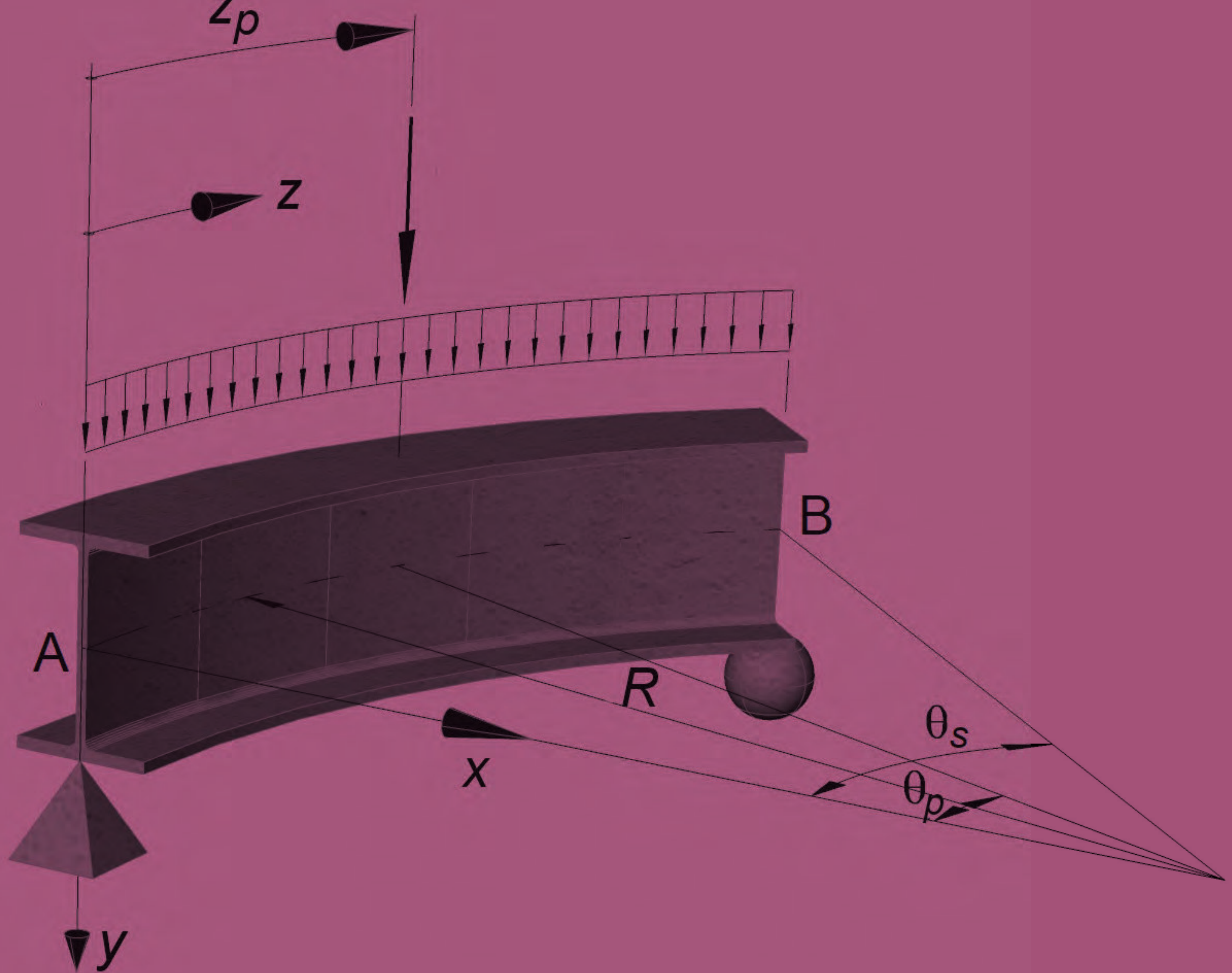

Design Guide 33

Curved Member Design

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Preface

This Design Guide provides guidance for the design of curved steel beams based on structural principles and adhering to the 2016 AISC *Specification for Structural Steel Buildings* and the 15th Edition AISC *Steel Construction Manual*. Both load and resistance factor design and allowable strength design methods are employed in the design examples.

