CHAPTER 14

Welded Connections

14.1 GENERAL

Welding is a process by which metallic parts are connected by heating their surfaces to a plastic or fluid state and allowing the parts to flow together and join (with or without the addition of other molten metal). It is impossible to determine when welding originated, but it was at least several thousand years ago. Metal-working, including welding, was quite an art in ancient Greece three thousand years ago, but welding had undoubtedly been performed for many centuries before that. Ancient welding probably was a forging process in which the metals were heated to a certain temperature (not to the melting stage) and hammered together.

Although modern welding has been available for many years, it has come into its own only in the last few decades for the building and bridge phases of structural engineering. The adoption of structural welding was quite slow for several decades, because many engineers thought that welding had two major disadvantages: (1) Welds had reduced fatigue strength, compared with riveted and bolted connections, and (2) it was impossible to ensure a high quality of welding without unreasonably extensive and costly inspection.

These attitudes persisted for many years, although tests began to indicate that neither reason was valid. Regardless of their validity, these views were widely held and undoubtedly slowed down the use of welding—particularly for highway bridges and, to an even greater extent, railroad bridges. Today, most engineers agree that welded joints have considerable fatigue strength. They will also admit that the rules governing the qualification of welders, the better techniques applied, and the excellent workmanship requirments of the AWS (American Welding Society) specifications make the inspection of welding a much less difficult problem. Furthermore, the chemistry of steels manufactured today is especially formulated to improve their weldability. Consequently, welding is now permitted for almost all structural work.

On the subject of welding, it is interesting to consider welded ships. Ships are subjected to severe impactive loadings that are difficult to predict, yet naval architects use

Roof framing for Cherokee Central Schools, Cherokee, NC. (Courtesy of CMC South Carolina Steel.)

all-welded ships with great success. A similar discussion can be made for airplanes and aeronautical engineers. The slowest adoption of structural welding was for railroad bridges. These bridges are undoubtedly subjected to heavier live loads, larger vibrations, and more stress reversals than highway bridges; but are their stress situations as serious and as difficult to predict as those for ships and planes?

14.2 ADVANTAGES OF WELDING

Today, it is possible to make use of the many advantages that welding offers, since the fatigue and inspection fears have been largely eliminated. Following are several of the many advantages that welding offers:

1. To most designers, the first advantage is economic, because the use of welding permits large savings in pounds of steel used. Welded structures allow the elimination of a large percentage of the gusset and splice plates necessary for bolted structures, as well as the elimination of bolt heads. In some bridge trusses, it may be possible to save up to 15 percent or more of the steel weight by welding.
2. Welding has a much wider range of application than bolting. Consider a steel pipe column and the difficulties of connecting it to other steel members by bolting. A bolted connection may be virtually impossible, but a welded connection presents few difficulties. Many similar situations can be imagined in which welding has a decided advantage.
3. Welded structures are more rigid, because the members often are welded directly to each other. Frequently, the connections for bolted structures are made through

intermediate connection angles or plates that deform due to load transfer, making the entire structure more flexible. On the other hand, greater rigidity can be a disadvantage where simple end connections with little moment resistance are desired. In such cases, designers must be careful as to the type of joints they specify.

4. The process of fusing pieces together creates the most truly continuous structures. Fusing results in one-piece construction, and because welded joints are as strong as or stronger than the base metal, no restrictions have to be placed on the joints. This continuity advantage has permitted the erection of countless slender and graceful statically indeterminate steel frames throughout the world. Some of the more outspoken proponents of welding have referred to bolted structures, with their heavy plates and abundance of bolts, as looking like tanks or armored cars compared with the clean, smooth lines of welded structures. For a graphic illustration of this advantage, compare the moment-resisting connections of Fig. 15.5.
5. It is easier to make changes in design and to correct errors during erection (and less expensive) if welding is used. A closely related advantage has certainly been illustrated in military engagements during the past few wars by the quick welding repairs made to military equipment under battle conditions.
6. Another item that is often important is the relative silence of welding. Imagine the importance of this fact when working near hospitals or schools or when making additions to existing buildings. Anyone with close-to-normal hearing who has attempted to work in an office within several hundred feet of a bolted job can attest to this advantage.
7. Fewer pieces are used, and as a result, time is saved in detailing, fabrication, and field erection.

14.3 AMERICAN WELDING SOCIETY

The American Welding Society's *Structural Welding Code*[1] is the generally recognized standard for welding in the United States. The AISC Specification clearly states that the provisions of the AWS Code apply under the AISC Specification, with only a few minor exceptions, and these are listed in AISC Specification J2. Both the AWS and the AASHTO Specifications cover dynamically loaded structures: Generally, the AWS specification is used for designing the welds for buildings subject to dynamic loads.

14.4 TYPES OF WELDING

Although both gas and arc welding are available, almost all structural welding is arc welding. Sir Humphry Davy discovered in 1801 how to create an electric arc by bringing close together two terminals of an electric circuit of relatively high voltage. Although he is generally given credit for the development of modern welding, a good many years elapsed after his discovery before welding was actually performed with the electric arc. (His work was of the greatest importance to the modern structural world, but it is

[1] American Welding Society, *Structural Welding Code-Steel*, AWS D.1.1-00 (Miami: AWS, 2006).