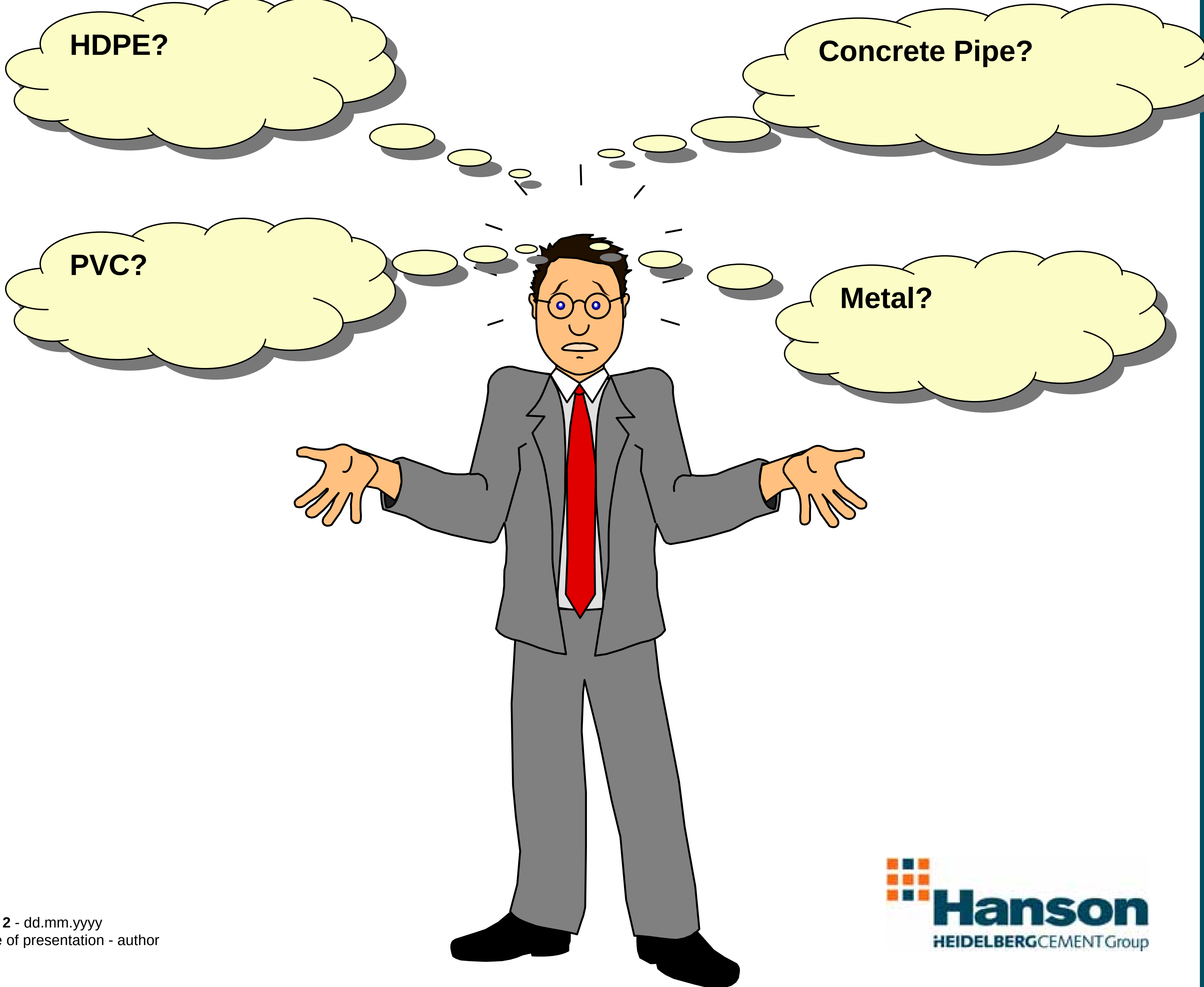
Pipe Design Basics


HDPE?
Concrete Pipe?
PVC?
Metal?

ASSESSMENT OF PIPE SYSTEMS

- **Technical**
- **Financial**
- **Risk**

TECHNICAL ASSESSMENT

- **Specifications and Standards**
  - ASTM, AASHTO, DOT
- **Quality Control**
- **Structural Design**
  - Rigid versus Flexible
  - Stiffness
  - Watertightness
  - Joints

TECHNICAL ASSESSMENT

- **Hydraulics**
  - Corrugation growth
  - Actual diameter
  - Joints
- **Fittings and Specials**
  - Availability
  - Uniformity
  - Quality
- **Connections to manholes**

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FINANCIAL ASSESSMENT

- Cost of supply
- Cost of proper installation
- Maintenance
- Service Life versus Project Life

FINANCIAL ASSESSMENT

- **Initial material purchase price**
- **Cost to install**
- **Cost to inspect and test**

} System Cost - budgeted

- **Cost to maintain**
- **Cost to replace**

} Maintenance funds - unbudgeted

- **Cost of failure**

} Unknown and unknowable

RISK ANALYSIS

- **Modes of Failure**
- Buckling due to poor installation
- Corrosion
- Combustion
- Disjointing
- Flotation
- Wash-out
- Abrasion
- Post Installation Connections
- Chemical Attack
- Track Record and similar Case Histories

