

TECHNICAL BULLETIN

CHANGING DIRECTION OF PVC PIPELINES IN OPEN CUT INSTALLATIONS

This bulletin provides guidance on changing direction in buried PVC pressure pipelines installed by open-cut methods. It applies to Westlake Pipe & Fittings PVC pipe and fittings used in water and wastewater applications.

Why Change Direction?

Changes in direction are often required to follow property boundaries, avoid obstacles, or connect to existing infrastructure. In these situations, planned changes in alignment should be made using fittings and/or restrained systems such as Certa-Lok®. Angular joint deflection and longitudinal bending may be used only for minor adjustments within published limits and are not recommended as primary design tools.

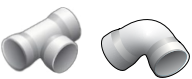
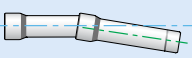
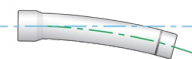
What Types of PVC Pipes and Fittings Does This Cover?

The pipes covered are Westlake PVC pipes used in water and wastewater systems, including pressure and non-pressure products such as AWWA C900/C909, ASTM D2241, ASTM D3034, and their associated fittings, as well as restrained systems like Certa-Lok®, Yelomine®, and reclaimed water pipe.

The joint-type lists and tables (IB, Certa-Lok RJ/RJIB, solvent-weld, sewer IB) are the ways those covered products are joined and the limits that apply to each.

Changing Direction Methods – At a Glance

There are three methods to change the direction of PVC pipelines: fittings, angular joint deflection, and longitudinal bending.

	Method	Primary Use	Typical Deflection / Radius	Notes
	Fittings	Planned changes in alignment	N/A	Use for major direction changes and tees
	Angular Joint Deflection	Minor alignment adjustments at each joint	Within published joint limits	Not a primary design tool
	Longitudinal Bending	Smooth, gradual changes over pipe length	Within published minimum bend radius	Must maintain recommended radii and limits

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Fittings – Primary Method for Direction Changes

Changes in pipeline direction should be made using fittings wherever practical. Westlake Pipe & Fittings recommends using elbows, tees, and wyes, together with appropriate joint restraint, as the primary method for designing bends, offsets, and vertical or horizontal alignment changes. Acceptable options include solvent-weld PVC fittings, push-on PVC fittings (injection-molded or fabricated), and ductile iron fittings (MJ or push-on).

Fittings that change the direction of pipelines—such as elbows, tees, and wyes—can be used at any point in a line. However, in pressure applications each change in direction creates a thrust force that tends to push the pipe joints apart. These thrust forces must be resisted by:

- Thrust blocks
- External pipe restraints
- Solvent-welded joints
- Self-restrained pipe such as Certa-Lok® family of products

For additional guidance on selecting and designing joint restraint, see the [“Thrust Forces”](#) section.

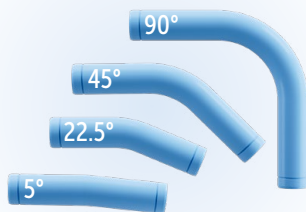
The use of a fitting allows straight insertion of the spigot into the bell, so the horizontal or vertical change in direction is made at the fitting, not at the joint. This simplifies construction and helps maintain proper joint performance. Because different fitting types have different insertion requirements, always check the bell depth of the fitting and, if necessary, re-mark the insertion line on the spigot to ensure the correct insertion depth is achieved.

Fitting Solutions Examples

Westlake Pipe & Fittings offers a wide variety of molded and fabricated fittings, including bends from 5° through 90°. The radius shape of the 5° bend produces virtually no axial forces; these fittings can typically be installed without additional joint restraint.



[5° Fluid-Tite High Deflection Couplings](#)



[C900 Certa-Lok® Sweeps](#)



[AquaConnect® AWWA C907 Molded PVC Fittings - 45° Elbow](#)

Deflecting the Joint at PVC Fittings

Maximum allowable angular deflection at PVC fittings depends on the product generally: 1° per bell for C900 fittings, up to 5° for sewer fittings, and 0.5° for restrained-joint Certa-Lok fittings. See specific product family product specification for additional details.

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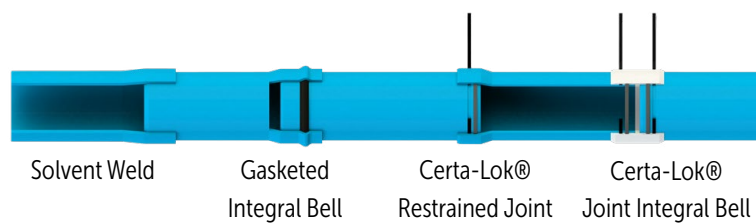
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Angular Joint Deflection – Limited Use for Minor Alignment Adjustments

Some PVC pipe joint designs permit limited angular deflection after assembly because of the clearance between the bell and spigot. This deflection is intended only to accommodate minor horizontal or vertical alignment adjustments during construction and should not be used as a substitute for fittings for planned changes in direction.

