taken from inventory.

The high strength of concrete pipe has long been appreciated by design engineers and is reliable and easily confirmed through routine plant testing. This provides assurance to the designer of conformity to particular design requirements. This allows designers to confidently match the structural advantages of concrete pipe with the installation conditions thereby providing the most economic design possible.
Pipe joints are routinely checked for dimensional accuracy following production. The rubber gaskets are designed to permit easy assembly while providing compression to maintain a watertight flexible seal. In spite of this attention to joint leakage prevention, leaks still can occur in the field. The following are a few typical causes and preventative measures that should be taken.

1. **Rebounding – Joint Opening**

   Prevention:
   
   a) proper joint lubrication;
   b) protect gaskets from extreme cold or heat;
   c) self-lube gaskets.

2. **Rolling or sliding gasket**

   Prevention:
   
   a) clean the joint surfaces and lubricate both bell and gasket surface;
   b) no lube required for roll-on gaskets;
   c) proper location of gasket on the spigot.

3. **Damaged – Chipped gasket seat or shoulder on spigot, or chipped bell on compression surface**

   Prevention:
   
   a) controlled by proper storage and handling of pipe.
4. **Deflected joints caused by rapid changes in alignment**

**Prevention:**

a) check laser setting;
b) place laser target in bell;
c) good alignment results in good joint performance;
d) proper installation procedure;
e) stable foundation.

5. **Hanging gasket (gasket pulled off gasket seat)**

caused by partially opening pipe joint, when adjusting alignment during installation

**Prevention:**

a) stable foundation;
b) proper construction of bedding under barrel of pipe;
c) proper compaction under bedding under maintenance hole/catchbasin structure.
Minimum Velocity

The issue of minimum velocity (0.6 m/s) to maintain self-cleaning is often a concern to designers in areas of minimum cover where pipe slope constraints are a problem. This is especially true in upstream areas where limited volume of flow is expected. Historically, this flow problem was often solved by connecting a catchbasin to the sanitary sewer or deliberately permitting infiltration. This past practice concerns present-day designers who must now design bottle-tight systems without the designed element of extraneous flow. This feature of contemporary systems often leaves the designer with limited options.

Some designers have sought justification of their flow-related flat slope design by looking to the superior smoothness claims of manufacturers of alternative pipe materials. However, European standards recognize that roughness increases with increased diameter of some thermoplastic pipe. This is primarily due to an increase in manufacturing tolerances with increased diameter.

Modern, rubber-gasketed concrete pipe is considered to be smooth wall pipe, and is free of the mortar joint roughness effect referenced in date research. This fact has been repeatedly confirmed by laboratory tests. Numerous field tests have also demonstrated that there is no technical reason to justify the assignment of different Manning “n” values for specific types of smooth wall pipe based on marginal differences in laboratory performance.

Whatever the Manning “n” value the designer chooses to use, based on laboratory results or historical performance, no difference between all smooth wall pipe materials can be justified. This is because the actual field conditions
add the same roughness characteristics to all types of smooth wall pipe material. In fact, the Ministry of the Environment Design Guide recommends a design value for Manning n=0.013 for all smooth wall pipe

**Maximum Velocity**

Maximum velocity is an issue often related to topography where steep slopes have to be accommodated in the design. The main design considerations are related to the maximum velocity that will cause abrasion of the pipe material, and the impact that high velocity flows can have on the receiving system or outfall structure. The downstream impact can be accommodated by a variety of methods including diameter changes and the use of in-line baffles or special outfall structures. Historically, it has been found that velocities up to 12 m/s do not create problems for concrete pipe (Ref 1&2).

Concrete pipe’s excellent performance for many years carrying mine tailings in slurry have proven concrete pipe’s ability to resist the severe combined conditions of high velocity and abrasive bed load (Ref 3). When mountainous topographic conditions exist, this long experience with concrete pipe has resulted in system drainage to permit a maximum velocity for sewers up to 12 m/s (Ref 4).

Current design restrictions on maximum velocity, limiting designers to 3 m/s, relate to the limited data available many years ago when these standards were established. These arbitrary limitations do not reflect the data currently available based on the many years of excellent field performance of concrete pipe.
References:

1. ACPA Concrete Pipe Handbook – pages 6-10.

2. ASCE WPCF Manual of Practice No. 9 – pages 128-129.


4. Special Order from City of Los Angeles, City Engineer. Re: Materials for Storm Drains: Storm Drain Design – Maximum Velocities.
PIECE TO MAINTENANCE HOLE FLEXIBLE CONNECTORS

Two types of flexible rubber connectors are available for connecting pipe to maintenance holes. Rubber connectors are either cast-in-place during manufacture of the precast product, or installed into a cored or preformed hole in the finished maintenance hole. Both types conform to CSA A257.3, ASTM C923, and its metric equivalent C923M.

These specifications cover the design, material, and most importantly, performance requirements for resilient connectors. The connectors must be able to withstand a minimum hydrostatic pressure of 90 kPa (13 psi) without leakage under CSA, and 70 kPa (10 psi) under ASTM. They must also be able to withstand a minimum axial deflection of 13 mm under CSA, 7 degrees under ASTM, and a shear test of 26 N/mm (150 lb/in) of pipe diameter without leakage.

Both flexible connectors are easy to use and provide a positive seal between the maintenance hole structure and the resilient connector, and between the resilient connector and the incoming pipe (refer to Figure 1). The installer inserts the pipe into the connector in the maintenance hole. Depending upon the system used, the installer may be required to tighten a clamp on the incoming pipe to make the positive seal.

The following are the benefits of these two systems over on-site field connections, where incoming pipe may be mortared into the maintenance hole.
Benefits:

- A flexible joint;
- An engineered connection;
- Quality controlled product;
- Efficient and economical to use;
- Complements gasketed pipeline and maintenance hole systems.

Figure 1
The Manning equation, developed about 1889, has come to be the primary equation used to determine the required hydraulic capacity for a given gravity sewer installation. Once the hydraulic capacity requirements are known, the pipe inside area can be determined.

