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Why Deflection Matters For Plastic Pipe

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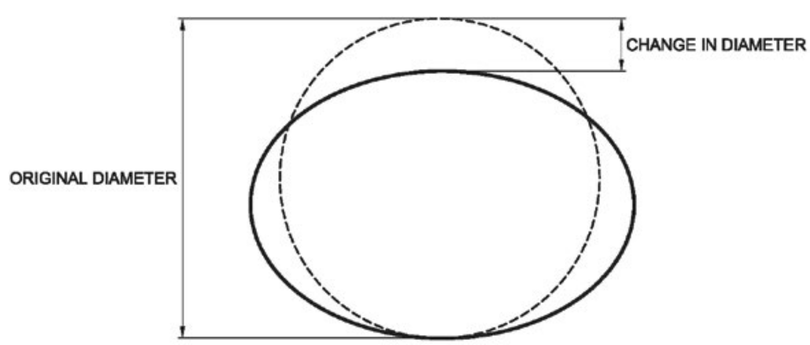
Pipe used in sewer and culvert applications are categorized as either "rigid" such as clay or concrete, or "flexible" such as plastic, glass reinforced polymer, or corrugated steel. The common definition for a flexible pipe is: a pipe that can deflect 2% or more without cracking. While new types of flexible pipe products are continually being introduced, one critical aspect of flexible pipe design has not changed; minimize ring deflection to ensure good, long-term performance of the pipe.

Concrete pipe is available in different strengths where the pipe walls are designed to resist a specified load. In contrast, flexible pipe is much more installation sensitive because the pipe itself has very little load-carrying capacity and as a result needs to transmit the loads to both its bedding support and the soil at the sides of the pipe. Flexible pipe is available in different stiffnesses which indicate the pipe's ability to resist deflection, however it's the pipe-soil interaction that is the major structural component of flexible pipe design. As the load on a flexible pipe increases, it becomes oval with the vertical diameter of the pipe decreasing and the horizontal diameter increasing. This decrease in vertical diameter is termed as the deflection, which is always expressed as a percentage.

Checking ring deflection in flexible pipe used for a sewer application is already mandatory in the Ontario Provincial Standards (OPS). OPSS 410, the construction specification for Pipe Sewer Installation in Open Cut, states that "ring deflection testing shall be performed on all pipe sewers constructed using plastic pipe". This clause highlights the fact that ring deflection is a critical component of flexible pipe performance and is an important measure for assessing the quality of the installation. While most of the deflection of a flexible pipe occurs in the first few months after backfilling, it could continue to increase for several years, especially for plastic pipe under sustained loading, or fluctuating groundwater levels. This is the reason for OPSS 410 also specifying that the initial deflection test must be performed "not sooner than



$$\text{\% DEFLECTION} = \frac{\text{CHANGE IN DIAMETER}}{\text{ORIGINAL DIAMETER}} \times 100$$

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30 Days after the completion of backfilling and installation of service connections".

The shape of a flexible pipe goes through several changes before it even reaches its final installation condition. The initial shape of a flexible pipe is rarely a perfect circle, especially for thermoplastic pipe that is left out in the hot sun, or is secured for transportation over long distances. In some cases, a pipe's own weight will cause the pipe to sag which requires temporary internal struts to keep the pipe as round as possible during installation. Also, the actual inside diameter of a flexible pipe may not be what the design engineer assumes. For example, a 600mm diameter nominal pipe size, has a "base inside diameter" listed in CSA B182.11, Standard Practice For The Installation Of Thermoplastic Drain, Storm, And Sewer Pipe And Fittings, as 579.11mm for SDR 35 PVC and 581.67mm for corrugated HDPE. This is already more than a 3% discrepancy below the nominal pipe size.