Fact - Buried Pipe Must Perform Two Critical Functions

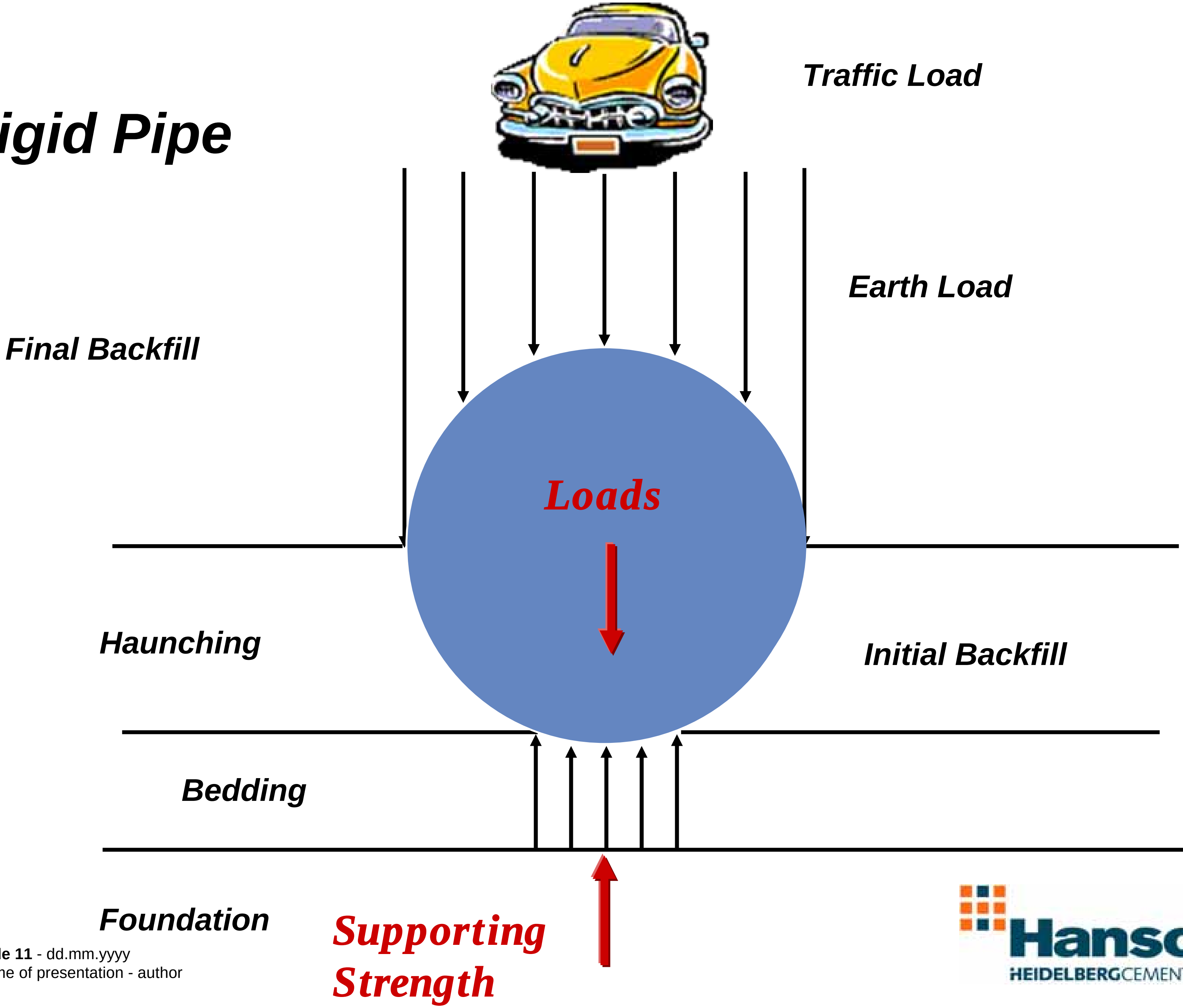
Buried Pipe

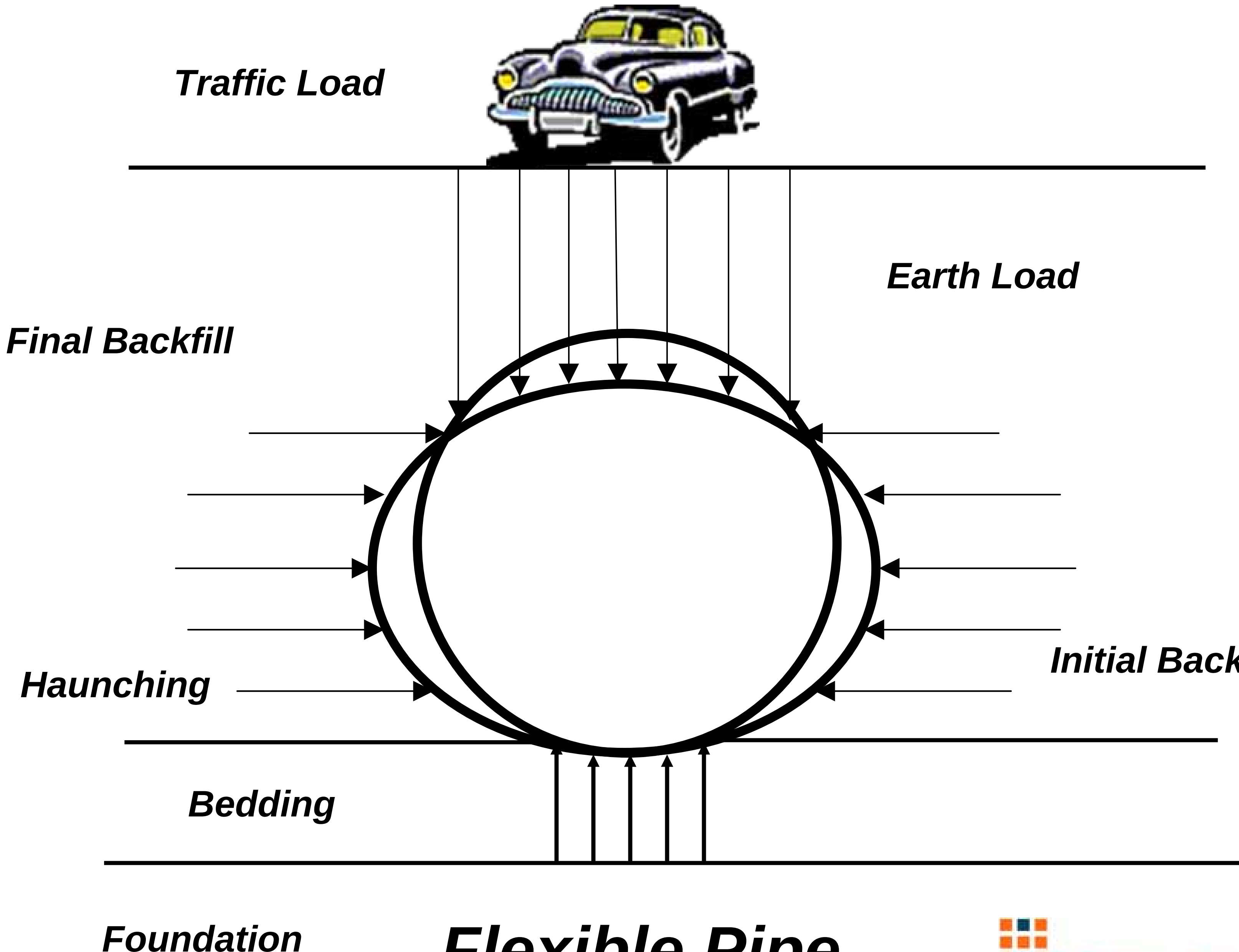
Conduit

Structure

How Do Rigid and Flexible Pipes Differ?