The Manning equation is,

\[
Q = \frac{1}{n} A R^{2/3} S^{1/2} \quad \text{(metric)}
\]

\[
Q = 1.486 \frac{A R^{2/3} S^{1/2}}{n} \quad \text{(imperial)}
\]

where,

- \( Q \) is the design flow of a sewer, m/s (ft/s);
- \( A \) is the cross-sectional area of the flow;
- \( R \) is the hydraulic radius, which equals the area of flow divided by the wetted perimeter, m (ft);
- \( S \) is the slope, m/m (ft/ft);
- \( n \) is Manning coefficient of roughness.
Manning Coefficient of Roughness

The Manning coefficient of roughness ‘n’ is an empirical value developed through the laboratory testing of flow through a gravity pipe. The coefficient is dimensionless and reflects the internal roughness of the pipe walls.

The difference between laboratory test values of Manning coefficient, n, and accepted design values can be significant. Although numerous tests by public and other agencies were used to establish Manning coefficient values, these laboratory results were obtained utilizing clean water and straight pipe sections without maintenance holes, debris, or other obstructions. The laboratory results indicate the only significant differences were between smooth wall and rough wall pipes. Rough wall, or corrugated pipe, have relatively high ‘n’ values and are approximately 2.5 to 3 times those of smooth wall pipe.

Recent revisions made to the Federal Highway Administration’s, HDS No. 5, “Hydraulic Design of Highway Culverts” have established new Manning Coefficient values for concrete pipe. The ‘n’ values for concrete pipe range from 0.010 to 0.011.

Manning ‘n’ values for Culverts

### Manning Equation

<table>
<thead>
<tr>
<th>Type of Culvert</th>
<th>Roughness of Corrugation</th>
<th>Manning ‘n’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Pipe</td>
<td>Smooth</td>
<td>0.010 - 0.011</td>
</tr>
<tr>
<td>Concrete Box</td>
<td>Smooth</td>
<td>0.012 - 0.015</td>
</tr>
<tr>
<td>Spiral Rib Metal Pipe</td>
<td>Smooth</td>
<td>0.012 - 0.013</td>
</tr>
<tr>
<td>Corrugated Metal Pipe, Pipe-</td>
<td>68 x 13 mm Annular</td>
<td>0.022 - 0.027</td>
</tr>
<tr>
<td>Arch and Box (Annular and Helical)</td>
<td>68 x 13 mm Helical</td>
<td>0.011 - 0.023</td>
</tr>
<tr>
<td>Helical Corrugations — See Figure B-3</td>
<td>150 x 25 mm Helical</td>
<td>0.022 - 0.025</td>
</tr>
<tr>
<td>Manning ‘n’ varies with barrel size</td>
<td>125 x 25 mm</td>
<td>0.025 - 0.026</td>
</tr>
<tr>
<td></td>
<td>75 x 25 mm</td>
<td>0.027 - 0.028</td>
</tr>
<tr>
<td></td>
<td>150 x 50 mm Structural Plate</td>
<td>0.033 - 0.035</td>
</tr>
<tr>
<td></td>
<td>230 x 64 mm Structural Plate</td>
<td>0.033 - 0.037</td>
</tr>
<tr>
<td>Corrugated Polyethylene</td>
<td>Smooth</td>
<td>0.009 - 0.015</td>
</tr>
<tr>
<td>Corrugated Polyethylene</td>
<td>Corrugated</td>
<td>0.018 - 0.025</td>
</tr>
<tr>
<td>Polyvinyl Chloride (PVC)</td>
<td>Smooth</td>
<td>0.009 - 0.011</td>
</tr>
</tbody>
</table>

**NOTE:** The Manning ‘n’ values indicated in this table were obtained in the laboratory and supported by the provided reference. Actual field values for culverts may vary depending on the effect of abrasion, corrosion, deflection, and joint conditions.

### Design Values of Manning ‘n’

Typically, Manning ‘n’ value for smooth wall pipe has been 0.013. The Ontario Ministry of the Environment published guidelines support this value for the coefficient of roughness as provided in “Design of Sanitary Sewage Works Systems, Storm Sewers (Interim), Water Distribution Systems and Water Storage Facilities – July 1984.
JOINTING PROCEDURE & RUBBER GASKET TYPES

Jointing of concrete pipe is the process of connecting one pipe to another in order to create a pipe system. This is accomplished by homing the spigot of one pipe into the bell of another pipe. Homing procedures are provided.

Several types of joints and sealant materials are utilized for concrete pipe, and maintenance holes, to satisfy a wide range of performance requirements. All of the joints are designed for ease of installation. Rubber gaskets are the most common sealant material and are used in sanitary and storm sewer systems to provide a soil and water tight joint.

Commonly used rubber gaskets include:

- Self-lubricating
- “O” Ring
- Positive Lock
- Single Off-set

Except for the roll-on and pre-lubricated types, the gasket and bell should be coated with a lubricant recommended by the manufacturer. The lubricant must be clean and be applied with a brush, cloth pad, sponge or glove. For “O” Ring gasket joints, the gasket recess must also be lubricated prior to the placement of the gasket. This will enable the tension in the gasket to self equalize.

Gaskets are required to be stored in a controlled environment at the manufacturer’s location, as well as on the job site. They need to be protected from prolonged exposure
Jointing Procedure

to sunlight, extreme heat in the summer, and extreme cold, snow and ice in the winter. Proper care of the gaskets prior to installation will ensure maximum ease of installation, and maximum sealing properties of the gaskets.

Gaskets are generally formulated for maximum sealing performance in a standard sewer installation carrying primarily storm water or sanitary sewage. Custom rubber formulations are available for special situations, where specific elements are being carried in the effluent.

These rubber gasket joints are required to meet CAN/CSA A257.3 and the Plant Prequalification Program for Precast Concrete Drainage Products.

Note: The bell and spigot configurations are for illustrative purposes only. Actual bell and spigot configurations may differ based on the manufacturer.

“O” Ring Gaskets:

Step 1: Ensure the bell, spigot and gasket for the joint are clean and free of debris.
Step 2: Using the lubricant supplied, thoroughly lubricate the face of the entire bell of the receiving pipe.

Step 3: Lubricate the “O” ring groove in the spigot of the pipe to be homed.

Step 4: Place the gasket in the lubricated groove. A well-lubricated groove will automatically equalize the tension in the gasket. For proper jointing, it is imperative that the tension in the gasket be equalized.

Step 5: Align the spigot with the bell ensuring that the gasket is in contact with the flared end of the bell around the complete circumference of the pipe, and home the joint.
Positive Lock Gaskets:

**DO NOT USE LUBRICANT**

Step 1: Ensure the bell, spigot and gasket for the joint are clean and free of debris.