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Chapter 1 Introduction

1.1 PURPOSE

In addition to the dramatic aesthetic effect of curved structures, the structural efficiency of arches and other vertically curved members makes them an attractive choice for both architects and engineers. Many commercial and industrial structures rely on horizontally curved members where straight members would be impractical. Although the visual appeal of curved structures is enhanced by their simplicity, the structural behavior of curved members can be much different from their straight counterparts. Despite the widespread use of curved structural steel members, detailed guidance relative to United States design practice is scarce. The purpose of this publication is to provide design guidance and practical information on the fabrication and detailing of curved members. Bender/roller companies who specialize in curving steel members can provide further information on the fabrication of curved members. AISC bender/roller companies are listed at the end of this Design Guide.

1.2 CURVED MEMBERS IN COMMERCIAL STRUCTURES

For commercial structures, the primary reason for using curved members is often the aesthetic appeal. Curved members can be fabricated to architecturally exposed structural steel (AESS) standards, making exposed steel an attractive option for these buildings. The additional cost of curving steelwork is often small in relation to the overall cost of the structure (King and Brown, 2001).

1.2.1 Vertically Curved Members

The ability of arches to span long distances provides an opportunity for large open spaces. A similar visual effect can be created with vertically curved roof beams, as shown under construction in Figure 1-1 and for the car dealership in Figure 1-2. The cost of curving the roof beams can be partially offset compared to non-curved construction by the savings in the ridge detail, flashing and apex connections (King and Brown, 2001). The pedestrian bridge in Figure 1-3 utilizes the structural efficiency of an arch while providing exposed structure aesthetics.

1.2.2 Horizontally Curved Members

Although horizontally curved members are less efficient structurally than straight beams, they are often used to carry loads at curved floors and roofs. Curved architecturally exposed beams were used for the recreation center in Figure 1-4 and the canopy in Figure 1-5. In some cases, such as for transportation and pedestrian bridges, horizontally curved structures are required due to geometrical constraints. Figure 1-6 shows horizontally curved truss segments for a light rail transit system.

1.2.3 Specialty Bends

Specialty bends are often required to form members to the proper geometry. Because parabolic curves are efficient for resisting gravity loads, many arches have a parabolic geometry (Figure 1-3), which requires a variable-radius specialty bend. A variable-radius curve was also used for the event pavilion in Figure 1-7, where the roof members were bent into an elliptical shape. Off-axis bending for the eave strut in Figure 1-8 was required because the center of curvature was not in the same plane as the member principal axis. Figure 1-9 shows a series of canopies that were bent into an S-curve, and Figure 1-10 shows a small-radius spiral staircase. The curved members in Figure 1-11 arch over a pedestrian bridge and serve as structural supports for the guardrail system. The art installation in Figure 1-12 illustrates the capability of bender/rollers to form complex curves with small, varying radii about multiple axes.

1.3 CURVED MEMBERS IN INDUSTRIAL STRUCTURES

Industrial buildings and nonbuilding structures are usually designed for functionality rather than aesthetics. Therefore, curved members are typically used out of necessity or because they are more efficient than straight members. For example, horizontally curved monorail beams are required where the monorail track must follow a curved path. Most liquid and bulk storage structures are constructed in a circular shape, which is efficient in resisting pressure from the stored contents. Curved members are used for circumferential roof members and shell stiffeners for these structures.

1.3.1 Vertically Curved Members

Vertically curved members are primarily used as circumferential shell stiffening rings for horizontal vessels, large industrial ducts, and tubular conveyor galleries.

1.3.2 Horizontally Curved Members

Horizontally curved members can be used for monorail beams, chimney grillages, circumferential shell stiffeners, and silo/tank roofs. Although most floor framing around circular vessels and chimneys is straight (potentially with curved grating openings), curved framing is also an option. Rothman (1980) discussed the design of a 120-ft-diameter, 50-ft-deep circular cofferdam using I-shaped members bent about their strong axis to form the ring walls. This efficient structural system allowed a large workspace that was unimpeded by internal bracing.

1.3.3 Specialty Bends

Specialty bends are used primarily for spiral stairs providing access for circular vessels and for monorail beams with compound curves, as shown in Figure 2-6(a). Helical strakes, which are protruding fins that can be connected near the top of slender stacks to suppress vortex-induced vibration, are shown in Figure 2-10.

Fig. 1-1. Vertically curved roof under construction (courtesy of AISC Bender/Roller Committee).