Rigid Pipe


Traffic Load
Earth Load
Final Backfill
Loads
Haunching
Initial Backfill
Bedding
Foundation
Supporting Strength



Flexible Pipe

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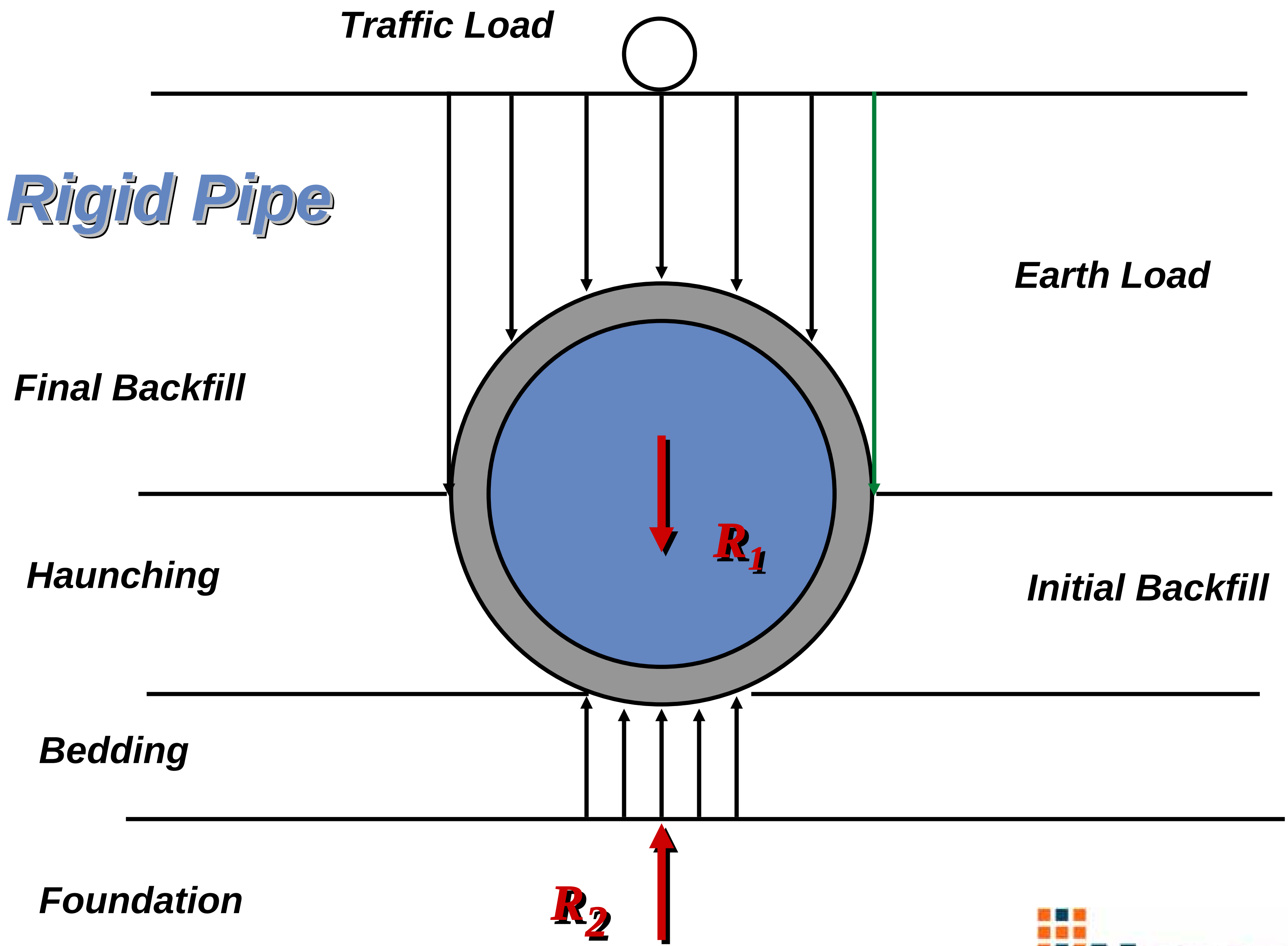
Rigid Pipe Has Inherent Strength

Flexible Pipe Does Not Have Inherent Strength

Relies on the quality of the installation creating the "Soil Structure Interaction" for strength.

How do we define the strength of concrete pipe?


Traffic Load
Rigid Pipe
Earth Load
Final Backfill
R_1
Haunching
Initial Backfill
Bedding
Foundation
R_2

