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## **Indirect vs. Direct Design**

**When do Designers Need to Think Beyond Classed Pipe?**

**Written by: Tannis Karklin, EIT**



Designers can opt between two design methods for Reinforced Concrete Pipe (RCP):

- Indirect Design
- Direct Design

This bulletin will discuss the appropriate applications for each of these methods to be used effectively. The most commonly used method is indirect design, in which the designer's goal is to determine the class of concrete pipe for the project. Each class represents a different load capacity with Class 1 being the lowest and Class 5 being the highest. The proof of design for indirect design is confirmed through three-edge bearing testing, which tests the pipe for strength. A service load (D-Load) is applied to the pipe, based on the dimensions and material properties of pipe manufactured according to ASTM C76. The pipe has passed the three edge bearing test when the D-Load value is reached and all visible cracks are smaller than 0.01 inches.



Figure 1: Three-Edge Bearing Machine

PipePac is a free software tool available online for indirect design of RCP. It allows designers to control inputs such as:

- Pipe Size
- Wall Thickness
- Soil Conditions
- Design/Manufacturing Standards
- Loading Conditions
- Depth of Cover
- Desired Installation Methods

The software outputs the required pipe class based on these parameters and is a great alternative to fill height tables. Use caution with fill height tables as they are designed to a specific set of parameters, which may not meet your local design requirements. PipePac is free, easy to use, and readily available online: <http://pipe.concretepipe.org/pipepac/>



Figure 2: PipePac software is free online and used for indirect design. PipeCar software can be purchased online and is used for direct design.

The indirect design method is the most commonly used design method for standard burial depths, but it only accounts for one mode of failure (flexure). What about shear and radial tension failures?

Direct design should be considered when the soil cover is so small that live loads are more significant or in deep burial applications. It is important to check other governing modes of failure for RCP with the following parameters:

- 1050mm diameter or larger
- Indirect design results of Class 4 or 5

Heavy vertical loads on large diameter pipe can cause the pipe to fail in diagonal or radial tension before it fails in flexure. Direct design uses Limit States Design to ensure the required steel area is appropriate to resist all other possible failure modes. The proof of design is not achieved through product testing but through the calculations of the factored loads in the design. PipeCar is the software of choice for direct design as it accounts for shear, radial tension, and flexural failures.



Figure 3 (left): Flexural Failure in Three-Edge Bearing Machine Test

Figure 4 (above): RCP Displaying Shear Failure

Below is a table summarizing the differences between the two design methods:

	<b>Indirect</b>	<b>Direct</b>
<b>Manufacturing Specification</b>	ASTM C76	ASTM C1417
<b>Design Standard</b>	ACPA Design Data 9	ASCE 15-98 or CHBDC
<b>Method</b>	Empirical	Limit States
<b>Result</b>	Pipe Class (1-5)	Design per Application
<b>Software</b>	Pipepac	Pipecar
<b>Proof of Design</b>	Three-Edge Bearing Test	In Design
<b>Failure Modes</b>	Flexure	Flexure, Diagonal Tension, Radial Tension

It is important to note that direct design can be more conservative in small diameter applications (pipe with an inner diameter less than 1050mm). Therefore, it is important to use indirect design to avoid additional expenses when classing small diameter pipe.

In closing, here are the steps to follow when determining which design method to use:

- 900mm diameter and smaller – Use indirect design
  - Utilize PipePac software for design
- 1050mm diameter and greater – Start with indirect design
  - Utilize PipePac software for design
- 1050mm diameter and greater – PipePac results showing a Class 4 or greater must be checked for shear as the governing mode of failure
  - Utilize PipeCar software to check shear
- 1050mm diameter and greater – If shear is governing then shear mitigation is required

If you would like any more information regarding this article, please feel free to contact us! We can arrange a meeting or schedule a presentation for your office.



Contact us for all your precast needs:

**Derek Light, P. Eng.**

Technical Marketing Manager, Canada Region

Cell: (403) 999-1246

Phone: (403) 720-9324

Derek.Light@lehighhanson.com

www.inlandpipe.com

**Tyson Dyck, EIT**

Technical Marketing Engineer in Training

Cell: (587) 990-8903

Phone: (780) 448-1351

Tyson.Dyck@lehighcement.com

www.inlandpipe.com

**Tannis Karklin, EIT**

Technical Marketing Engineer in Training

Cell: (204)-250-5270

Phone: (204)-336-5013

Tannis.Karklin@lehighhanson.com

www.inlandpipe.com



**British Columbia**

OCEAN PIPE

9265 Oak St.

Vancouver, BC V6P 4B8

Toll free tel: 1888 788 2211

Office tel: 604 269 6700

Fax: 604 261 6751

**Southern Alberta**

INLAND PIPE

7336 112<sup>th</sup> Ave. NW

Calgary, AB T3R 1R8

Toll free tel: 1 800 268 078

Office tel: 403 279 5531

Fax: 403 279 7648

**Northern Alberta**

INLAND PIPE

12250 170 Street

Edmonton, AB T5V 1L7

Tel: 780 448 1351

Fax: 780 448 1354

**Saskatchewan**

INLAND PIPE

300 10<sup>th</sup> Ave.

Regina, SK, S4N 6G7

Toll Free tel: 1877 974 7473

Office tel: 204 334 4300

Fax: 204 334 7957

**Manitoba**

INLAND PIPE

2494 Ferrier St.

Winnipeg, MB, R2V 4P6

Toll Free tel: 1 877 974 7473

Office tel: 204 334 4300

Fax: 204 334 7957

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