Westlake Pipe & Fittings produces PVC pipe products in four different joint styles:

- Gasketed Integral Bell (IB)
- Certa-Lok Restrained Joint (RJ)
- Joint Integral Bell (RJIB)
- Solvent Welded (SW)



ANGULAR JOINT DEFLECTION	
Joint Type	Maximum Angular Joint Deflection
IB*	1°
Sewer IB**	5°
Certa-Lok RJ	0.5° per side of coupling 1° total per joint
Certa-Lok RJIB	0.5°
Solvent Weld	None

*Refer to applicable product family product specification sheets for additional joint deflection details.

**Up to 5° maximum, depending on diameter. See the applicable product specification for exact limits.

Angular Deflection - How To Calculate

The maximum angular deflection permitted varies for each joint type. A simple formula may be used to calculate the horizontal or vertical offset at the end of the deflected pipe:

$$A = 12 L \sin\beta$$

Where

L = laying length of pipe, feet

β = maximum joint deflection angle, degrees

A = offset at the end of the deflected pipe, inches

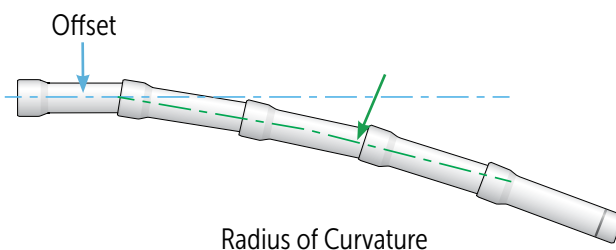
The corresponding radius of curvature is:

$$R = \frac{L}{2\sin(\beta/2)}$$

Where

R = radius of curvature, feet

MAX. OFFSET DUE TO ANGULAR JOINT DEFLECTION		
Pipe Lay Length (ft)	1° IB	0.5° RJIB
10'	2.09	1.05
14'	2.93	1.47
20'	4.19	2.09
40'	8.38	4.19



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Longitudinal Bending – Limited Use in Traditional Bell and Spigot

Due to the flexible nature of PVC, longitudinal bending of PVC pipe is possible as long as the flexural stress limits of the pipe are not exceeded. The following formulas can be used to calculate the minimum bend radius, angle of lateral deflection, and the distance offset at the end of a flexed, solid wall pipe. The values for modulus of elasticity and allowable flexural stress are temperature dependent. For longitudinal bending calculations review pages 7 and 8.

ALLOWABLE BENDING RADIUS

$$R_b = \frac{ED_o}{24S_b}$$

BENDING ANGLE AND PERCENT DEFLECTION

$$\alpha = \frac{57.3 L}{2R_b}$$

$$\alpha(\%) = 100 * \tan(\alpha)$$

BENDING STRAIN / DEFLECTION FACTOR

$$A = 24R_b \sin^2 \alpha$$

Where

R_b = pipe bending radius, feet

E = PVC modulus of elasticity, psi

D_o = pipe outside diameter, inches

S_b = allowable flexural stress, psi

α = angle of lateral deflection, degrees

L = lay length of pipe, feet

A = offset of the end of the deflected pipe, inches

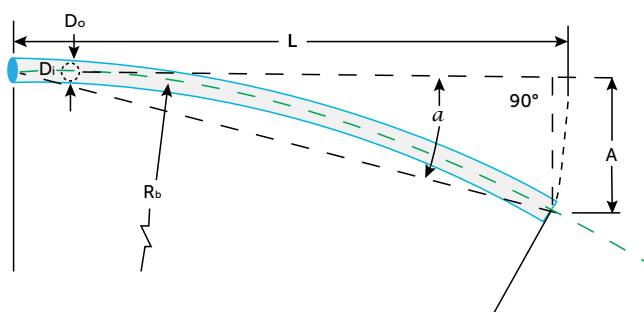


Figure 1: Longitudinal Bending Diagram

(Adapted from the PVC Pipe Association Handbook of PVC Pipe Design and Construction)

Longitudinal Bending – Certa-Lok®

Certa-Lok pipe joints are engineered to provide bi-directional restraint against both tensile and compressive forces. This allows the pipe string to bend uniformly while limiting joint deflection and reducing stresses in the joint area. As a result, the design limiting factor for bending is the allowable flexural stress in the pipe wall. In practice, strings of Certa-Lok pipe segments can achieve bending radii comparable to fusible PVC pipe.