3-Edge Bearing

D-Load

Class

$$D - Load_{.01} = \frac{W_E + W_L}{D \times B.F} \times F.S.$$

$$W_E = EarthLoad\ \#/\ ft.$$

$$W_L = LiveLoad$$

$$D = Diameter\ \ ft.$$

$$B.F. = BeddingFactor$$

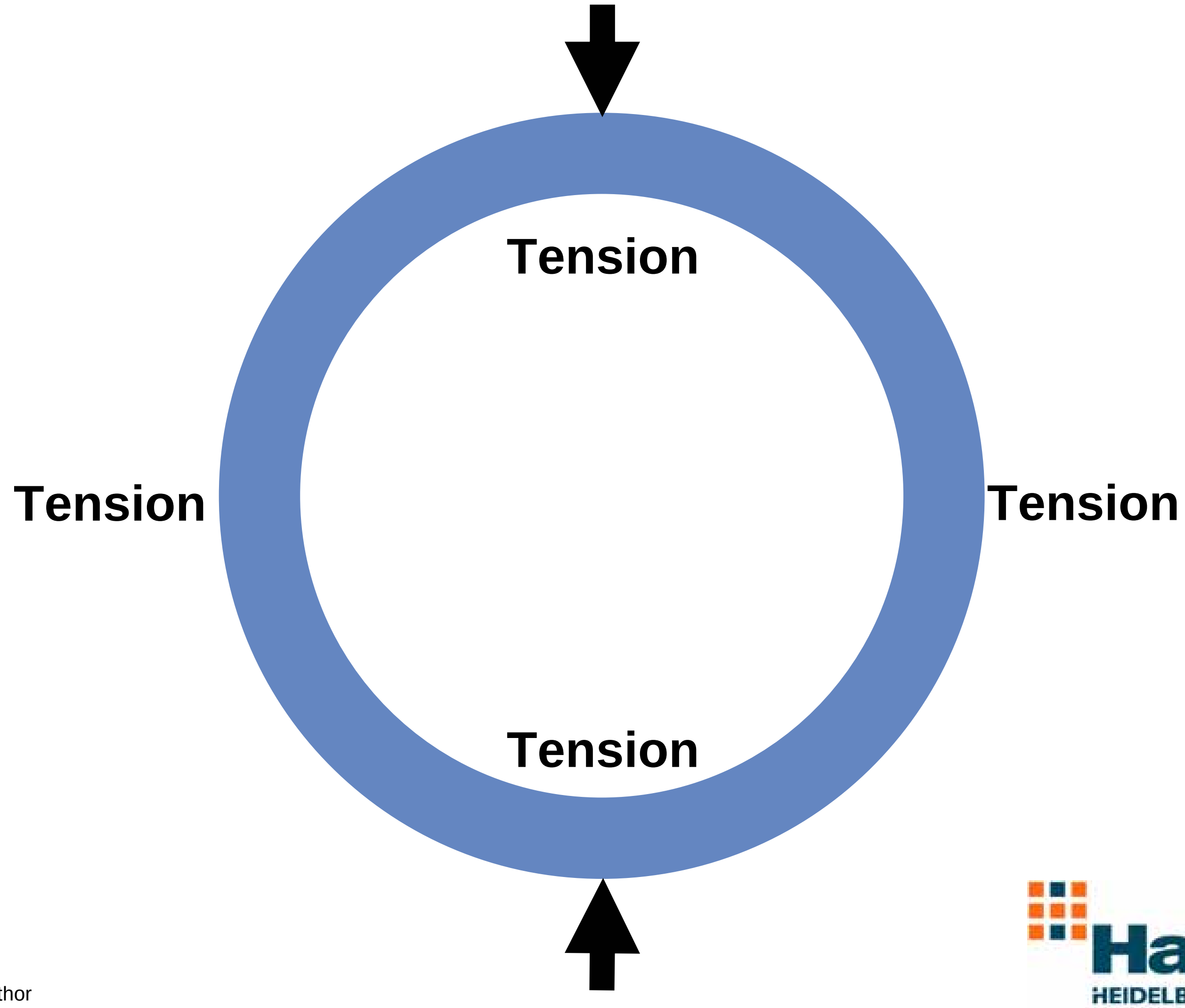
$$F.S. = SafetyFactor$$

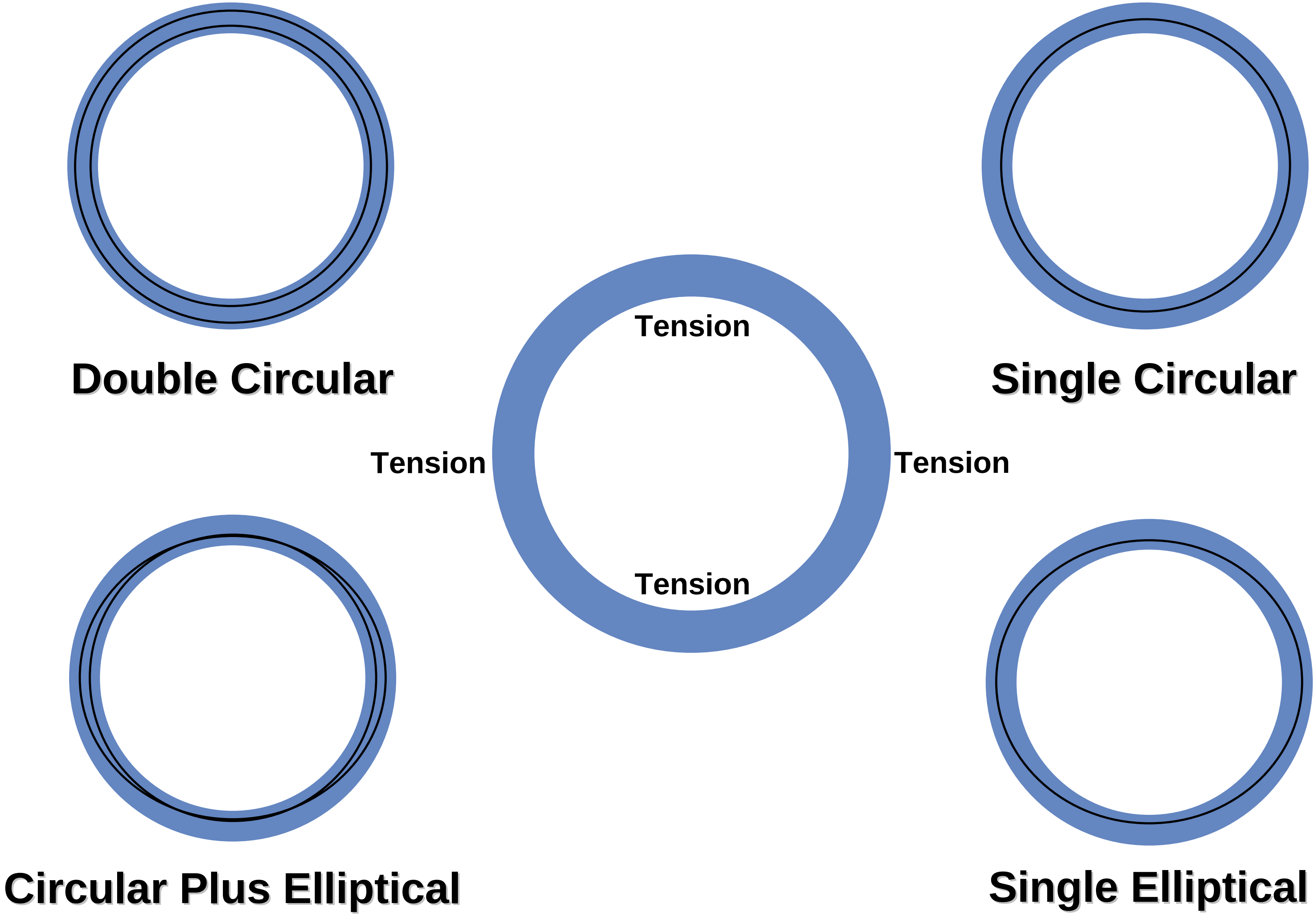
Gravity Pipe *Classes*

AASHTO M170 ASTM C76 Class	D-Load .01	D-Load Ult.
I	800	1200
II	1000	1500
III	1350	2000
IV	2000	3000
V	3000	3750