Step 2: Place positive lock gasket on the spigot end of the pipe, with the gasket protrusion on the leading edge of the spigot.

Step 3: Align the spigot with the bell and home the joint. If this procedure is followed, the spigot will be heard striking the bell when the gasket rolls over.
**Single Offset Gaskets:**

Step 1: Ensure the bell, spigot and gasket for the joint are clean and free of debris.

Step 2: Place single offset gasket on the spigot end of the pipe, the gasket must be placed against the spigot shoulder and the tension in the gasket must be equalized.

Step 3: Using the lubricant supplied, lubricate the bell of the pipe and the top of the gasket thoroughly. Align the spigot with the bell ensuring that the gasket is in contact with the flared end of the bell around the complete circumference of the pipe and home the pipe together.
Self-Lubricating Gaskets:

DO NOT LUBRICATE

Step 1: Ensure the bell, spigot and gasket for the joint are clean and free of debris.

Step 2: Place self lubricating gasket on the spigot end of the pipe, with the mantle portion up. The gasket must be seated against the spigot shoulder.
Step 3: Align the spigot with the bell and home the joint. When the joint is homed, the mantle section slides over the compression area of the gasket and comes to rest on the spigot shoulder.

Homing Procedures:

Joints for pipe sizes up to 600mm in diameter can usually be assembled by means of a bar and wood block. The axis of the pipe section to be installed should be aligned as closely as possible to the axis of the last installed pipe section, and the tongue, or spigot, end inserted slightly into the bell, or groove. A bar is then driven into the bedding and wedged against the bottom bell, or groove, end of the pipe section being installed. A wood block is placed horizontally across the end of the pipe to act as a fulcrum point, and to protect the joint end during assembly. By pushing the top of the vertical bar forward, lever action pushes the pipe into a home position.

Large diameter pipe can be jointed by placing a “dead man” blocking system inside the installed pipe, several sections back from the last installed section, which is connected by means of a chain or cable to a strong block placed across the end of the pipe section being installed. The pipe is pulled home by lever action similar to the
Jointing Procedure

external assembly. Mechanical details of the specific apparatus used for pipe pullers, or come along devices, may vary, but the basic lever action principle is used to develop the necessary controlled pulling force.

Pipe manufactured with lifting system devices are homed differently. See page 15 for an illustration of the proper procedure.

For maintenance holes, the mass of the section added to the maintenance hole stack will normally home the joint.

Note: The excavating equipment must not be used to push pipe sections together. The force applied by such equipment can damage the pipe joints.
For a designer or municipality, comfort in the knowledge of pipe specifications for all gravity sewer products may not be practical or deemed necessary. However, without this knowledge, pipe materials that arrive on a job-site may in fact be unacceptable, and thus awareness of the specifications becomes essential.

For the most part gravity sewer pipe can be identified as Concrete, Polyvinyl Chloride (PVC) or High Density Polyethylene (HDPE). Each of these materials has their own specifications. In Ontario, the Ontario Provincial Standard Specification (OPSS) document identifies the appropriate standards for materials and quality assurance. There is also the Canadian Standards Association (CSA) which certify materials, products and performance specifications for many products including pipe. Furthermore, as you review the standards you may find references to American Society for Testing and Materials (ASTM) specifications from which CSA standards for pipe were derived. You may also, depending on the pipe material you are researching, find references to the American Association of State Highway Transportation Officials (ASSHTO) and or American Society of Civil Engineers (ASCE). It therefore becomes easy to understand how specifiers and designers lose track of the appropriate standards or specifications and, understandably, put their faith in government agencies assuming they have done their homework.

In an effort to simplify pipe specifications, the following breakdown will identify where to look for the appropriate standards for Concrete Pipe, PVC Pipe and HDPE Pipe.

**CONCRETE PIPE**

**OPSS 1820** – Material Specification for Concrete Pipe

**CAN/CSA A257.1** – Circular Concrete Culvert, Storm Drain, Sewer Pipe and Fittings (non-reinforced)
Gravity Sewer Pipe Specifications

CAN/CSA A257.2 – Reinforced Circular Concrete Culvert, Storm Drain, Sewer Pipe and Fittings

CAN/CSA A257.3 – Joints for Circular Concrete Sewer and Culvert Pipe, Manhole Sections and Fittings

POLYVINYL CHLORIDE PIPE

OPSS 1841 – Material Specification for Polyvinyl Chloride (PVC) Pipe Products

CAN/CSA 182.2 – PVC Sewer Pipe and Fittings

CAN/CSA 182.4 – Profile PVC Sewer Pipe and Fittings

HIGH DENSITY POLYETHYLENE PIPE

OPSS 1840 – Material Specification for Non-Pressure Polyethylene Plastic Pipe Products

CAN/CSA 182.6-02 – Profile Polyethylene Sewer Pipe and Fittings for Leak Proof Sewer Application.

CAN/CSA 182.8-02 – Profile Polyethylene Storm Sewer Drainage Pipe and Fittings.

Although these specifications seem simple enough, be aware that for flexible pipe, these specifications in many cases reference other standards as well. This in itself may again confuse and frustrate even the most dedicated researcher. It is therefore imperative to ensure that whatever pipe material you choose, you insist on third-party test results supporting the specifications.
For the concrete pipe industry that means products supplied from a producer certified under the Plant Prequalification Program. This is an extensive third party certification program based on CSA standards. The program is monitored by the Ministry of Transportation, Ontario Provisional Standards, Municipal Engineers Association and the Ontario Concrete Pipe Association and is the only program of its kind for gravity sewer pipe products in the Province of Ontario.

For all other pipe materials (PVC and HDPE) certification by the Canadian Standards Association is the only third party review available to a designer or municipality to ensure that the pipe that arrives on the job-site has met the standards outlined in CSA.

When designing sewer infrastructure, ensure quality pipe materials make it to your job-site. The triangular emblem is the symbol for concrete pipe certification and the CSA logos ensure flexible pipe certification. Don’t leave your pipe material quality to chance, insist on certified gravity sewer pipe on your next project.

