Clean and clear detailing drawings can make every bend a smooth bend.

Around the Bend

What Detailers Should Know About Bending Steel

By Mark King

The aesthetic appeal of curved structural steel has created an ever-expanding market for steel bending skills. Architects and engineers continually challenge detailers, fabricators, and benders to turn their vision into an accurate structure. But benders and fabricators can't successfully perform their work without clearly detailed drawings and instructions. The detailer with an understanding of curved steel, and with a clear and meticulous approach to drafting, is indispensable to the process.

From a bender's perspective, clear detailing drawings for curved steel should include:

- member size,
- member profile,
- bend direction of material being curved, and
- consistent dimensioning.

Clarity and Consistency

A few common drawing conventions make details easily comprehensible despite the great variety in types and sizes of structural steel used in bending. For example, details of structural profiles such as angles, channels, wide-flange shapes, and tees should make use of dashed lines and solid lines to show flange, leg, and web orientations in relation to radius. This approach, illustrated in Figure A, clearly shows the direction material is bent, whether it is hard way, easy way, leg in, flange out, etc.

This same approach is also useful in depicting curved members of certain profiles that include tangents of different lengths. When bent with different length tangents, the following profiles will make components that can only be configured one way: angle leg in or leg out, channel the hard way, tee stem up/down, and rail "ball" up. For example: An L3×3 bent leg in with a 24″ tangent on one end and a 36″ tangent on the other, can not be flipped over or turned 180° and remain the same cross section in relation to radius.

Careless application of line types and member orientation can result in a bent member that may not be usable, and at minimum may require extensive rework. It is also helpful to dimension the depth of the cross section when a member is shown in a radius view, as shown in Figure B. This accurately illustrates which leg of odd leg angle (i.e. L4×3×¼) or which face of rectangular tube steel (i.e. HSS 12×4) is depicted in that view. Showing the depth of material in conjunction with solid versus dashed lines simplifies interpretation of profile cross section in relation to bending direction.

Going in Circles

Clear mathematical information is critical to bender calculations. Drawings must clearly show all included dimensions, like radius, degree, arc length, chord length, rise, and tangent length. Showing radius and then stating the arc length at that specific radius (i.e. 12′-4″ arc length at 10′-0″ radius) clarifies material length required. This is important when curved members have mitered ends versus square cut ends because of the greater variance between inside and outside arc lengths. Taking chord and rise dimensions from the same positions (such as inside face to inside face) makes it much easier to interpret the dimensions and perform calculations with them. For example, an inside chord dimension in conjunction with an outside rise dimension on a curved member with mitered ends may not be easily interpreted, because the working points for both sets of dimensions are different.

How Much is Enough?

The amount of information required in the details of curved members is greatly dependent on the complexity of its configuration. Other than clearly showing size and bend direction, details need to provide enough information to accurately perform the bend.

For simple arcs without tangents, only two or three of the following factors are required: radius, chord, rise, arc length, and/or degree. For example, giving a radius and a required degree is enough

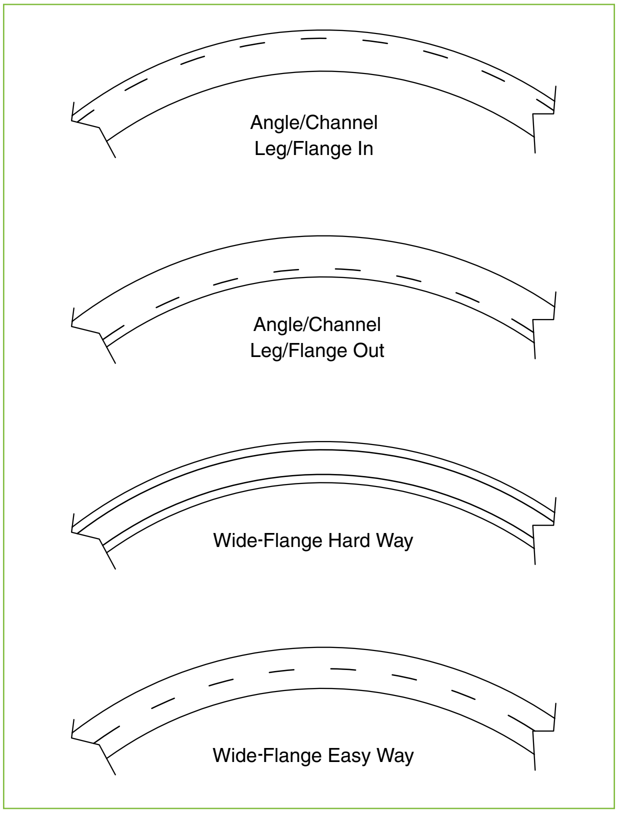

Figure A: Proper use of hidden lines makes it easier to define the orientation of the member.