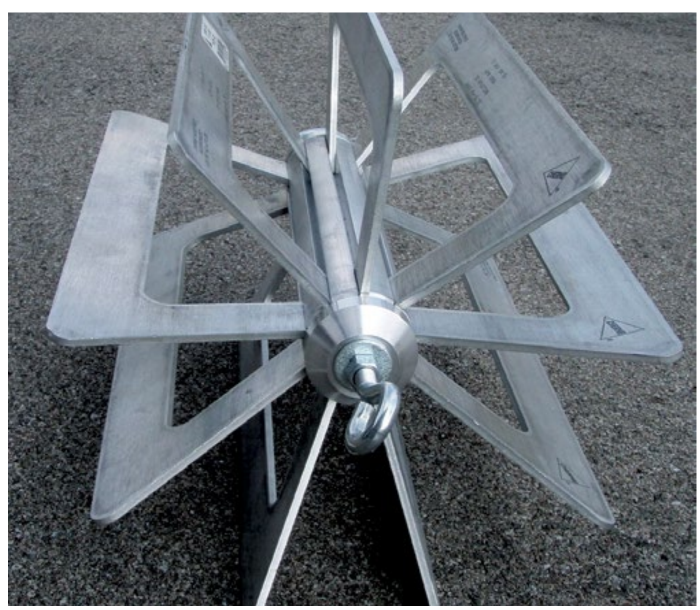
A proper flexible pipe design must specify the allowable deflection, and specify the soil embedment necessary to ensure the pipe will not deflect more than its allowable limit. This is done by specifying a trench width that is appropriate for the native soil condition, using the proper granular backfill materials and compaction effort, and using the highest quality flexible pipe products available. This latter point can be difficult because the long-term performance history of many flexible pipe products is limited.

Excessive deflection will not only affect the pipe's hydraulic performance such as decreased flow velocity, sediment build-up, corrugation growth, and other factors that contribute to hydrogen sulfide corrosion; but it may lead to harmful strain levels in the pipe wall that can trigger structural failure modes such as cracking, inverse curvature, and wall buckling. Excessive deflection can also compromise the pipe joint performance which can lead to exfiltration or infiltration, and the loss of backfill material causing sinkholes.

Engineers must be aware that the allowable deflection limit is different for the various flexible pipe materials. Applying a standard allowable deflection such as 5% will provide a factor of safety that ranges from more than 4 for some flexible pipe installations, to less than 1 (likely failure) for others depending on the stability and load-carrying capability of the soil around the pipe.

Most design engineers rely on design tables to determine if a pipe material is structurally adequate for their project such as the Height of Fill tables available in the Ontario Provincial Standards. The danger with this, especially for installation-sensitive pipe, is that many assumptions have been made by the creators of these design tables. Designers must keep in mind that these design tables do not replace good engineering and site condition assessments that might make their installation unique. In fact, one of the leading manufacturers of plastic pipe has this disclaimer right in the

Mandrel test starting at a Maintenance Hole



Typical mandrel with 9 arms

opening paragraph of every design table that they provide: "The information in this document is designed to provide answers to general cover height questions; the data provided is not intended to be used for project design. The design procedure described in the Structures section (Section 2) of the Drainage Handbook provides detailed information for analyzing most common installation conditions. This procedure should be utilized for project specific designs."