Concrete Pipe Certification Stamp

Flexible Pipe Certification Stamp
Canadian Highway Bridge Design Code Bedding Standard for Circular Concrete Pipe

In May 2001 the Canadian Standards Association published the revised edition of the Canadian Highway Bridge Design Code S06-00. In Section 7 Buried Structures, the identification and acceptance of the Standard Installations for Direct Design bedding specification is introduced. With the adoption of this standard, which has a long history and has been widely accepted by the American Society of Engineers and promoted through ASCE Specification 15-93, the circular concrete pipe design methodology took a significant and long-awaited step forward. Furthermore, in May of 2002 the Ministry of Transportation adopted the revised Canadian Highway Bridge Design Code paving the way for the utilization of Standard Installation Design Theory for concrete pipe installations in Ontario.

Direct design procedures for concrete pipe have been used for over 30 years and utilize the soil pressure distribution (refer to Figure 1). This pressure distribution was developed and based upon results of the finite element analysis program SPIDA (Soil-Pipe Interaction Design and Analysis) and verified through typical installations. This pressure distribution is more representative of actual buried pipe conditions due to the inclusion of pipe support voids in the haunch area.

To describe these new standards, the words versatile and flexible come to mind. For a designer the range of installation types (Type 1 to Type 4) offer a concrete pipe designer the ability to tailor any individual project to suit site conditions including; available
bedding materials, native soil conditions, inspection provisions and budgetary constraints.

In a Type 1 installation for example, the native soil that constitutes the trench wall adjacent to the pipe and below the springline must be of good quality; able to support the compacted bedding material between the pipe and the trench wall. Through the use of this controlled soil envelope, a wide load distribution is achieved. This situation therefore translates to a lesser dependence on inherent pipe strength that inevitably lowers the pipe material costs.

On the other hand, for installations where the native soil is acceptable but perhaps not of the highest grade (silts and low plasticity clays), a Type 4 installation may be a more appropriate consideration for the designer. This installation type requires little or no inspection, minimal compaction, and allows for the use of native soils as backfill around the pipe. This installation will have lower pipe embedment and installation costs but will place a greater dependence on the inherent pipe strength. A Type 4 design would be most suited to pipe installations where support for a road structure is not necessary or immediate, as some settlements within the pipe trench may occur.

The design associated with the Standard Installations is grounded in conservatism. The loads and pressures experienced by the pipe in the installed condition have been analyzed in depth and modeled through the SPIDA finite element program. Those analyses are based on the following key assumptions:

1. The worst case (embankment) loadings are used with the traditional direct design procedure still employed.

2. Voids are assumed to exist in the haunch area of the pipe.
3. In recognition of the variability of the loading characteristics, the new installations are based on the greatest predicted loads for design.

4. Through quantification of material and compaction requirements, a degree of uncertainty has been eliminated, not so with the use of any other specifications – Ontario Provincial Standard Specifications included.

One of the greatest benefits of the new installation types is that they are quantifiable, that is, they prescribe definite and measurable levels of acceptance for native soils, bedding materials and compaction efforts. As indicated in Figure 2, each of the new installations has specific material requirements, and accompanying compaction levels making each installation type uniquely different.

To relate these new installations to current practices of today is easily done. For many municipalities in the Province of Ontario the Provincial Standards (OPSD) or some modified form represent the ‘standard of care’ for bedding concrete pipe. These standards although helpful do not identify bedding material types, native soil considerations or compaction levels. The municipality or the consultant representing the owner must specify all these parameters. For example, it is common to see a concrete pipe bedding standard specifying granular ‘A’ type material to springline compacted to 95% SPD. A close look at the Type 1 or Type 2 installations would suggest that what we have been doing all along can now be quantified and be specific in terms of pipe strength design requirements.

Standard Installations and the theories are not new. What is new is that we can now relate what has been common for concrete pipe bedding practices specifically to pipe strength requirements. The guesswork for concrete pipe design is now a thing of the past. When specifying concrete pipe, specify Standard Installations and be confident you have achieved the most accurate and cost-effective design.
**Figure 2a: Embankment**

![Embankment Diagram]

- Overfill - SW, ML, or CL
- \( H \)
- \( D_0 \)
- \( D_0 / 6 \) (Min.)
- Haunch
- Lower Side
- Bedding
- Outer Bedding material and compaction each side, same requirements as haunch
- Middle Bedding loosely placed uncompacted bedding except for Type 4

**Figure 2b: Trench**

![Trench Diagram]

- Overfill - SW, ML, or CL
- \( D_0 / 6 \) (Min.)
- \( H \)
- \( D_0 \) (Min.)
- Excavation line as required
- Haunch
- Lower Side
- Bedding
- Outer Bedding material and compaction each side, same requirements as haunch
- Middle Bedding loosely placed uncompacted bedding except for Type 4
Historically, the construction of a drop structure was an elaborate system of pipe, maintenance hole connections and concrete. The system, for pipe elevation differences greater than 600mm, utilized a pipe tee connection and a vertical pipe extending between the tee and the 90 degree elbow connected to the maintenance hole at an elevation nearer to the outlet elevation. This was known as a field connection. That is to say, the contractor would make his inlet pipe connection to the structure with a tee or wye configuration that would allow for low to medium flows to travel down the drop pipe and enter the maintenance hole at or near the elevation of the outlet pipe. This system would allow all but very high flows to enter the maintenance hole in a controlled fashion at or near the outlet pipe elevation. Once the contractor had made his connection, the system of drop pipes would have to either be encased in concrete and/or anchored to the maintenance hole wall to ensure the integrity of the drop pipe system was maintained. This process is very time consuming and awkward for the contractor and depending on the site conditions and native soil stability, the work would often have to done outside of normal protection offered by trench shields putting the workers at tremendous risk.

Today

Within the last decade maintenance hole manufacturers offered an alternative known as the precast external drop structure. This product was produced at the manufacturing facility as an add-on to the external wall of the maintenance hole riser sections. This would afford the contractor
the opportunity to be installing his drop structure at the same time as he was installing the maintenance hole. Once the drop structure was complete, a tee or wye fitting would be connected to the maintenance hole at the inlet elevation. A flexible pipe would be jointed to the fitting and installed into the top of the precast external drop structure and jointed at the bottom into a 90 degree elbow which closely matched the outlet pipe elevation.

Due to concerns related to production and handling of the external drop system, alternatives were considered. One such alternative was the internal drop structure, a system that some municipalities in Ontario already accepted for a field modification of existing systems already in service. With this knowledge and the support of the contracting community, a proposal was forwarded to the Ontario Provincial Standards Drainage Committee. The proposal recommended the acceptance of the internal drop structure for new construction and the creation of a new internal drop standard to be incorporated into the Provincial specifications to ensure standardized manufacturing practices.