For open cut installations, many restrained joint products like Certa-Lok® prevent over deflection of the joint. Certa-Lok® allows for several pipe segments to be strung together prior to bending. Stringing pipe before bending eliminates the challenges of bending individual segments. For additional information on Certa-Lok® view "[Longitudinal Bending of Certa-Lok® PVC Pipe](#)" technical bulletin.

For Certa-Lok allowable bending radius calculations, review pages 9 and 10.

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What is Thrust Force?

When the direction, diameter, or speed of fluid flow in a pipeline changes, the momentum of the fluid creates thrust forces at bends, tees, dead ends, and other changes in cross-section. If these forces are not properly restrained at joints and fittings, the pipeline may experience joint separation.

How to Manage Thrust Forces

Thrust force attempts to push the pipe joints apart and must be counteracted by using thrust blocks, external pipe restraints, solvent welded joints, or self-restrained pipe such as our Certa-Lok family of products.

Certa-Lok®

Westlake Pipe & Fittings' Certa-Lok self-restraining pipe system provides a restrained joint by utilizing precision-machined grooves on the pipe spigot and inside the pipe bell or coupling. When assembled, a spline is manually inserted or embedded in the pipe bell, or coupling, engages a groove in the spigot resulting in a continuous circumferential restrained joint that locks the segments of pipe together. A flexible elastomeric gasket located in a groove in the pipe bell, or coupling, provides a hydraulic pressure seal.

Mechanical Joint Restraints

Westlake Pipe & Fittings will accept mechanical joint restraints that are specifically designed and tested for use with our PVC pressure pipe. It is the responsibility of the restraint manufacturer to confirm that their product has been tested for the intended pipe size, DR, and material and that it is compatible with Westlake Pipe & Fittings' PVC products. Mechanical restraints for PVCO (AWWA C909) shall only be used when specifically qualified by the restraint manufacturer for that product.

Westlake Pipe & Fittings does not assume liability for the use of external restraints that are not confirmed compatible with the pipe and fittings supplied.

Concrete Thrust Blocking

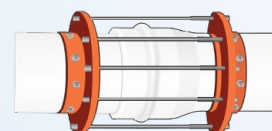
Concrete thrust blocks transfer the unbalanced thrust force from a fitting into the surrounding undisturbed soil. The block's purpose is to spread that force over enough soil area that the soil's bearing capacity resists the thrust force. For horizontal bends, tees, and dead ends, the block must be sized and oriented so it pushes into undisturbed soil in the direction of thrust, per the designer's calculations and AWWA M23.

Thrust blocks shall be cast in place against undisturbed soil; pre-cast blocks are not permitted. For vertical changes in direction, the fitting should be anchored to the thrust block. The size and shape of each block are determined by the designer based on pipe size, fitting angle, pressure, and soil conditions.

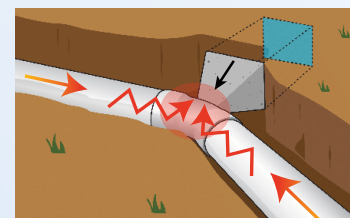
For quick and accurate restraint length calculations, EBAA Iron's online calculator lets you enter project details like pipe material, soil type, and fitting type to determine the required length of restrained joints. For calculations, visit: www.ebaa.com/calculator



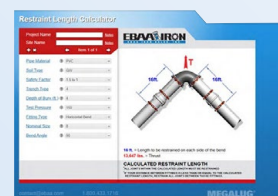
Certa-Lok Self Restrained Spline



Mechanical Restrained Joints



Thrust forces at the fitting are resisted by the concrete thrust block bearing against undisturbed soil.



EBAA Calculator

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Installation Tips and Trick

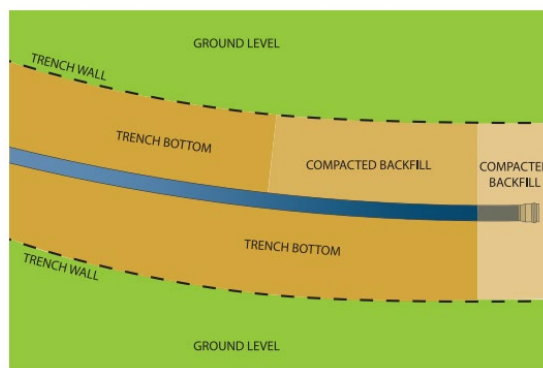
Open-Cut (Trench) and Exposed Installations

Westlake Pipe & Fittings recommends that fittings be the primary method for accommodating alignment changes in open-cut pipelines. Bends, offsets, and changes in direction should be made with appropriately sized fittings wherever practical. Joint deflection or longitudinal bending of the pipe may be used only within the allowable limits and only when fittings or shorter pipe segments cannot reasonably be used. **The maximum offsets of angular joint deflection and longitudinal bending cannot be combined.** For design planning purposes, only the offset from angular joint deflection or longitudinal bending can be used. If greater offsets are required, utilize shorter pipe segments or place a fitting in the line.