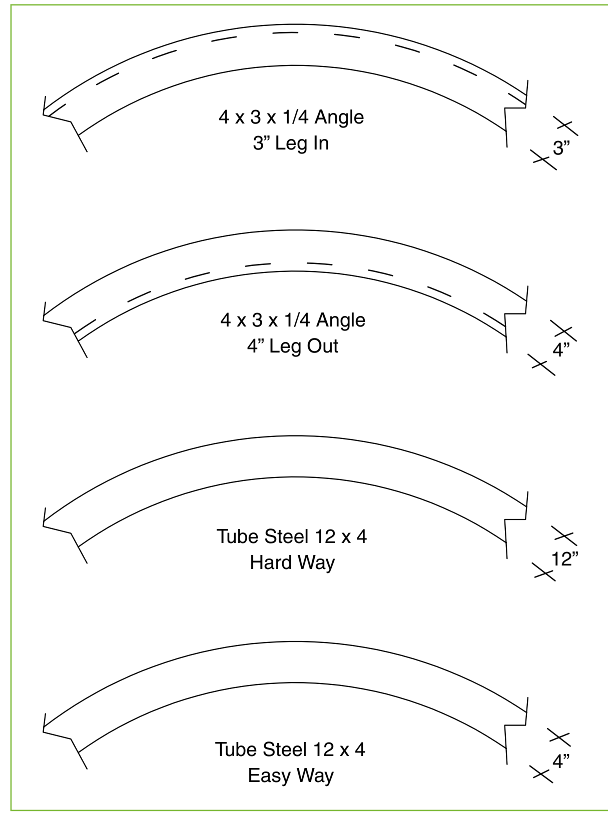

Figure B: Dimensioning the depth of the cross section in radius view helps define the orientation of the member.

information to bend a simple arc. If tangents are required, dimensioning needs to show a tangent length from the point of tangency to the end, or the length between two points of tangency. Tangents with miter cuts should show lengths at the inside and the outside, or a length on one side and a degree of cut in relation to the tangent, not the radius.

The amount of information required in details for benders to process s-curves, off-axis profiles, ellipses, multiple-axis bends (compound radius), and circular stair components can be far more involved.

Off-axis bends, where the material is rotated out of square in a cross sectional view, should be detailed similarly to normal bends but with one additional component: a cross sectional or end view of the material is required to show the rotation of the material in relation to the bend plane. This view should show the degree of rotation or triangulated dimensioning to indicate rotation. The same end view will also clarify bend direction of particular off-axis bent profiles in some cases. For example, an off-axis bent angle or channel is detailed more clearly when some lines in the radius view are eliminated and the end view is used to show bend direction. Trying to outline all of the lines of the material in a radius view can become cluttered and confusing.

Multiple-axis bends, where material is bent in two planes, should be detailed as two separate views showing a radius specific to each view, with the same required components for simple bends represented in each view. For example, a channel that is bent both the hard way and the easy way (flange in or flange out) should implement dashed and solid lines just like simple bends in both views. This method of dual views in conjunction with circular math factors (i.e. radius, arc length, tangents, etc.) given in each view is the clearest way to depict bend directions and associated necessary information in relation to the profile. Trying to detail multiple-axis bends using only one view is not easily interpreted or depicted clearly.

S-curves, where bends occur in the same plane but in opposite directions, should be detailed with the same components as simple bends, with special attention paid to how dimensioning is represented. These bends may require checking against full-scale layouts. Keeping dimensions parallel or perpendicular to included tangents is important for ease of interpretation. Treating each bend in an s-curve as a separate bend when dimensioning will make bend calculations and layouts easier. If the bends in an s-curve achieve different degrees of arc, a chord length or degree dimension that includes both bends may not be useful for calculations and processing.

