Beam Cambering Methods and Costs

By Erin Criste

Natural mill camber exists in all steel shapes as a result of the rolling and cooling processes inherent in steel shape production. W-shapes are straightened at the mill to a curvature that is within the tolerances specified in ASTM Specification A6, which allows a maximum natural mill camber of ⅛ inch for each 10 feet of length (for most wide-flange beams). When beams are specified without camber, the beam is fabricated with the natural camber oriented up.

As bay sizes increase and floor-to-floor height decrease, camber can be induced to counter initial deflections and reduce the required depth and weight of members. The tolerances for induced camber are provided in Section 6 of the American Institute of Steel Construction's (AISC) *Code of Standard Practice for Steel Buildings and Bridges*: -0/+ ½ inch plus an additional ⅛ inch for each 10 feet or fraction thereof over 50 feet.

These tolerances are measured in the fabrication shop in the unstressed condition.

Note that the AISC Code also allows that no further cambering is required for beams received by the fabricator with 75% of the specified camber. This provision recognizes that it is difficult to induce small camber ordinates. Moreover, it scratches the surface of the reality that cambering is not an exact process.

Cambering Methods

Not much has changed over the past thirty years in the general means and methods that a fabricator uses to induce camber in a member. In a fabrication shop, generally camber is applied using force (cold bending) or by applying heat (hot bending).

Cold bending is the most common method to induce camber in a member, and it usually involves the use of brute force. A steel beam is placed in a cambering machine – often built by the fabricator – with pivot points about 20 feet apart and a pair of hydraulic jacks centered at two points about 6 feet apart. The rams are advanced to deform (deflect) the beam, and when the ram is retracted some residual deformation remains. This process is repeated until the desired deformation (induced camber) is provided along the beam.

Hot bending generally is more labor intensive and time consuming, and may increase the costs associated with cambering. In hot bending, a member is heated in wedge-shaped segments along the member at uniformly (not necessarily equally) spaced points, symmetric about the member centerline. As a wedge is heated, the steel expands (gets slightly thicker due to restraint) and bends the member in a direction opposite to the intended camber as the longitudinal restraint of the cold steel around it resists the expansion. As it cools, the steel shrinks and reverses the bending to induce the intended camber, again due to the longitudinal restraint. Additional wedges may be heated until the desired result (specified camber) is obtained. Hot bending is used extensively in the repair of structural members that are damaged.

In specialty roller-bender shops, there are additional methods used to induce camber. These include rolling, incremental bending, hot bending, rotary-draw bending, and induction bending.

Rules of Thumb

When specifying camber, the following general rules of thumb should be considered:

- Only specify camber when ¾ inch or more is required, and work in ¼-inch increments. Cambers smaller than ¾ inch generally are hard to induce.
- Don't camber beams shorter than 24 feet long. The typical machine configuration has pivot points too wide apart for shorter beams.
- Watch out for thin-web beams. Cambering is generally not performed on beams with a web thickness less than or equal to ¼ inch The local forces involved in cambering can damage thin webs.
- Watch out for shallow beams. As the depth falls below a nominal 14-inch depth, the beam may tend to twist in the machine.
- Remember these types of beams that don't work well with camber: spandrel beams, beams in moment frames, beams subject to torsion, cantilevered beams, beams with bracing connections attached to them, beams with non uniform cross-sections, beams with non uniform loading conditions, and beams subject to cyclical loading conditions.

Of course, you can ask a fabricator should you need to do something that might encroach on one of these general recommendations. Perhaps they can make suggestions.

Load Determination

When determining how much camber to specify, know that opinions differ on the amount of load to consider. In general, the range of load considered for cambering beams varies from two-thirds of the dead load only to full dead load including super-imposed dead loads plus 10% of the live load. Providing insufficient camber to accommodate all of the dead load could result in ponding of the floor-system concrete (and the possibility for overload) at the center of the beam. However, over-cambering a member could result in slab thickness concerns (possibly exposing shear studs on composite beams or compromising the slab fire rating). Perhaps a good approach is to select the camber ordinate to maintain a small amount of camber (say ½ inch or so) after the slab is placed. It is also beneficial to allow for some variation in slab thickness (as opposed to selecting and specifying the ideal minimum slab thickness). This combination will allow a much more adaptable system during construction, should camber variations occur. In the end, the amount of camber specified depends on the desired finished floor profile considered by the architect and the engineer of record.

General Cambering Costs

Often, it is less expensive to increase the beam size to reduce deflections and shear studs required in composite beams. In other cases, camber can provide cost savings to a project. Cambering costs vary depending on the project and are affected by factors such as member length, depth, the type of camber, and the amount of camber specified.

Typical cold cambering costs range from $15-$45 per beam, according to a December 2008 survey of various US fabricators conducted by the AISC Steel Solutions Center. For example, a 30-foot-long beam that weighs 50 pounds per foot at 45¢ per pound (based on average US domestic mill pricing for structural steel shapes in December 2008) equates to a beam base cost of approximately $675, not including fabrication costs. An approximate charge of $30 to cold camber this beam is equivalent to specifying an additional 5 pounds per linear foot. Thus, it is more economical to specify camber in a beam if more than 5 pounds per linear foot are needed to achieve the desired serviceability (deflection) tolerances and criteria. Additional factors should be considered, such as a change in shear studs in composite beams that also will impact this comparison.

Of the various fabricators surveyed, cold cambering was considered to work the best and provide the most consistent results of the methods they used for inducing camber. As another method of inducing camber, heat cambering costs vary from approximately five to ten times the cost of cold cambering. Generally heat cambering is used only on members that exceed the capacity of the cold-cambering machine. Most fabricators are typically capable of inducing camber in members up to approximately 3 to 4 inches on a 60-foot span after which, generally, the member would be sent to a specialty bender and would be considered a rolled member, not cambered. To learn more about bending and producer methods and capabilities, visit **www.aisc.org/benders**.

Connections

Connections for cambered beams generally are slightly rotated with the camber, though it is possible to fabricate with square end connections. The fabricator and detailer generally know which type must be used based upon the actual cambers and lengths.

Bolt holes in the middle of the flange of a beam being cambered are a consideration, as they could lead to rupture during cambering. Fabricators may have to adjust their camber procedure to avoid problems with holes in the flanges.

Finally, remember that beam deflection criteria and cambers must coexist where members meet to assure proper transitions between the framing – especially if adjacent members are of different size and length.

Conclusions

The costs associated with specifying camber are affected by several factors including the size, grade, and shape of the structural steel member, and may or may not support the decision to camber. The amount of camber specified depends on the desired finished floor profile considered for design. Rules of thumb provide general guidelines to assist when specifying camber. Cold cambering is the most common method of inducing camber, but hot bending is an alternative method used.▪

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For questions regarding specific cambering capabilities and costs for a project, consult a local fabricator or specialty bender early in the design process for assistance, or contact AISC's Steel Solutions Center (**www.aisc.org**).

References

The references below provide more information and guidance. For questions regarding specific cambering capabilities and costs for a project, consult a local fabricator or specialty bender early in the design process for assistance, or contact AISC's Steel Solutions Center at 866.ASK.AISC or **solutions@aisc.org**.

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