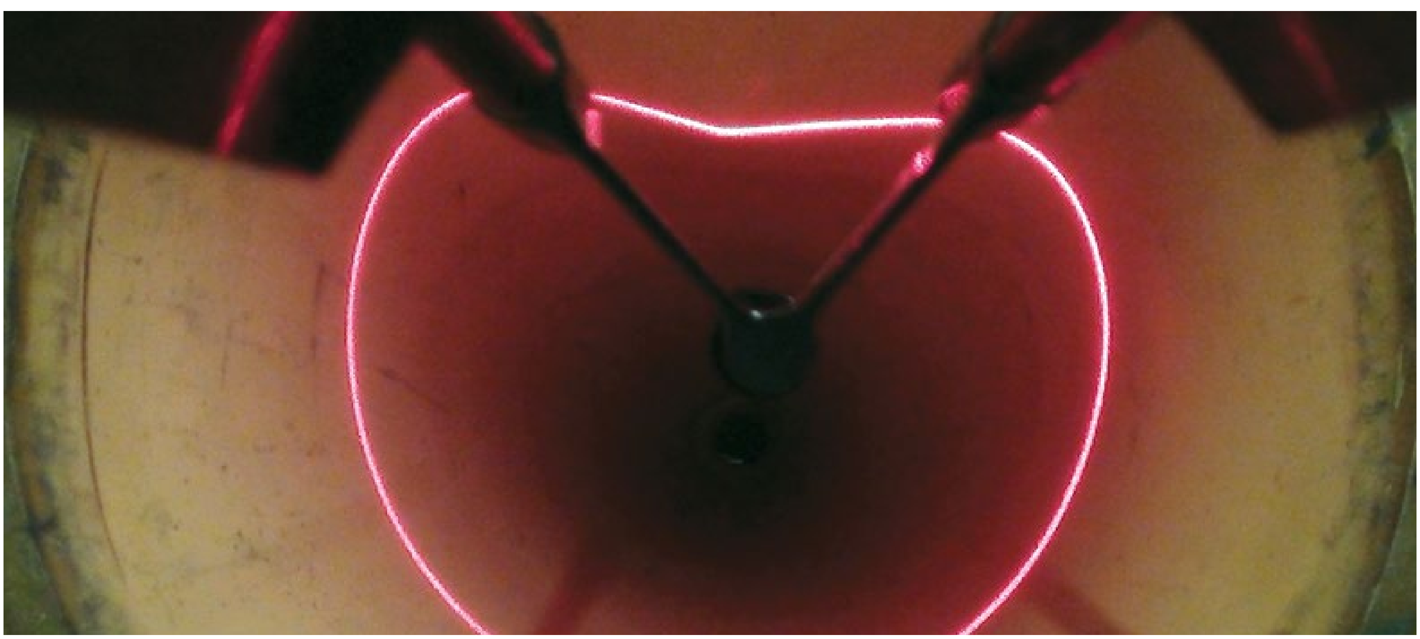
Municipalities must realize that CCTV inspections of pipelines are not adequate for checking deflection. While CCTV inspections are useful for visually checking a pipeline, it does not provide quantitative data such as ring deflection measurements. Additionally, pipe materials that have black interiors make it difficult to perform even routine CCTV visual inspections, which is why municipalities like the Region of Peel in Ontario requires only plastic pipe with light coloured interiors.

For the ring deflection test, OPSS 410 requires a suitably designed mandrel, cylindrical in shape, and constructed with an odd number (minimum of 9) of evenly spaced arms or prongs. The minimum diameter of the circle scribed around the outside of the mandrel arms is equal to the allowable deflected pipe diameter ± 1 mm. As the mandrel is pulled through a pipeline, any section that does not allow the mandrel to pass is considered to have failed the deflection test. The mandrel pull is the most common field test for checking ring deflection, however because it is only a go/no-go test new technology like laser profiling is gaining popularity as an accurate method of measuring deflection which is also becoming less cost-prohibitive.

A laser profiler is a tool that can be mounted to a CCTV camera, a laser ring is projected onto the internal surface of the pipe and the recorded video image is then processed by computer software to produce a continuous, 3D model of the pipeline. This information can be easily analyzed for deflection issues and becomes an invaluable tool for asset management departments to determine if a pipe is changing by comparing laser profile reports over time.

The University of Texas at Arlington recently completed a study of 176 plastic pipe culverts through 9 different US States. The report found an alarmingly high number of these culverts suffering from excessive deformation and signs of structural failure. Although site conditions, climate, and construction specifications can widely vary, the poor results from one border state, Michigan, should be a warning sign to Ontario on how significant this issue is.

To access the full report from University of Texas, follow the link:
www.uta.edu/ce/abolmaali/hdpe%20report.pdf



Inverse curvature outlined by laser profiler
(Image: Courtesy of Maverick Inspection Ltd.)