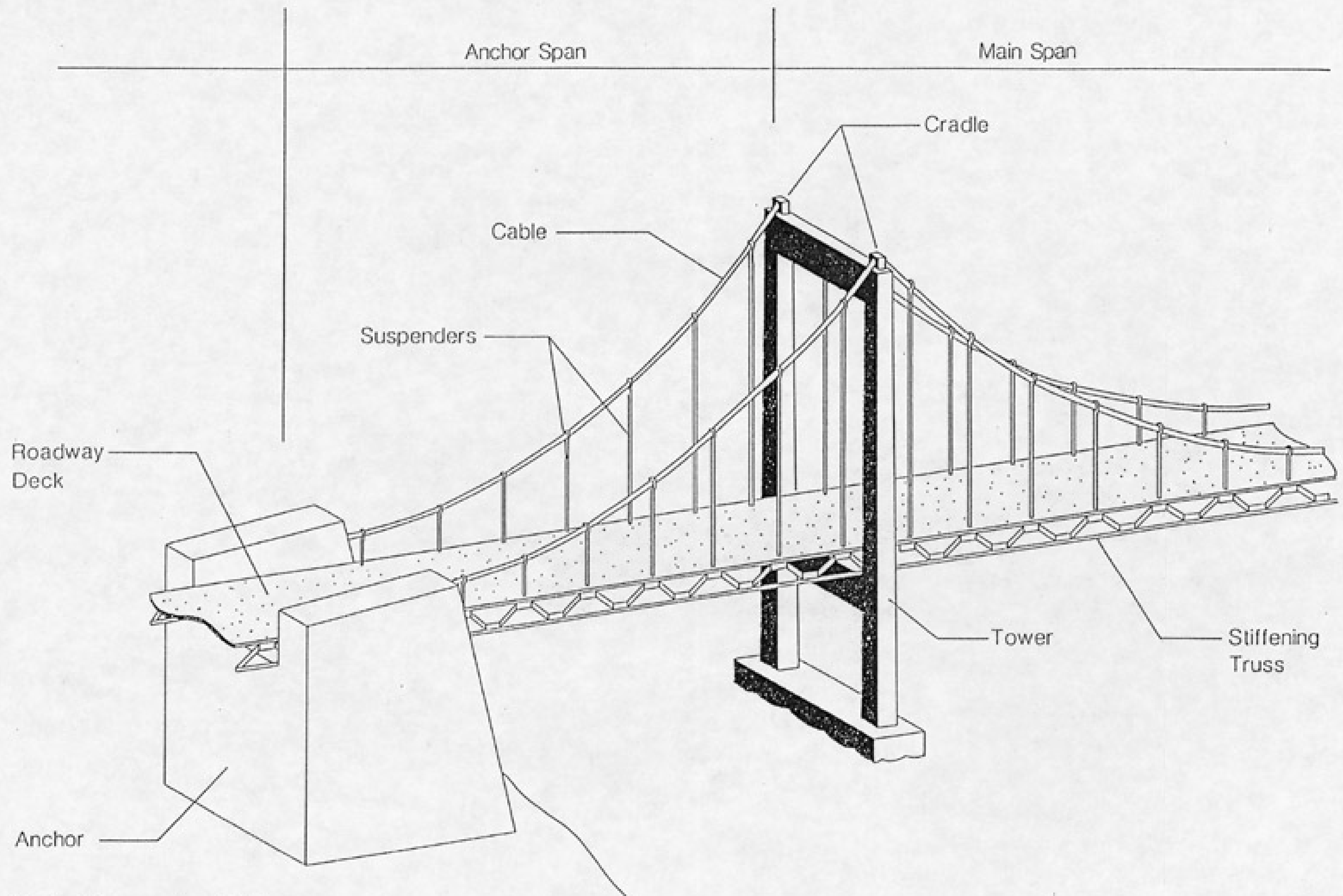
SECTION VIII: METAL SUSPENSION, ARCH, AND CANTILEVER BRIDGES

Based on historical research and review of Maryland Historical Trust historic resource survey forms, it appears that few metal suspension, metal arch, and metal cantilever bridges are extant in Maryland. Structures exemplifying the development of these three bridge types, however, were built in the state from the beginning of the nineteenth century. Although there are few surviving nineteenth century suspension, metal arch, or cantilever bridges in the state, these structural types are well represented by important Maryland bridges built between 1940 and 1955. For this reason, each of these types deserves some discussion in any context for the evaluation of historic bridges in Maryland.