Benefits

After careful consideration and recognition of the benefits the internal drop system provides, an internal drop specification was drafted in the spring of 2002 by the Ontario Provincial Standards Drainage Committee and will be incorporated into the Provincial standards in November of 2002. The system allows for the drop structure to be constructed and strapped to the inside wall of the maintenance hole.
The benefits range from the manufacturers of the drop structure to the contractors who install it, to the municipalities who maintain them. From a manufacturing standpoint, to no longer have the production difficulty the two-step drop structure construction presented, would improve production rates and lower costs. The awkward shape and lack of balance point for the product often created difficulty with handling and raised issues with respect to safe handling practices. For the contractor, to have the approval to construct drop structures from the safety of the installed maintenance hole structure would virtually eliminate safety concerns. Not only that, but the production delays for the contractor to build the external drop structures would disappear thus reducing the overall project costs.

For the owner, each of these previously mentioned factors contribute to the overall success and quality of the completed project. Simple access through the opening in the maintenance hole is all that would be necessary for regular monitoring, cleaning or maintenance of the internal drop system.

The following illustrations provide the details of the standard. This standard provides a safe and maintenance friendly solution to the age-old problem of the manhole drop connection.
Internal Drop Structure

- Sewer Tee
- Removable Cap Optional
- 300 mm Max. from sewer invert to first strap
- 600 mm Max. Typ
- 45 33/64 wye cleanout
- PVC Drop Pipe
- Stainless Steel Strap. Typ
- Maintenance Hole Wall
- Note 1
- 90° Elbow
- Benching to invert of channel

OCPA Concrete Pipe Information Booklet
**Maintenance Hole in Section**

- Maintenance hole as specified
- Granular Bedding
- Side View
- Front View
- Flow
- 304 Stainless steel wedge anchor 16x75 mm with nut and washer. Typ
- 6x40 mm Stainless Steel Strap
- Maintenance Hole Wall

**Fastener Detail**

**Notes:**

1. At the elbow a stainless steel strap required at bottom of bell.
2. Internal drop structure to be used in maintenance holes 1500 mm diameter and larger, with a minimum internal clearance of 1200 mm
3. Drop pipe to be one size smaller than the incoming sewer, with a minimum 150mm dia. and maximum of 450mm dia.
4. All dimensions are in millimetres unless otherwise shown.
Concrete Pipe

Reinforced concrete pipe is the interaction of two historically strong and durable products, steel and concrete. The compressive strength of concrete and the tensile strength of steel combine together to resist live load and earth load forces imparted on a reinforced concrete pipe when it is installed. *Figures 1a & 1b* illustrate the compressive and tensile forces that act on a circular pipe in an installed condition. The reader will note the steel reinforced concrete structure is required to resist the forces in critical zones. For example, at the invert and obvert of the pipe, tensile forces resist the effects of loading, while at the outside bottom and inside springline of the pipe, compressive forces resist the effects of loading. The unique marriage of concrete and steel effectively create a structure capable of being designed to withstand virtually any loading condition.

*Figure 1a*
Design methodologies of concrete pipe used today have been in existence since the 1920’s. Work at Iowa State University by M.G. Spangler determined the impact of design loads (earth and live) on the structure. At that time, empirical work done by several researchers proposed pressure distribution fabric around the concrete pipe. From this work, design methods were introduced, which had limitations due the availability of testing apparatus. In addition, the design methodologies were not easy to use, as the age of computer computation had not arrived. A simple and reliable design method did not exist until Professor W. J. Schlick of Iowa State University developed an indirect design method to simplify the design process. Using a simple leaf gauge of 1/100th of an inch
(0.3mm), he proposed that a service (design) crack be used as a measurable and reproducible method for determining pipe strength. There is little structural significance to the 0.01” (0.3mm) crack; it is simply a test criterion accepted by the CSA and ASTM standards for reinforced concrete pipe and is visibly the first indication the pipe load is in transfer from the concrete to the steel.

**Autogenous Healing**

This phenomenon occurs between opposing surfaces of narrow cracks. The mechanism of the healing is the hard white ‘crust like’ formation on the concrete pipe known as calcium carbonate. The crack healing requires the presence of moisture, which when reacting with cement powder, restarts the hydration (curing) process. Autogenous healing has also been witnessed where debris enters the crack and over time fills the crack.

![Autogeneous Healing](image)

*Autogeneous Healing*

The strength of the healed crack has been studied under laboratory conditions. It has been suggested that full healing creates a monolithic structure, so the pipe is “as good as new”, and should be considered structurally sound and capable of performing in the manner originally intended.
Regardless of the mechanism, autogenous healing will occur in concrete pipe that has cracked. The question is how wide a crack can be healed? The answer is not simple. Literature reports cracks as wide as 1.5mm (Loving) healed in a period of 5 years. Edvardsen found that cracks of 0.2mm healed completely within 7 weeks. It appears that the narrower the crack, the more rapid the healing can occur. The Ohio DOT has developed Supplemental Specification 802, Post Construction Inspection of Storm Sewers and Drainage Structures identifies the rehabilitation methods for installed pipe which has evidence of cracking. The specification requires the contractor to “Do Nothing” for cracks up to 1.8mm in width, with the expectation that autogenous healing will create a watertight pipe over a period of a few years.

**Three Edge Bearing Method**

The most common method of design for reinforced concrete pipe is the Three Edge Bearing Indirect Design Method. Using this method, an estimate of loads expected to act on the reinforced concrete pipe, usually earth and live loads, are calculated. The pipe strength required to resist these loads is determined using the Three Edge Bearing equation,

\[
\text{T.E.B.} = \frac{\text{LOAD}}{\text{BEDDING FACTOR}} \times \text{FACTOR OF SAFTEY}
\]

where, T.E.B is the pipe supporting strength required, Load is the load acting on the pipe (dead and live), Bedding Factor is defined as the ratio between the supporting strength of buried pipe to the strength of the pipe determined in the Three Edge Bearing test, Factor of
Safety, which is defined in CSA as 1.5 for pipe strength to 100D, and 1.25 for 140D pipe.