Three-Edge-Bearing

ASTM C76, C506, C507
ASTM C497

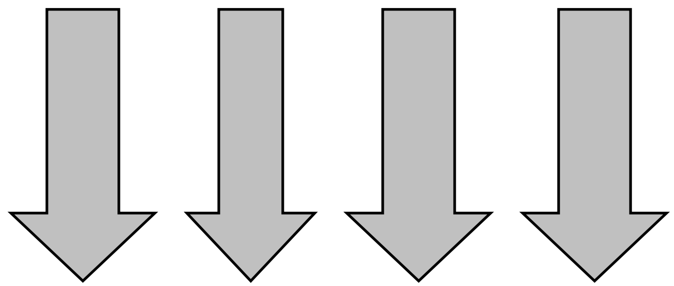

Tension
Tension
Tension
Tension



Tension
Double Circular
Single Circular
Tension
Tension
Tension
Circular Plus Elliptical
Single Elliptical

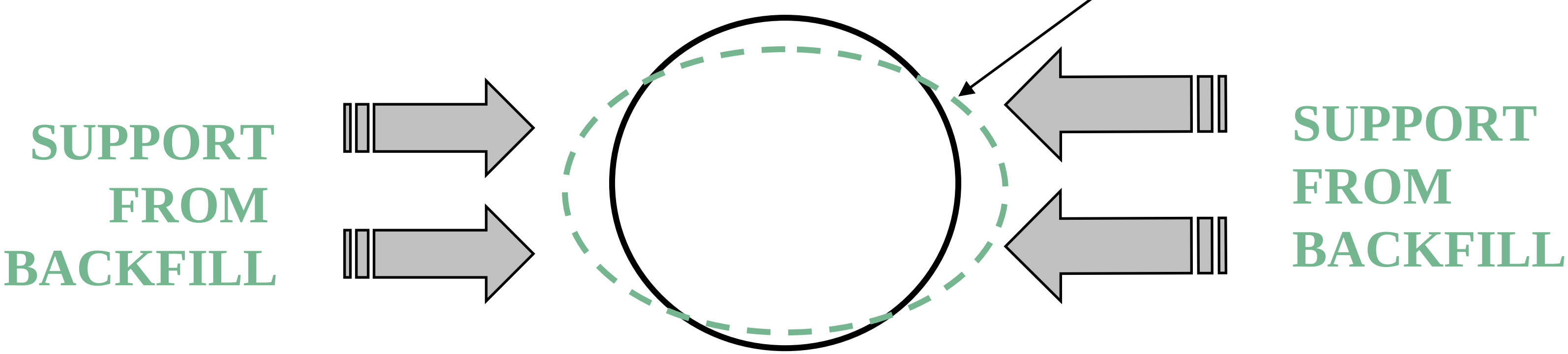
Flexible Pipe Design

Live load applied



Dead load applied

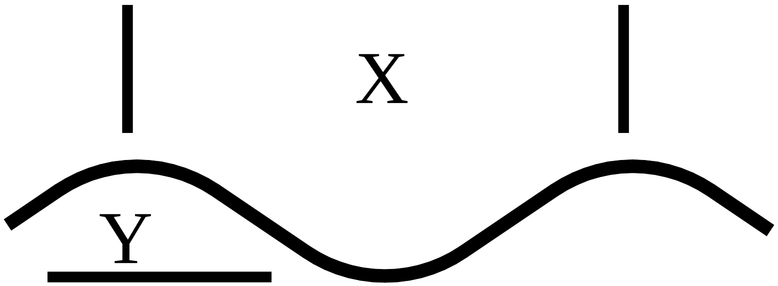
Structure deflects towards fill

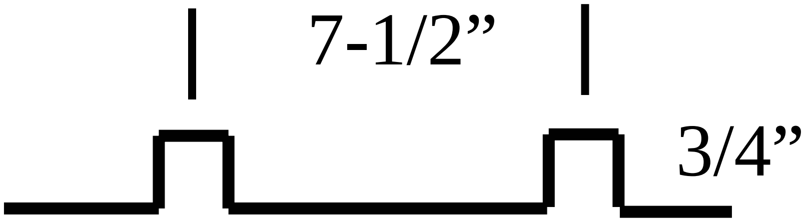


CSP Pipe Design

Corrugation Profiles

- **2 2/3" x 1/2"**
- **3" x 1"**
- **5" x 1'**
- **3/4" x 3/4" x 7-1/2" (Spiral Rib)**





Structural Plate SPCSP

6 x 2 corrugation
5 thicknesses
60 inch diameter to 20 ft spans

CSP Design Methods

- AISI
- ASTM A 796
- AASHTO
- Canadian Highway Bridge Design Code

Structural Design of CMP

1. Check minimum allowable cover
2. Select degree of backfill compaction
3. Calculate design pressure
4. Compute ring compression in pipe wall
5. Calculate the allowable compressive stress
6. Determine wall thickness
7. Check minimum handling stiffness
8. Check seam strength if applicable
9. Check special condition for pipe arches and arches

-Source: Chapter 6 Handbook of Steel Drainage and Highway Construction Products

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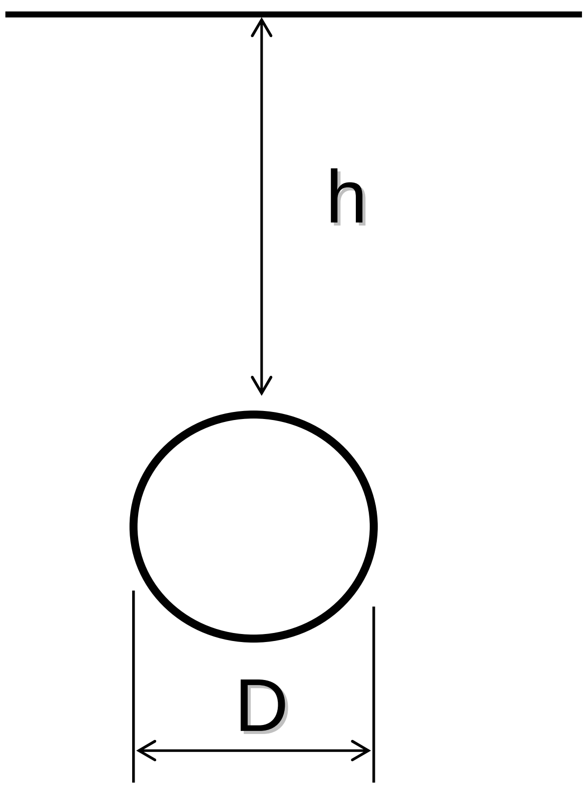
Design Pressure