When bending PVC pipe longitudinally, the two pipe segments of the assembled joint must remain in straight alignment through bracing or backfill. A fulcrum should be created at the inside of the curve of the pipe's midpoint using compacted backfill.

Only manual force should be used to bend PVC pipe in open-cut and exposed installations. Using mechanical equipment could easily surpass the allowable flexural stress limits of the pipe. **For this reason, longitudinal bending of pipe larger than 12 in. is not recommended in open-cut installations due to the large forces required.**

Example of PVC pipeline installed in an open-cut trench where longitudinal bending may be used to accommodate alignment change.



Trenchless Installation of Certa-Lok® Pipe

Certa-Lok restrained-joint PVC pipe is designed for trenchless applications such as pipe bursting and directional drilling, providing a robust, gasketed joint that assembles quickly without fusion or special equipment. For detailed trenchless installation guidelines, refer to the Certa-Lok trenchless installation brochure: [USING CERTA-LOK® PIPE FOR HORIZONTAL DIRECTIONAL DRILLING \(HDD\)](#)

Warnings

The assembly of all pipe joints should be performed with both segments in straight alignment and in accordance with all manufacturer and industry standard instructions. Spigot insertion depths must still be maintained on gasketed integral bell PVC pipe joints after angular joint deflection and longitudinal bending. Angular joint deflection should be kept within the published maximum per-joint limit and used only to accommodate minor installation irregularities, not as a substitute for fittings for alignment changes. Exceeding the posted maximum angular joint deflection values can cause failure of the pipe through fracture or loss of gasket sealing integrity. Violating the minimum bend radius of a pipe segment will subject the pipe wall to excessive stresses that can cause fracture.

Reference

Uni-Bell PVC Pipe Association. Handbook of PVC Pipe Design and Construction. 6th Ed. Chapters 8, 10, & 13.

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Longitudinal Bending Table Calculations

The following tables provide reference values for our common product families and lay lengths for pipe at 73.3°F. Allowable flexural stress (S_b) is assumed 800psi and PVC modulus of elasticity (E) is 400,000psi for cell class 12454.

AWWA C900 AND C909 PIPE GASKETED INTEGRAL BELL					
Nom. Size	D_o (in)	R_b (ft)	L=20'		
			a (deg)	a (%)	A (in)
4"	4.8	100	5.7	10.0	23.9
6"	6.9	144	4.0	7.0	16.7
8"	9.1	189	3.0	5.3	12.7
10"	11.1	231	2.5	4.3	10.4
12"	13.2	275	2.1	3.6	8.7
14"	Deflection values are not provided for 14–36 in. sizes. Longitudinal bending of pipe larger than 12 in. in open-cut installations is not recommended because the large diameter and stiffness of the pipe require significant bending forces.				
16"					
18"					
20"					
24"					
27"					
30"					
36"					

GRAVITY SEWER PIPE ASTM D3034 GASKETED INTEGRAL BELL								
Nom. Size	D_o (in)	R_b (ft)	L = 14'			L = 20'		
			α (deg)	α (%)	A (in)	α (deg)	α (%)	A (in)
4"	4.2	35	11.4	20.2	33.0	16.3	29.3	66.5
6"	6.3	52	7.7	13.5	22.4	11.0	19.4	45.3
8"	8.4	70	5.7	10.0	16.7	8.2	14.4	34.1
10"	10.5	88	4.6	8.0	13.4	6.5	11.5	27.3
12"	12.5	104	3.9	6.7	11.3	5.5	9.6	23.0
15"	15.3	128	3.1	5.5	9.2	4.5	7.9	18.8
18"	Deflection values are not provided for 18–36 in. sizes. Longitudinal bending of pipe larger than 15 in. in open-cut installations is not recommended because the large diameter and stiffness of the pipe require significant bending forces.							
20"								
21"								
24"								
30"								
36"								