Reinforced concrete pipe design theory, the Three Edge Bearing Equation, and estimations for the variables used in solving for the T.E.B. were determined in laboratory conditions over many years at Iowa State University by Marston, Spangler and Schlick and are still in use today. Based on current research and technology, this empirical process is considered to be very conservative, however, is still in use in many jurisdictions today.

**Classification of Cracks**

As presented above, reinforced concrete pipe is designed to permit cracking. The design crack, 0.3mm in width over a length of not less than 300mm is the measure used. Notwithstanding this process, cracking of reinforced concrete pipe can present a concern to infrastructure owners. Why is this?

Cracks in reinforced concrete pipe are generally discovered through video surveys or visual assessments done as a requirement of the contract. Timing of such inspection
The Significance of Cracking in Concrete Pipe

is typically prior to the assumption of an installed system by the owner. It is very important that owners undertake these types of inspections to elevate the accountability of all those involved in the satisfaction of the contract. There can be no denying that proper installation and inspection will have a tremendous impact on the satisfaction of the expected service life of new system. Moreover, it cannot be understated the importance for owners to understand when a crack in a concrete pipe is a problem and when it is not. Issues, which may arise in the evaluation of cracks, include:

- Width
- Length
- Orientation
- Location
- Severity

We will address each of these issues in the following sections.
Width

As discussed earlier, the design (service) crack used in reinforced concrete pipe is the 0.3mm crack over a length of at least 300mm. This crack will generally appear at the invert, and occasionally the obvert, of the reinforced concrete pipe as the highest tensile stress or moment incurred by the pipe loads occurs at these locations. The design crack is V-shaped in nature and is widest at the surface penetrating usually no further than the first reinforcing cage in the pipe. It is very difficult to determine the magnitude or significance of a crack and the unavoidable magnification of the crack in the pipe that is inherent with video inspection technology today. As a result it is critical that analysis of sewer video be done by trained personnel. Training programs are offered on a regular basis by the North American Association of Pipeline Inspectors and more information can be found at www.catt.ca.

Hairline cracks are extremely fine cracks, narrower than design cracks yet can be visible during video inspections. Hairline cracks are often mistaken as design cracks, yet the hairline crack is in fact the prelude to the appearance of the design crack.

Shrinkage cracks can occur during the curing process of reinforced concrete pipe. As concrete cures, moisture disappears from the concrete matrix. Depending on the rate of curing, shrinkage cracks can occur, i.e. the more rapid the curing, the greater likelihood of shrinkage cracks. Shrinkage cracks are generally hairline type cracks appearing circumferentially on the outer surface of the pipe barrel and quite often do not penetrate through the pipe wall.
The width of a crack is a critical consideration when determining the impact on the durability and or structural integrity of an installed reinforced concrete pipe. However, it is not as simple as saying the design crack is a limiting factor. The design crack can appear at as little as 50% of the ultimate (failure) load and therefore, experience and judgement must be used to determine the impact of cracking.

**Length**

The length of a crack is rarely an indication of poor quality of material or weak installation practices. In most if not all conditions where a crack is evident in a pipe, the width and location of the crack is more critical to understand and evaluate.

**Orientation**

Longitudinal cracks run lengthwise along the barrel of the pipe and can be single cracks or in some instances of severe damage can become multi-directional in appearance. Circumferential cracks run around the barrel of the pipe and may or may not propagate the full inner circumference of the pipe barrel.
The Significance of Cracking in Concrete Pipe

Location of Cracks

Understanding how pipe performs in the installed condition is critical when evaluating the location of a crack.

Longitudinal cracks visible at the invert or obvert of the pipe are indications the pipe has excepted the load to which it was designed. Longitudinal cracking at any other location along the inside barrel of the pipe can generally be attributed to poor construction practices which may include but are not limited to improper handling or weak installation and backfilling techniques. For example, insufficient cover over the crown of the pipe prior to the utilization of heavy compaction equipment can result in damage to the pipe.

Multi-directional longitudinal cracking, an indication the pipe has been subjected to some sort of impact load, can most certainly be attributed to the lack of care taken when installing or handling the pipe. This evidence should be considered carefully when assessing the integrity and future performance of the installed pipe.
Multi-directional cracking at the pipe joint

Circumferential cracks are in no way attributed to the installation conditions to which the pipe was designed to handle. In fact, cracks propagating circumferentially on the inner surface of the pipe can be attributed in most cases to differential settlements in the pipe bedding. This condition can result from uneven placement and over-compaction of the bedding material creating point loads along the barrel of the pipe. Furthermore, failure to dig ‘bell holes’ to accept a protruding pipe bell, a feature of many small to mid range diametre pipe, can lead to the development of circumferential cracking at or just beyond the pipe joint.
Severity

The key to determining if structural concerns exist is the degree or severity of the damage to the pipe. Hairline and design cracks are not a result of damage to the pipe and therefore needn’t be considered for repair. Otherwise, longitudinal and circumferential cracking is an indication of damage to which the severity must be assessed. As discussed earlier, autogenous healing is a powerful process in the repair of minor damage sustained by a concrete pipe.

In most if not all cases where autogenous healing has sealed the defect, the integrity of the pipe should be considered sound. Pipe cracking or damage beyond the scope of autogenous healing must be evaluated further. Open cracks (greater than 1.8mm in width) or cracks where concrete has been displaced must be considered for a structural type of repair. Also of concern would be a crack or defect that is allowing water to infiltrate into the pipe system. The infiltration can be relatively clear or it can be ‘rust-like’ in terms of its colour. The latter is an indication the steel in the pipe is being impacted by water. Regardless, both situations require remediation, the extent of which must be assessed on the amount of the infiltration and structural damage.
The Significance of Cracking in Concrete Pipe

Basis of Acceptance

The final acceptance of reinforced concrete pipe should be subject to visual or video inspection. This is the only way to ensure the ultimate owner of the system has assurance that the pipeline will be durable and achieve its intended service life. During the evaluation process of video inspection, the owner must be aware of what the video is actually showing. Distortion can occur due to the presence of water or to magnification of the video. To properly evaluate the extent of the crack, actual measurements must take place. If this is not possible due to the size of the pipe, the owner should rely on professional judgement. The practitioner should look for the visible signs of structural damage. If the crack appears wide, and the pipe is displaced on either side of the crack, or the location of the crack is not conducive with the design crack, concern is justified. If no displacement is apparent, the process of autogenous healing will, in all likelihood, seal the crack and ensure the longevity of the reinforced concrete pipe can be achieved.
INSPECTION, UNLOADING, STORAGE & INSTALLATION OF PRECAST CONCRETE ADJUSTMENT UNITS

Manufacturing of the precast concrete adjustment units done in accordance to CSA A257.4 and OPSD 704.010.