- Design pressure $P_v = K(DL + LL)$

Load Reduction Factor



If h < D, K = 1

If h > D

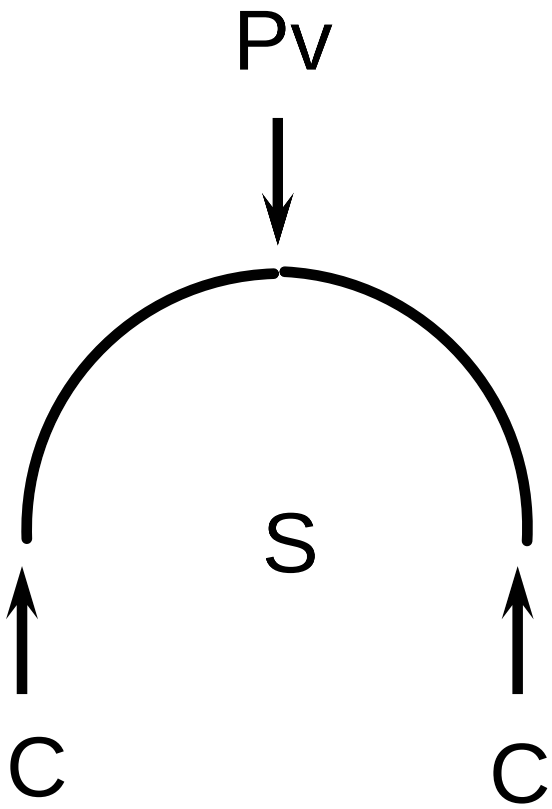
a load reduction
factor (K) can be applied

For 85% Standard Proctor K = 0.86
For 90% Standard Proctor K = 0.75
For 95% Standard Proctor K = 0.65

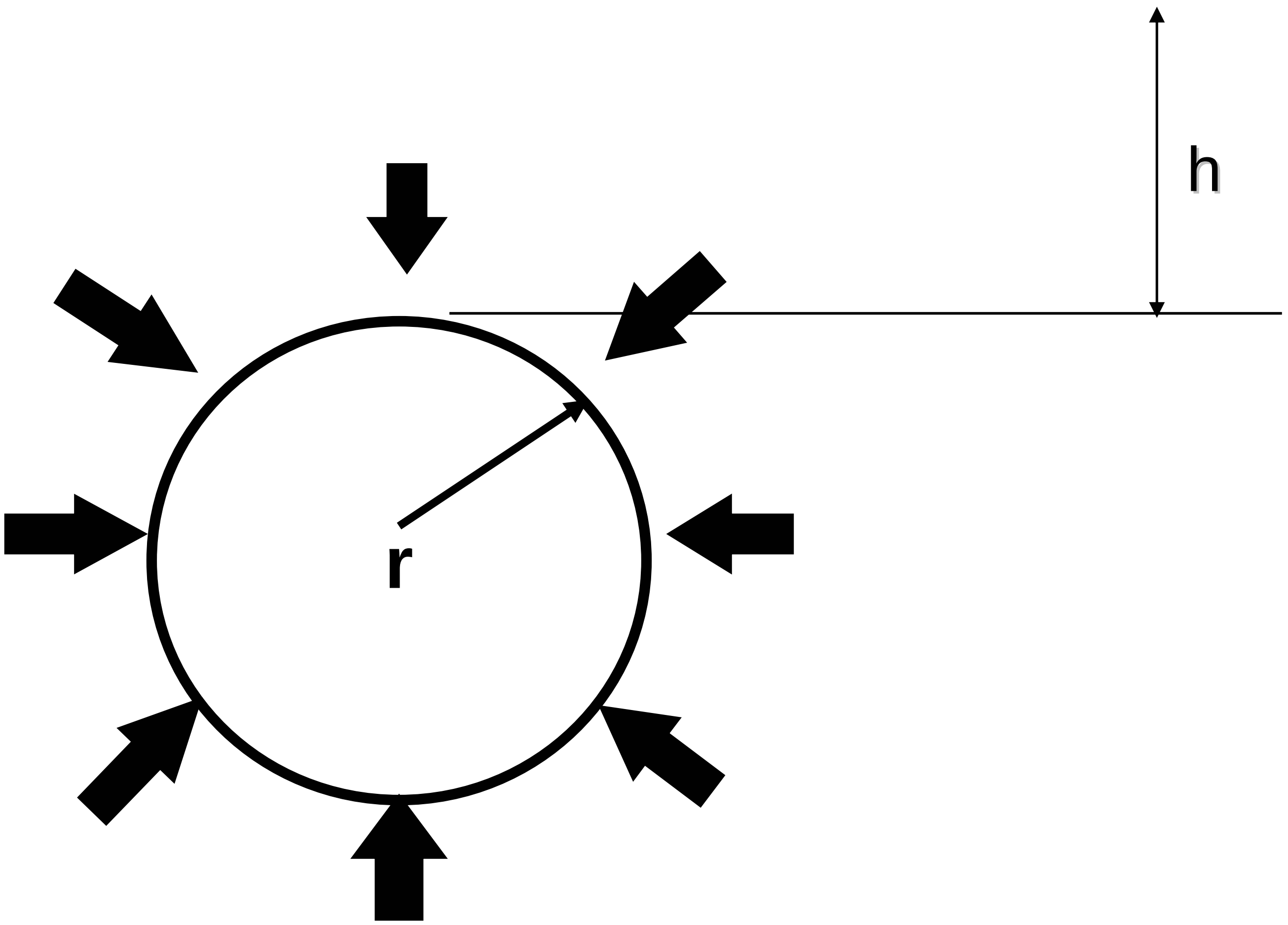
Wall Stress

- **Compressive Thrust**

C = Pv x S/2



Ring Compression Theory



$$C = P_v \times r$$

Required Wall Thickness

- **Minimum wall thickness required to carry the compression in the pipe wall.**
- **$A = C / f_c$**

Handling Stiffness

- **For practical handling and stiffness, minimum requirements have been established through experience.**
- **The Flexibility Factor FF is defined by:**

$$FF = D^2/EI$$

Where:

- D = diameter in mm
- E = modulus of elasticity
- I = moment of inertia of wall

Recommended maximum values:

- Factory made pipe FF= 0.0433 up to 120 inch dia.
- Bolted seam field assembled FF= 0.022

Seam Strength

- **Check seam strength for riveted CSP and SPCSP**
- **Seam Strength not applicable for helical lockseam**

Plastic Pipe Design

Plastic Pipe

Design requires the calculation of;

- Deflection, using the Modified Iowa Formula
- Buckling, by determination of the critical buckling pressure
- Bending, by determination of the bending strain and bending stress