HISTORICAL DEVELOPMENT: METAL SUSPENSION BRIDGES

Many technological historians have asserted that the suspension bridge is one of the oldest bridge types in the world. There is documentation that such bridges were utilized in a range of non-Western ancient societies, notably in the Far East (Tibet, China) and South America (Peru and Bolivia, areas in the former Inca Empire). Such early bridges utilized the basic principle of suspension bridges--the hanging, or suspension, of a walkway or roadway from a rope or bundle of vines anchored at both ends. A major technological advance, attributed to Tibetan bridge builders, occurred when the walkway or roadway, previously laid directly on the rope or cable, was attached instead to hangers, or suspenders, between the rope or cable and the deck. Although this innovation meant that the anchor points had to be higher in order to bring the deck level with the proper grade of an existing approach roadway, the use of suspenders opened technology to possibilities for stiffening the deck, thereby decreasing the tendency of the bridge to swing or twist under loads or wind-generated force (Lay 1992).

As suspension bridge technology became more refined, a range of cable systems was developed (Figure 16). Chain links, wire ropes, and twisted strand cables (bundled and wrapped) were employed. Besides the cables, the roadway deck, and the suspenders, the basic components of a modern suspension bridge include towers, over which are draped the cables (held in place there by saddles or cradles), and heavy masonry abutments (or anchorages) where the cables descending from the tower tops are securely anchored. This typical design configuration results in division of the bridge into a main span and two side, or anchor, spans, with approach spans often of other structural types. Suspenders on the bridges (consisting of eyebars, rods, or steel ropes) are usually spaced at equal intervals and are vertical. On twentieth century structures,



Typical Suspension Bridge

FIGURE 16: Typical Suspension Bridge

SOURCE: Pennsylvania Historical and Museum Commission and Pennsylvania Department of Transportation 1986 the suspenders usually connect to the cables by means of bolted bands. The tendency of suspension bridge cables to deflect (swing or twist under the application of loading) is typically counteracted by the stiffening of the deck with a truss system beneath it, although this system was preceded by use of long floor joists extending across several beams (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:77).

Suspension bridges are highly significant in the history of American bridge technology because they were the earliest all-iron bridges constructed in the United States. Modern suspension bridge technology was largely pioneered by three distinguished suspension bridge builders active in the early nineteenth century, James Finley, Charles Ellet, and John A. Roebling. Finley, a judge and self-trained bridge constructor from Fayette County, Pennsylvania designed and built the first known suspension bridge in the United States over Jacob's Creek, at Uniontown, Pennsylvania, in 1801. Thereafter, some 40 Finley suspension spans were built. Finley's so-called "chain" bridges incorporated for the first time in the Western Hemisphere the use of suspenders to carry the deck at a level with the approaching roadway (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:76-79).

The Finley spans were "chain" bridges because their cables were composed of wrought iron chains made of square bars, formed into links often ranging from 5 to 10 feet in length. Finley's Jacob's Creek span featured one-inch square bars, with vertical suspenders of varying lengths attached to each chain link and carrying the roadway's timber floor beams by means of a stirrup-like arrangement. Finley's earliest bridge was 13 feet wide and spanned 70 feet; later bridges he built, such as the famous 1807 "Chain Bridge" on the Potomac above Georgetown and a span constructed to his patent in about 1820 at Will's Creek near Cumberland in Maryland, were longer and wider, but generally followed the same chain-dependent design as his early spans. Construction of such chain bridges generally involved careful movement into place of the entire cables, which were lifted into position over the masonry towers and secured by various means to the abutments (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:79).