Inspection:

• Precast concrete adjustment units should be inspected on the truck when they arrive at the jobsite before they are unloaded to ensure that no damage has occurred during transit. Damaged or missing items must be reported at this time.

• Precast concrete adjustment units of same size should be bundled together using strapping for transportation, handling, and storage. Banding of the bundles should not be removed until immediately prior to installation.

Unloading:

The work procedures for material handling, worker safety, and the modification of backhoes, loaders and forklifts for the use as cranes or similar hoisting devices must comply with the relevant sections of the Ontario Regulation 213/91 made under the Occupational Health and Safety Act.

• Precast concrete adjustment unit bundles should be unloaded on a level site using the appropriate lifting equipment. Weights and measures can be obtained from the manufacturer.

• Capacities of lift assemblies, devices, forklifts and cranes should be checked before unloading.

• When using forklift equipment, care must be taken
to ensure the inside of the adjustment units are not damaged or broken. Wooden planks should be used to ensure the forks do not come in direct contact with the adjustment unit bundle.

- Precast concrete adjustment unit bundles should be unloaded to a secure area where further movement will not be necessary until immediately prior to installation.

- Bundles should not be opened until adjustment units are required.

- When single adjustment units are unloaded, ensure that two laborers are lifting the adjuster on a dry flat surface and that the maximum lifting weight is not exceeded.

*These procedures for unloading and handling may vary therefore always verify recommended techniques with the concrete adjustment manufacturer.*

**Storage:**

- Precast concrete adjustment units should be stored in bundles if possible in an area where on-site activities do not require several movements of the bundles.

- Precast concrete adjustment unit bundles should be placed on planks to allow for ease of handling while keeping the units clean and free of debris.

- Single adjustment units and or open bundles should be stacked vertically on wood planks or pallets and stored in a secure location away from construction traffic.

- All joint sealant material should be stored in a cool dry environment and should be kept dry and clean and protected from oil, grease and excessive heat.
Installation:

The contractor is responsible to follow the jobsite jurisdiction specification. The following practice is presented based on OPSS 408 and OPSD 704.010.

1. Place a level bed of mortar with sufficient thickness to ensure the adjustment unit will rest free from contact with the concrete maintenance hole or catchbasin.

2. Seat the adjustment unit in the mortar ensuring the unit is level and concentric with the opening in the structure.

3. To place additional adjustment units, apply either a bed of mortar or a continuous strip of butyl tape around the installed adjustment unit.

4. Seat the adjustment unit and ensure it is level and the opening remains consistent with installed unit. Ensure units that allow for step installations have the openings for the steps properly aligned between adjustment units and the maintenance hole steps.

5. Follow steps three and four for further adjustment unit placement.

6. To install the frame and cover, apply a bed of mortar or a continuous ring of butyl tape to the installed adjustment unit and set frame in place.

Note:

Allow at least 160mm for the frame and cover height. Final grade adjustments of the frame and cover can be made through the use of spacers of various heights which can be placed on the final concrete adjustment unit to ensure frame and cover match finished road elevation and slope.
Curved Alignment

Changes in direction of sewer lines are usually accomplished at manhole structures. Grade and alignment changes in concrete pipe sewers, however, can be incorporated into the line through the use of deflected straight pipe, radius pipe or specials.

Deflected Straight Pipe

With concrete pipe installed in straight alignment and the joints in a home (or normal) position, the joint space, or distance between the ends of adjacent pipe sections, is essentially uniform around the periphery of the pipe. Starting from this home position any joint may be opened up to the maximum permissible on one side while the other side remains in the home position. The difference between the home and opened joint space is generally designated as the pull. The maximum permissible pull must be limited to that opening which will provide satisfactory joint performance. This varies for different joint configurations and is best obtained from the pipe manufacturer.

The radius of curvature which may be obtained by this method is a function of the deflection angle per joint (joint opening), diameter of the pipe and the length of the pipe sections.

The radius of curvature is computed by the equation:

\[
R = \frac{L}{2 \left( \tan \left( \frac{1}{2} \frac{\Delta}{N} \right) \right)}
\]  

(1)

where:

\( R \) = radius of curvature, metres
Curved Alignment

L = length of pipe sections measured along the centerline, metres
\( \Delta = \) total deflection angle of curve, degrees
N = number of pipe with pulled joints
\( \frac{\Delta}{N} = \) total deflection of each pipe, degrees

*Figure 1: Deflected Straight Pipe*

From *Figure 1*, the deflection angle is further defined as:

\[
\frac{1}{2} \frac{\Delta}{N} = \sin^{-1} \left( \frac{\text{PULL}}{2(D + 2t)} \right) \quad \text{or} \quad \sin^{-1} \left( \frac{\text{PULL}}{2B_c} \right)
\]

*where:*

- PULL = joint opening, millimetres
- D = inside pipe diameter, millimetres
- t = wall thickness, millimetres
- \( B_c \) = outside pipe diameter, millimetres
The joint opening and pipe length required to provide a curved pipeline alignment may be calculated using the unit values found in Table 1 on page 123. The table tabulates the radius of a pipeline constructed of standard 2.44 metre laying length pipe with a 13 mm joint opening (PULL). Other pipeline radii may be calculated by changing, first, the joint opening, and if necessary, the pipe laying length. A 2.44 metre laying length is standard for most concrete pipe manufacturers. Other lengths may require special manufacturing procedures. Changes in the design radius are directly proportional to the pipe laying length and inversely proportional to the joint opening. The specific pull per pipe joint is found by the equation:

\[ PULL_X = \left( \frac{L_X}{L_8} \right) \left( \frac{R_U}{R_X} \right) \left( PULL_8 \right) \]  \hspace{1cm} (3)

\[ R_X = \left( \frac{L_X}{L_8} \right) \left( \frac{PULL_8}{PULL_X} \right) R_U \]  \hspace{1cm} (4)

**where:**

- PULL = the joint opening
- Ru = the Unit Radius (Taken from Table 1)
- Lx = Length of deflected pipe

Specific radii may be calculated by the following procedure:
- Select the unit radius of curvature for the specified diameter pipe from the chart.
- Increase or decrease the joint opening (PULL) in Equation 1 to obtain the design radius. If the required joint opening exceeds the pipe manufacturers recommendations, select a pipe with a shorter laying length. Common non-standard are 1.22 and 1.83 metre pipe lengths. Check with the pipe manufacturer for availability of nonstandard lengths.
- Recalculate the pull for the shorter laying length pipe.
As illustrated in Figure 2, when concrete pipe is installed on curved alignment using deflected straight pipe, the point of curve (P.C.) is at the midpoint of the last unde- flected pipe section and the point of tangent (P.T.) is at the midpoint of the last pulled pipe.