-Source: www.plasticpipe.org

Chapter 5: Design Methodology

The Complete Corrugated Polyethylene Pipe Design Manual and Installation Guide

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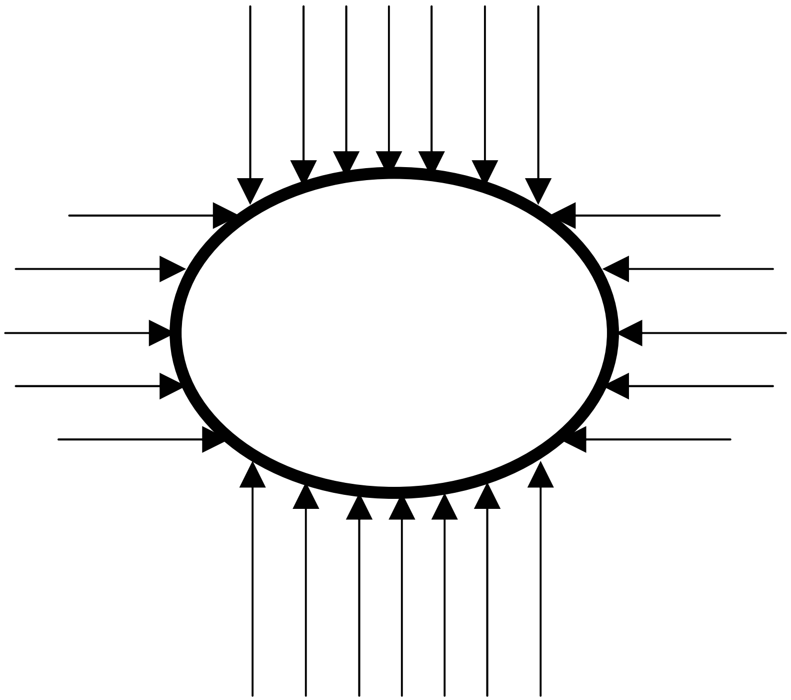
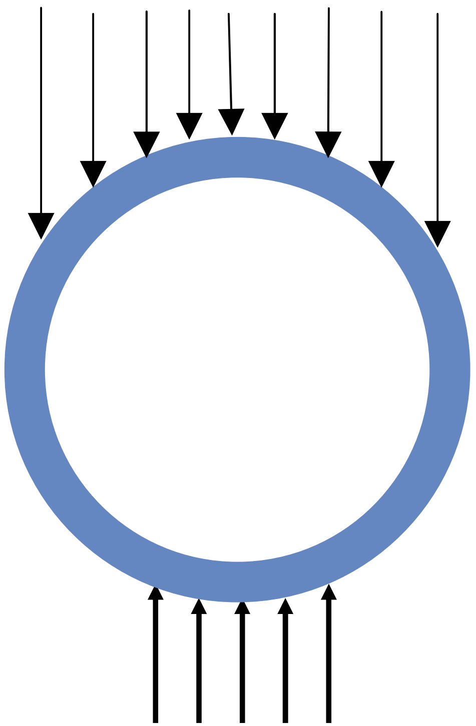


90% - 95% of supporting strength contributed by installation (bedding factor)

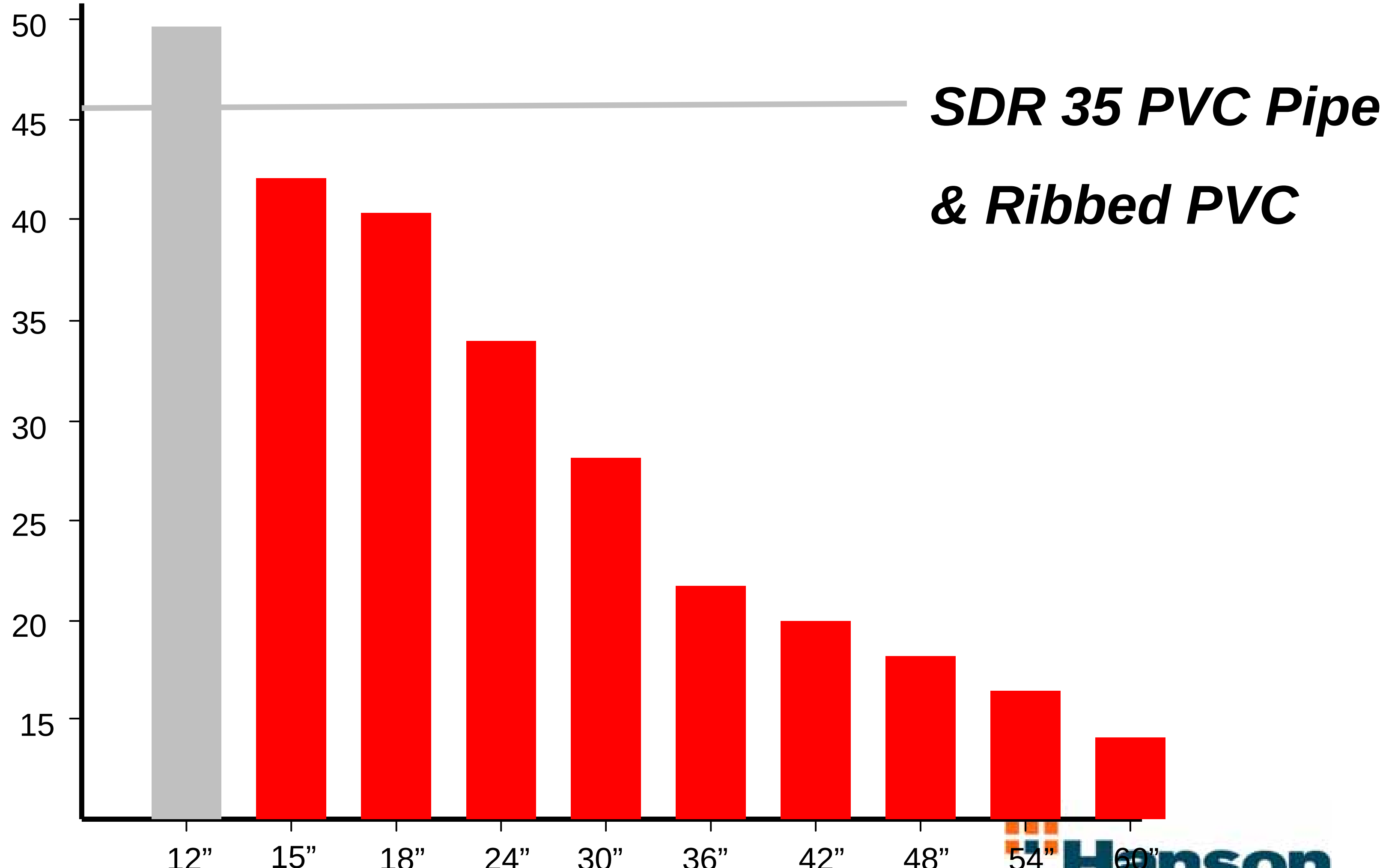
Flexible



As little as 30% of supporting strength contributed by installation (bedding factor)

