KANSAS DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION TO THE
STANDARD SPECIFICATIONS, EDITION OF 1990

SECTION 702

STRUCTURAL STEEL CONSTRUCTION
HEAT-CURVED ROLLED BEAMS AND WELDED PLATE GIRDERS

1.0 DESCRIPTION.

This Special Provision covers the requirements for heat-curving rolled beams and welded plate girders to obtain horizontal curvature.

Before any fabrication is begun and prior to submittal of prints of shop drawings for the structural steel, the Contractor or fabricator may request permission to heat-curve rolled beams in the shop or to heat-curve welded plate girders in lieu of flame cutting flanges to the desired horizontal curvature. The request and proposed shop procedure shall indicate the type of heating, heating temperature, position for heating, sequence of operations and the values to be used to compensate for possible loss of camber of heat-curved girders in service. The proposed procedure shall conform to the following requirements and limitations, and shall be shown on the shop plans.

2.0 LIMITATIONS.

2.1 Material. Steels that are manufactured to a specified minimum yield point greater than 50 ksi (345 MPa), except for ASTM A 709 Grade HPS70W (ASTM A 709 HPS345W), shall not be heat-curved.

2.2 Minimum Radius of Curvature. For heat-curved beams and girders, the horizontal radius of curvature measured to the centerline of the girder web shall not be less than 150 feet (46 m), and shall not be less than the larger of the values calculated (at any and all cross sections throughout the length of the girder) from the following two equations:

$$R = \frac{14\, b\, D}{\sqrt{Fy}\;\Psi\;t} \qquad \left(\text{metric equation } R = \frac{37\, b\, D}{\sqrt{Fy}\;\Psi\;t}\right)$$

$$R = \frac{7500\; b}{Fy\;\;\Psi} \qquad \left(\text{metric equation } R = \frac{15700\;\; b}{Fy\;\;\Psi}\right)$$

Where:

R = Radius in inches (mm).

F_y = Specified minimum yield point in ksi (MPa) of steel in the girder web.

Ψ = Ratio of the total cross-sectional area to the cross-sectional area of both flanges.

b = Width of widest flange in inches (mm).
D = Clear distance between the flanges in inches (mm).
t = Thickness of web in inches (mm).

In addition to the above requirements, the radius shall not be less than 1000 feet (305 m) when the flange thickness exceeds 3 inches (75 mm), or the flange width exceeds 30 inches (750 mm).

3.0 FABRICATION REQUIREMENTS.

3.1 Type of Heating. Beams and girders may be curved by either continuous or V-type heating as approved by the Engineer. For the continuous method, a strip along the edge of the tip and bottom flange shall be heated simultaneously; the strip shall be of sufficient width and temperature to obtain the required curvature. For the V-type heating, the top and bottom flanges shall be heated in truncated triangular or wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange; the spacing and temperature shall be as required to obtain the required curvature, and the heating shall progress along the top and bottom flange at approximately the same rate.

For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached*****. When the radius of curvature is 1000 feet (305 m) or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1000 feet (305 m), the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to one-eighth of the flange or 3 inches (75 mm), whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches (250 mm). Variations in the patterns prescribed above may be made with the approval of the Engineer.

*****To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surface that intersects the web) so that heat is not applied directly to the web.

For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is 1¼ inches (32 mm) or greater, in which case, the 2 surfaces shall be heated concurrently. The maximum temperature shall be as prescribed below.

3.2 Temperature. The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1150°F (620ºC) as measured by temperature indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600°F (315ºC); the method of artificial cooling is subject to the approval of the Engineer.

3.3 Position for Heating. The girder may be heat-curved with the web in either a vertical or horizontal position. When curved in the vertical position, the girder must be braced or supported in such a manner that the tendency of the girder to deflect laterally during the heat-curving process will not cause the girder to overturn.

When curved in the horizontal position, the girder must be supported near its ends and at intermediate points, as required, to obtain a uniform curvature; the bending stress in the flanges due to the dead weight (mass) of the girder must not exceed the usual allowable design stress. When the girder is positioned horizontally for heating, intermediate safety catch blocks must be maintained at the mid-length of the girder within 2 inches (50 mm) of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

3.4 Sequence of Operations. The girder shall be heat-curved in the fabrication shop before it is painted. The heat-curving operation may be conducted either before or after all the required welding of transverse intermediate stiffeners is completed. However, unless provisions are made for girder shrinkage, connection plates and bearing stiffeners shall be located and attached after heat-curving. If longitudinal stiffeners are required, they shall be heat-curved or oxygen-cut separately and then welded to the curved girder. When cover plates are to be attached to rolled beams, they may be attached before heat-curving if the total thickness of one flange and cover plate is less than 2½ inches (65 mm) and the radius of curvature is greater than 1000 feet (305 m). For the other rolled beams with cover plates, the beams must be heat-curved before the cover plates are attached; cover plates must be either heat-curved or oxygen-cut separately and then welded to the curved beam.

3.5 Camber. Girders shall be cambered before heat-curving. Camber for rolled beams may be obtained by heat-cambering methods approved by the Engineer. For plate girders, the web shall be cut to the prescribed camber with suitable allowance for shrinkage due to cutting, welding, and heat-curving. However, subject to the approval of the Engineer, moderate deviations from specified camber may be corrected by a carefully supervised application of heat.

3.6 Measurement of Curvature and Camber. Horizontal curvature and vertical camber shall not be measured for final acceptance before all welding and heating operations are completed and the flanges have cooled to a uniform temperature. Horizontal curvature shall be checked with the girder in the vertical position by measuring off-sets from a string line or wire attached to both flanges or by using other suitable means; camber shall be checked by adequate means.

4.0 CAMBER LOSS.

The designer may require additional camber to compensate for possible loss of camber of heat-curved girders in service as residual stresses dissipate. The maximum amount of camber in millimeters at any section along the length L of the girder shall be equal to:

$$\Delta = \left(\frac{\Delta_{DL}}{\Delta_M}\right)\left(\Delta_M + \Delta_R\right) \qquad \left(\text{metric equation } \Delta = \left(\frac{\Delta_{DL}}{\Delta_M}\right)\left(\Delta_M + \Delta_R\right)\right)$$

$$\Delta_R = \left(\frac{0.02 \quad L^2 \quad Fy}{E \quad Yn}\right)\left(\frac{1000 - R}{850}\right) \qquad \left(\text{metric equation } \Delta_R = \left(\frac{0.02 \quad L^2 \quad Fy}{E \quad Yn}\right)\left(\frac{305 - R}{259}\right)\right)$$

Δ_R = 0 for radii greater than 1000 feet (305 m).

Where:

Δ = amount of camber in inches (mm).

Δ_{DL} = camber in inches at any point along the length L calculated by usual procedures to compensate for deflection due to dead loads or any other specified loads.

Δ_M = maximum value of Δ_{DL} in inches (mm) within the length L.

Δ_R = correction for the radius in inches (mm).
E = modulus of elasticity in ksi (MPa).
F_y = specified minimum yield point in ksi (MPa) of the girder flange.
Y_n = distance from the neutral axis to the extreme outer fiber in inches (mm) (maximum distance for non-symmetrical sections).
L = span length for simple spans, or the distance between a simple end support and the point of dead load contraflexure, or the distance between points of dead load contraflexure for continuous spans. L is measured in inches (mm).
R = radius of curvature in feet (m).

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