**Figure 2: Curved Alignment Using Deflected Straight Pipe**

![Curved Alignment Diagram](image)

**Radius Pipe**

Radius pipe, also referred to as bevelled or mitered pipe, incorporates the deflection angle into the pipe joint. The pipe is manufactured by shortening one side of the pipe. The amount of shortening or drop for any given pipe is dependent on manufacturing feasibility. Because of the possibility of greater deflection angles per joint, sharper curvature with correspondingly shorter radii can be obtained with radius pipe than with deflected straight pipe. As in the case of deflected straight pipe, the radius of curvature which may be obtained by radius pipe is a func-
Curved Alignment

tion of the deflection angle per joint, diameter of the pipe, length of pipe sections and wall thickness. The radius of curvature is computed by the equation:

\[
R = \frac{L}{\tan \left( \frac{\Delta}{N} \right)} - \left( \frac{D}{2} + t \right)
\]  

(5)

where:

\[ \Delta = \text{total deflection angle of curve, degrees} \]
\[ N = \text{number of radius pipe} \]
\[ L = \text{standard pipe length being used, metres} \]
\[ \frac{\Delta}{N} = \text{total deflection angle of each pipe} \]

Figure 3: Radius Pipe
From *Figure 3*, the radius of curvature can be expressed in terms of the drop and is given by the equation:

\[
R = \frac{L(D + 2t)}{\text{DROP}} - \left( \frac{D}{2} + t \right) \tag{6}
\]

\[
R = B_c \left( \frac{L}{\text{DROP}} - \frac{1}{2} \right) \tag{7}
\]

\[
\text{DROP} = \frac{LB_c}{R + B_{c/2}} \tag{8}
\]

where:

- \(B_c\) = outside diameter of the pipe, metres

*Figure 5* presents \(R/B_c\) ratios for drops from 25 mm through 375 mm and commonly manufactured pipe lengths. Since the maximum permissible drop for any given pipe is dependent on manufacturing feasibility, it is essential to coordinate the design of radius pipe with the pipe manufacturer. Many manufacturers have standardized joint configurations and deflections for specific radii and economics may be realized by utilizing standard radius pipe.

As illustrated in *Figure 4*, when concrete pipe is installed on curved alignment using radius pipe, the pipe sections are oriented such that the plane of the dropped joint is tangent to the theoretical circular curve. Projection of the joints do not converge at a common point, but are tangents to a common circle of diameter equal to the length of pipe sections. The point of curve (P.C.) is at the midpoint of the last straight pipe and the point of tangent (P.T.) is one half of the standard pipe length back from the straight end of the last radius pipe. The required number of pieces of radius pipe is equal to the length of the circular curve in metres divided by
Curved Alignment

Minimum radius of curvature obtained from equations (1) and (5) are approximate, but are within a range of accuracy that will enable the pipe to be readily installed to fit the required alignment. A reasonable amount of field adjustment is possible for radius pipe by pulling the joints in the same manner as with deflected straight pipe.

Special precast sections can be used for extremely short radius curves which cannot be negotiated with either deflected straight pipe or with conventional radius pipe. Sharper curves, can be handled by using special short lengths of
Curved Alignment

radius pipe rather than standard lengths. These may be computed in accordance with the methods discussed for radius pipe. Certain types of manufacturing processes permit the use of a dropped joint on both ends of the pipe, which effectively doubles the deflection. Special bends, or elbows can be manufactured to meet any required deflection angle and some manufacturers produce standard bends which provide given angular deflection per section. One or more of these methods may be employed to meet the most severe alignment requirements. Since manufacturing processes and local standards vary, local concrete pipe manufacturers should be consulted to determine the availability and geometric configuration of special sections.

The following example illustrates proper use of the Tables and Figures.

**Given:**

A 1050 mm diametre concrete pipe storm sewer is to be installed on curved alignment corresponding to the roadway curvature. The pipe will be manufactured in 2.44 metre lengths with a 113 mm wall thickness. The curve data for the roadway curb is:

point of intersection station P.I. = 50+00
point of curve station P.C. = 49+29.6

<table>
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<tr>
<th>Size (mm)</th>
<th>Radius (m)</th>
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<tr>
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<tr>
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</tr>
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</table>

Table 1: Unit Radius of Curvature For 2.44 Metre Straight Deflected Pipe With 13 mm Pull
Curved Alignment

point of tangent station P.T. = 50+63.1
total deflection angle $\Delta = 45^\circ$
radius of curvature $R = 51.8$ metres

**Find:**
The required pull per joint for deflected straight pipe or the required drop for radius pipe.

**Solution:**
From Table 1, for a 1050 mm diametre pipe, the radius of curvature for a 13 mm pull is 124.4 metres. The required pull for 51.8 metres is:

$$PULL_x = \left( \frac{2.44}{2.44} \right) \left( \frac{124.4}{51.8} \right) \left( 13 \right) = 31.22 \text{ mm}$$

To evaluate the required drop for radius pipe to negotiate the roadway curvature, it is first necessary to calculate the $R/Bc$ ratio:

$$\frac{R}{Bc} = \frac{51.8}{1.276} = 40.8$$

Enter *Figure 5* on the vertical scale at $R/Bc$ 40.8. Proceed horizontally until the line representing $L = 2.44$ metres is intersected. At this point the horizontal scale shows the required drop to be 59 mm. Or:

$$DROP = \frac{(2.44)(1.27)}{51.8 + 1.27/2} = 0.059 \text{ m} = 59 \text{ mm}$$
Answer:
Radius pipe with a 60 mm drop would be required. **It is important to consult local concrete pipe manufacturers to determine the feasibility of manufacturing a 1050 mm diameter pipe with the required drop.**

Figure 5: Radius of Curvature for Radius Pipe