Rigid

Diminishing Stiffness of Plastic Pipe



Modified Iowa Formula

$$\text{Deflection} = \frac{\text{Load}}{\text{Pipe Stiffness} + (\text{Constant})\,(\text{Soil Stiffness})}$$

$$\Delta y = \frac{1000K\,(D_L\,W_C + W_L)}{\boxed{0.149\ PS} + \boxed{0.061\ E'}}$$

3.5 - 10% (0.149 PS)

90 – 96.5% (0.061 E')

References


LOCATION
AND
DESIGN
STATE OF OHIO
DEPARTMENT OF TRANSPORTATION
MANUAL
VOLUME TWO
DRAINAGE DESIGN
The OHIO DEPARTMENT
of TRANSPORTATION

Pipe Materials

STATE OF OHIO

DEPARTMENT OF TRANSPORTATION
COLUMBUS, OHIO

CONSTRUCTION AND MATERIAL SPECIFICATIONS

JANUARY 1, 2005
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Pipe Materials
ODOT Construction and Materials

Type A Conduits - Culverts:

Non-reinforced concrete pipe, Class 3	706.01
Reinforced concrete pipe	706.02
Reinforced concrete pipe, epoxy coated	706.03
Reinforced concrete elliptical pipe	706.04
Precast reinforced concrete box sections	706.05
Precast reinforced concrete 3-sided flat topped culverts	706.051
Precast reinforced concrete arch sections	706.052
Vitrified clay pipe (extra strength only)	706.08
Corrugated steel conduits	707.01 or 707.02
Structural plate corrugated steel structures	707.03
Precoated, galvanized steel culverts	707.04
Bituminous coated corrugated steel pipe and pipe arches with paved invert	707.05 or 707.07
Corrugated aluminum alloy pipe	707.21 or 707.22
Aluminum alloy structural plate conduits	707.23
Corrugated steel box culverts	707.15
Corrugated aluminum box culverts	707.25

Type B Conduits - Storm sewers or sanitary under pavement:

Non-reinforced concrete pipe, Class 3	706.01
Reinforced concrete pipe	706.02
Reinforced concrete elliptical pipe	706.04
Precast reinforced concrete box sections	706.05
Vitrified clay pipe (extra strength only)	706.08
Mortar lined corrugated steel pipe	707.11
Corrugated steel spiral rib pipe	707.12
Bituminous lined corrugated steel pipe	707.13 or 707.14
Corrugated aluminum spiral rib pipe	707.24
Corrugated polyethylene smooth lined pipe	707.33
Polyvinyl chloride plastic pipe (non-perforated)	707.41
Polyvinyl chloride corrugated smooth interior pipe	707.42
Polyvinyl chloride profile wall pipe	707.43
Polyvinyl chloride sanitary pipe	707.44
Polyvinyl chloride solid wall pipe	707.45
Polyvinyl chloride drain waste and vent pipe	707.46
Polyvinyl chloride ABS composite pipe	707.47
ABS drain waste and vent pipe	707.51
ABS sewer pipe	707.52
Ductile iron pipe (sanitary)	748.01
Polyvinyl chloride pipe (sanitary)	748.02

Pipe Materials

- **Type C Conduits**
  – Storm sewers or sanitary sewers not under pavements
- **Type D Conduits**
  – Drive Pipes and Bikeways
- **Type E Conduits**
  – Miscellaneous small drains and connectors
- **Type F Conduits**
  – Conduits on steep slopes under drain outlets

Steps for Material Selection

- Field Review
- Hydraulics
- Structural Strength
- Service Life
- Material Analysis
- Plan Alternates

Field Review

- Determine pH of the water
  - Use an instrument that is capable of accuracy of 0.1
    - Use Figures 1002-2 through 1002-3 only if no flow is present when performing the field check

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Field Review

- Determine if there is a presence of abrasive material.
  - Abrasive Material – Presence of gravel, stones, or a course sand in the barrel of an existing conduit (or in the existing stream bed) that has a stream gradient or flow sufficient to cause movement of the abrasive material.
  - Assume abrasive conditions if there is any question about the bed material.

Field Review

- Investigate the condition of existing structures.
    - If a replacement structure, look at the existing structure.
    - If a new structure look at any adjacent existing structures.

Structural Strength

- Structural strength for Metal Conduits (steel and aluminum)
  - Select the gauge thickness and corrugation profile that is adequate (based upon fill height).
    - Figures 1008-1 through 1008-9 (steel)
    - Figures 1008-15 through 1008-21 (aluminum) (**NOT Aluminized**)

Structural Strength

- Structural Strength for Concrete Conduits
  - Select the D-load that is adequate for structural strength (based upon fill height).
    - Figures 1008-10 through 1008-14

Service Life

- Service life is either 50 or 75 years
  - Use 50 years as a minimum .
  - Use 75 years for high fills (>16’), under freeways, or where future costs may be high to replace the structure.

Service Life

- Durability for Metal Conduits
  - Use the obtained pH and abrasiveness observation to determine the gauge thickness.
  - Use figures 1002-5(50) through 1002-6(75) & the general notes for the figures.

Service Life

- Durability for Concrete Conduits
  - Check for adequate service life based upon the pH, pipe slope, and pipe rise.
  - Use figure 1002-4.

Material Analysis

- For metal conduit, choose the higher gauge thickness from the structural design, or the durability analysis.
    - When durability thickness is higher than structural thickness, provide the 1-inch corrugation profile for pipe diameters over 48 inches.

Plan Alternates

- **Place all available material options in the plan (all metal alternatives and concrete).**
  - In some cases, only one material may be specified in the plan:
    - If the outlet velocity in a concrete pipe requires a ring chamber and the velocity of the metal alternative is below 20fps, then metal may be used exclusively.
    - When encountering excessive cover for a concrete pipe.

Plan Alternates

- Where a larger corrugated metal pipe would require a higher pavement grade to satisfy minimum cover requirements, concrete may be used exclusively.

- Where a metal pipe arch is required hydraulically and a round concrete pipe would work, concrete may be used exclusively.

- Do not need to specify minimum D-loads or minimum gauge thicknesses in the item call-out.

Plan Alternates

- Show the following in the plan:
  - D-load or gauge thickness if it is above the minimum shown in the specifications.
  - The conduit shown in the plans should be the longest length pipe (the smallest diameter).
  - Hydraulic Design Information
  - Other information (see L&D, Vol. 3, Section 1312.2)

Thank You