Wire rope for cables was first employed in 1816, for a private toll footbridge over the Schuylkill built by Josiah White and Erskine Hazard, who were co-owners of a Philadelphia wire concern. In England in 1826, highway and bridge engineer Thomas Telford, aware of Finley's accomplishments, designed the first large-scale suspension bridge in the world, over the Menai Straits. Two years later, the world's first all-steel suspension span was erected over the Danube Canal in Vienna, anticipating twentieth century structures (DeLony 1993:2-3). Under the impetus provided by the Finley spans, the White-Erskine bridge, and the European suspension bridges of the 1820s, American suspension bridge design was again materially advanced by the contemporaries and occasional rivals in the field, Charles Ellet and John A. Roebling. Although the Erskine-White wire rope structure had collapsed, wire rope spans were revived in the United States by Ellet, who had studied Europe's suspension bridges. In 1841-1842, Ellet's first major wire suspension bridge replaced Lewis Wernwag's covered timber "Colossus" bridge over the Schuylkill (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:80).

Between 1846 and 1849, Ellet designed and built his most significant structure, the Wheeling suspension bridge at Wheeling, West Virginia, whose 1,100-foot span was for many years the longest in the world. Ellet's scholarly biographer, Gene Lewis, uncovered no evidence that any Ellet suspension bridges were built in Maryland, but it is certain that Ellet proposed in 1832 and again in 1854 to erect suspension spans over the Potomac on a scale equivalent to that of the Wheeling Bridge (Ellet 1854; Lewis 1968; Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:80). John Roebling also is not known to have designed and constructed any Maryland bridges, but his signal advance, the method of building a cable in place by "spinning" or "stringing" it using a traveling sheave, dramatically affected suspension bridge technology in the nineteenth and twentieth centuries. Roebling's bridges, such as his masterpiece the 1883 Brooklyn Bridge, largely built by his son Washington, had thick cables composed of such spun wires grouped into strands and then bound together in a circular geometric form. The cables were typically clamped at intervals for attachment of the suspenders (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:82-83).

With adoption of the Ellet and Roebling techniques, twentieth century suspension bridge technology, like other types of bridge engineering, has been characterized by scientific analysis of suspension, stiffening, and anchoring principles, resulting in the design and construction of ever-larger suspension spans. During the mid-1920s, Allegheny County, Pennsylvania, Chief Engineer Vernon R. Covell designed three innovative Allegheny River suspension bridges at Pittsburgh. Lacking heavy anchorages or abutments, these spans were self-anchored because their cables at the ends were attached to a stiffening, underdeck truss system running the full length of the bridge. The stiffening truss acted like a compression member to resist the tension of the suspended cables. Covell's bridges also were the first major pin-connected eyebar chain bridges built since the previous century; their employment of eyebars, however, led to increased wear and was not generally followed in subsequent twentieth century bridge construction (Pennsylvania Historical and Museum Commission, and Pennsylvania Department of Transportation 1986:82-84).

Significant large suspension spans of the twentieth century include Othmar Ammann's 1931 George Washington Bridge, which reached a wire cable strength of 240,000 pounds per square inch (compared to the Brooklyn Bridge's 160,000 p.s.i); the 1937 Golden Gate Bridge designed by Joseph Strauss, with innovative cofferdams utilized to sink the pneumatic caissons into the bay floor; and New York City's 1964 Verrazano Narrows Bridge, also designed by Ammann, in which the compacted cables are splayed into individual strands wrapping around massive eyebars embedded in the concrete anchorages. These bridges employed essentially the basic technology of suspension bridges in the United States, on a large scale, as pioneered by Finley, and especially Ellet and Roebling during the early nineteenth century (DeLony 1993:138-139, 143-145).