Another type of bend that requires special attention to dimensioning methods is an **ellipse or multiple-radius bend**. Beyond the standard detailing approaches, multiple-radius bends should dimension each radius and its required arc length separately. These types of bends may also necessitate the bender to check parts on a full-scale layout. Where radii transition from one radius into another, even minor flaws in arc lengths can greatly affect the overall dimensions of the part. For this reason, also including numerous dimensions in a type of x and y coordinate or "run and rise" layout is helpful. The required frequency of these dimensions depends on the variance in radii, length of the part, and the accuracy required. More dimensions are better than fewer—then the bender can use as many dimensions as he needs to perform quality work.

The last—and possibly most complex type of bend—is a **spiral or circular stair component**. To perform calculations and process the bend, details should show, at

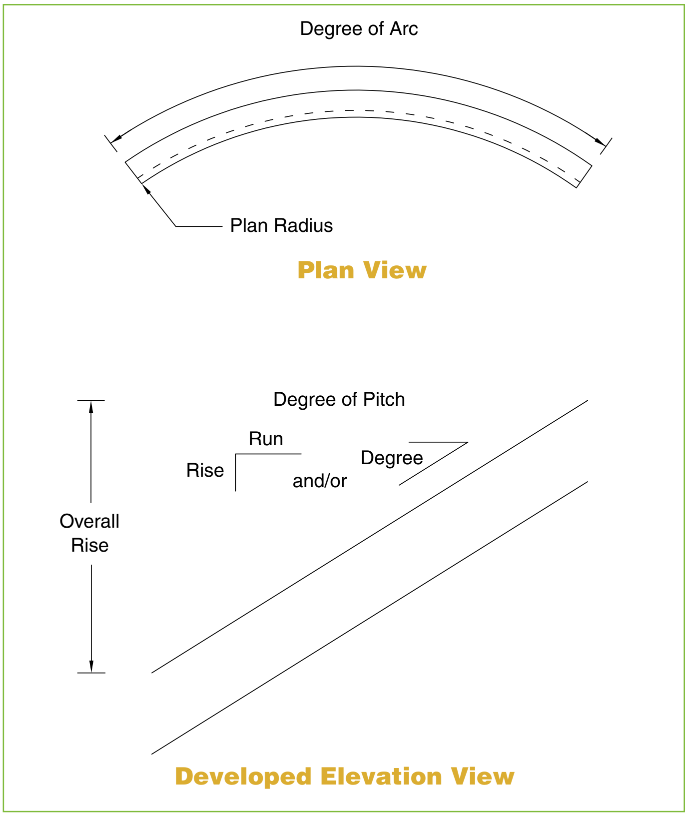

Figure C: Detailing views for a spiral bend.

a minimum, the radius in plan view, the degree of arc in plan view of spiral section only, the overall rise of the spiral section only, the degree of pitch, and direction of rotation interpreted as clockwise or counter clockwise up.

The clearest way to detail all of these factors is to show the spiral in separate plan views and developed elevation views. The developed elevation shows the bend in a "flattened" or "unwrapped" view. Figure C shows these details using channel, spiraled flange out, as an example profile.

The specified minimum factors can be represented in other ways, but must be able to be calculated from other dimensions if not given explicitly.

Both the plan radius and degree of arc in plan can be calculated if the details show a chord and rise specific to the arc in plan view. An overall run given in the developed elevation view is the same as arc length in plan view. This factor, in conjunction with plan radius, would generate a required degree of arc in plan view. The overall rise can be generated by using a trigonometric function of arc length in plan view/overall run in developed elevation and the degree of pitch. It can also be generated if a riser height and number of risers is given. The degree of pitch can be calculated from rise and run (expressed as 7" in 12" for example) or from the overall rise and arc length in plan view. It is important to align all of these dimensioning factors with the spiral section only. Including flat stair-landing sections in factors like overall run and degree of arc may not allow the bender to easily calculate the required factors that pertain to the spiraled section only.

The direction of rotation (clockwise/counter clockwise up) is derived from interpretation of the two separate views. The spiral illustrated in Figure C is bent as clockwise up.

Conclusion

These tips only cover the basics of detailing bends. For complex situations, most benders will be happy to answer questions and to help you avoid potential problems earlier—rather than later—in the process. ★

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