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CHANGING DIRECTION OF PVC PIPELINES IN
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ASTM D2241 PIPE GASKETED IB														
Nom. Size	D _o (in.)	R _b (ft)	L = 10'			L = 20'			L = 40			L = 42'		
			α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)
1½"	1.9	31.7	9.0	15.9	18.8	18.1	32.6	73.2	36.2	73.1	264.8	38.0	78.0	287.8
2"	2.4	39.6	7.2	12.7	15.1	14.5	25.8	59.3	28.9	55.3	222.5	30.4	58.6	243.2
2½"	2.9	47.9	6.0	10.5	12.5	12.0	21.2	49.4	23.9	44.4	189.1	25.1	46.9	207.2
3"	3.5	58.3	4.9	8.6	10.3	9.8	17.3	40.8	19.7	35.7	158.3	20.6	37.7	173.9
4"	4.5	75	3.8	6.7	8.0	7.6	13.4	31.8	15.3	27.3	125.0	16.0	28.8	137.5
6"	6.6	110	2.6	4.5	5.5	5.2	9.1	21.8	10.4	18.4	86.3	10.9	19.3	95.1
8"	8.6	144	2.0	3.5	4.2	4.0	7.0	16.6	8.0	14.0	66.2	8.4	14.7	73.0
10"	10.8	179	1.6	2.8	3.4	3.2	5.6	13.4	6.4	11.2	53.4	6.7	11.8	58.9
12"	12.8	213	1.3	2.3	2.8	2.7	4.7	11.3	5.4	9.4	44.9	5.6	9.9	49.5
14"	Deflection values are not provided for 14–16 in. sizes. Longitudinal bending of pipe larger than 12 in. in open-cut installations is not recommended because the large diameter and stiffness of the pipe require significant bending forces.													
16"														

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Longitudinal Bending of Certa-Lok® PVC Pipe

For open cut installations, many restrained joint products like Certa-Lok® prevent over deflection of the joint. Certa-Lok allows for several pipe segments to be strung together prior to bending. Stringing pipe before bending eliminates the challenges of bending individual segments. For further details, refer to the restrained joint sections of this guide. For additional information on Certa-Lok view ["Longitudinal Bending of Certa-Lok® PVC Pipe"](#) technical bulletin.

Allowable Bend Radius of Certa-Lok Pipe

CERTA-LOK® AWWA C900								
Nom. Size	D _o (in.)	R _b (ft)	L=20'			L=40'		
			α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)
6"	6.9	144	4.0	7.0	16.7	8.0	14.0	66.4
8"	9.05	189	3.0	5.3	12.7	6.1	10.6	50.7
10"	11.1	231	2.5	4.3	10.4	5.0	8.7	41.4
12"	13.2	275	2.1	3.6	8.7	4.2	7.3	34.9
14"	Deflection values are not provided for 14–24 in. sizes. Longitudinal bending of pipe larger than 15 in. in open-cut installations is not recommended because the large diameter and stiffness of the pipe require significant bending forces.							
16"								
18"								
20"								
24"								

CERTA-FLO®								
Nom. Size	D _o (in.)	R _b (ft)	L = 10'			L = 20'		
			α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)
4"	4.5	75	3.8	6.7	8.0	7.6	13.4	31.8
6"	6.6	110	2.6	4.5	5.5	5.2	9.1	21.8
8"	8.6	144	2.0	3.5	4.2	4.0	7.0	16.6
10"	10.8	179	1.6	2.8	3.4	3.2	5.6	13.4
12"	12.8	213	1.3	2.3	2.8	2.7	4.7	11.3

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CHANGING DIRECTION OF PVC PIPELINES IN OPEN CUT INSTALLATIONS

Allowable bend radius of Certa-Lok® pipe (*continued*)

YELOMINE® ASTM D2241								
Nom. Size	D _o (in.)	R _b (ft)	L = 10			L = 20'		
			α (deg)	α (%)	A (in.)	α (deg)	α (%)	A (in.)
4"	4.5	75	3.8	6.7	8.0	7.6	13.4	31.8
6"	6.6	110	2.6	4.5	5.5	5.2	9.1	21.8
8"	8.6	144	2.0	3.5	4.2	4.0	7.0	16.6
10"	10.8	179	1.6	2.8	3.4	3.2	5.6	13.4
12"	12.8	213	1.3	2.3	2.8	2.7	4.7	11.3

CERTA-COM® ALLOWABLE OFFSETS					
Nom. Size	D _o (in.)	R _b (ft)	L = 20'		
			α (deg)	α (%)	A (in.)
3"	3.5	65	8.8	15.5	36.6
4"	4.5	65	8.8	15.5	36.6
5"	5.6	65	8.8	15.5	36.6
6"	6.6	65	8.8	15.5	36.6
8"	8.6	72	8.0	14.0	33.1