Al-Mustansiriyah University
College of Engineering
Highway & Transportation Department
4th Year Stage/ Lecture Notes
Subject Code: 506064052

Design of Steel Bridges Structures

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Al-Mustansiriyah Bridges/ Steel Part at Middle

1. Superstructures Forms of Steel Bridges

1.1. Slab-Steel Beam Bridges

The common forms of steel bridges, utilized for short- and medium-span highway structures and variously referred to as slab-steel beam, slab-stringer and slab-steel girder. Structurally, they consist of rolled steel beams (W-shapes) parallel to traffic with usually equally spaced transversely to support a reinforced concrete deck (Figure 1.1). For longer spans in the 100 - 200 ft range, plate girders are used. Plate girders are simply built-up steel beams fabricated from two flange plates and a web plate, the webs being deeper than those available with the deepest rolled beams. Steel plate girder bridges are particularly suitable for bridges curved in plan.

1.2. Orthotropic Steel Bridges

These forms are characterized by stiffened steel plate decks supported on longitudinal girders (I-beams or box beams), thus called orthotropic bridges or orthotropic steel deck bridges (Figure 1.2). Orthotropic bridges are lightweight, very economical and possessed excellent structural characteristics. These bridge types evolved in Europe primarily Germany the longest structure of this type in the world has 5542 ft spans and built to across San Francisco Bay, California.

1.3. Composite Steel Box Girder Bridges

Composite steel box girder bridges are suitable for single spans longer than 75 ft and for continuous spans longer than 120 ft. These are tubular bridge superstructures in which the bottom flange and the web are fabricated from steel plate while the deck is made from reinforced concrete, hence they are termed as composite. A box girder may be a single-cell, twin-cell or multiple-cell (multicellular) structure (Figure 1.3). Alternatively, a steel box girder may have two or more separate closed cross sections with reinforced concrete deck also known as multispine bridge. The webs of box girders may be vertical or inclined; the latter gives the advantage of narrower bottom flange. The top flange widths are usually wider enough to provide the required bearing surface for the concrete deck supported on them as well as for placement of shear connectors necessary to develop composite action.

Because of their closed cross sections, box girder bridges possess high strength and torsional rigidity in comparison with an equal number of open cross sections such as rolled beams or plate girders. Their high torsional strength makes them the most suitable for curved bridges that are inherently subjected to torsional moments. Also, they are preferred for grade separation structures in urban areas. From architectural wise, the inclined webs of a box girder give the bridge an aesthetically pleasing appearance.

1.4. Delta Frame Steel Bridges

Delta frame bridges are essentially rigid frame structures that consist of superstructures supported on vertical or inclined monolithic legs (columns) as shown in Figure 1.4. They are considered economically suitable for medium-span lengths. For analytical purposes, delta frame bridges may be treated similar to two-hinged or fixed arches. The only difference is that instead of generally accepted form of continuous smooth curve of an arch axis, a rigid frame bridge with inclined legs has an arch axis that is trapezoidal in form and a rigid frame bridge with vertical legs has a rectangular form.

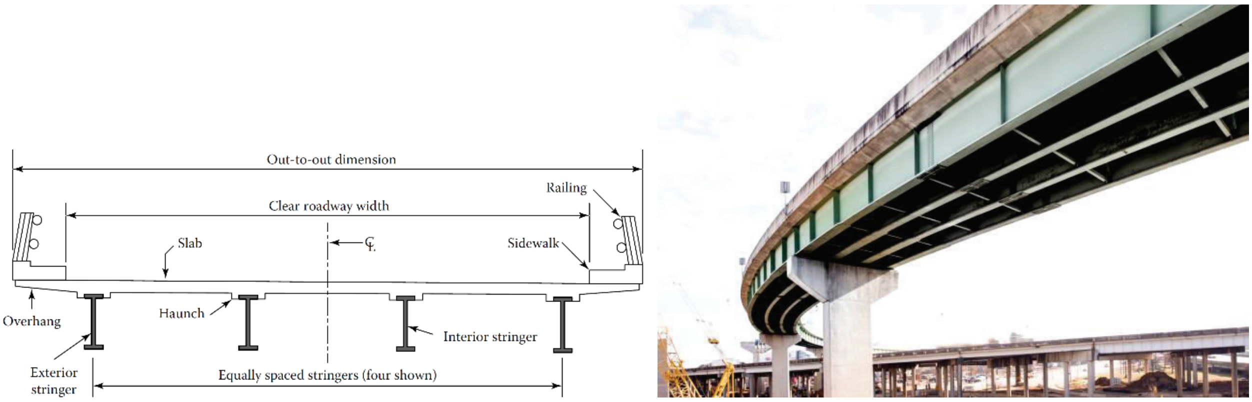

Figure 1.1: Slab-Steel Beam Bridges

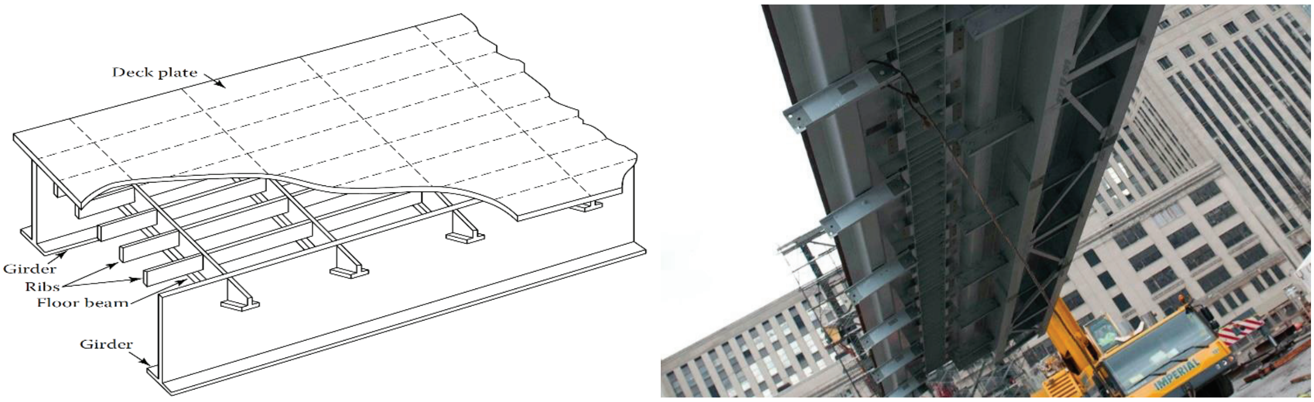

Figure 1.2: Orthotropic Steel Bridges

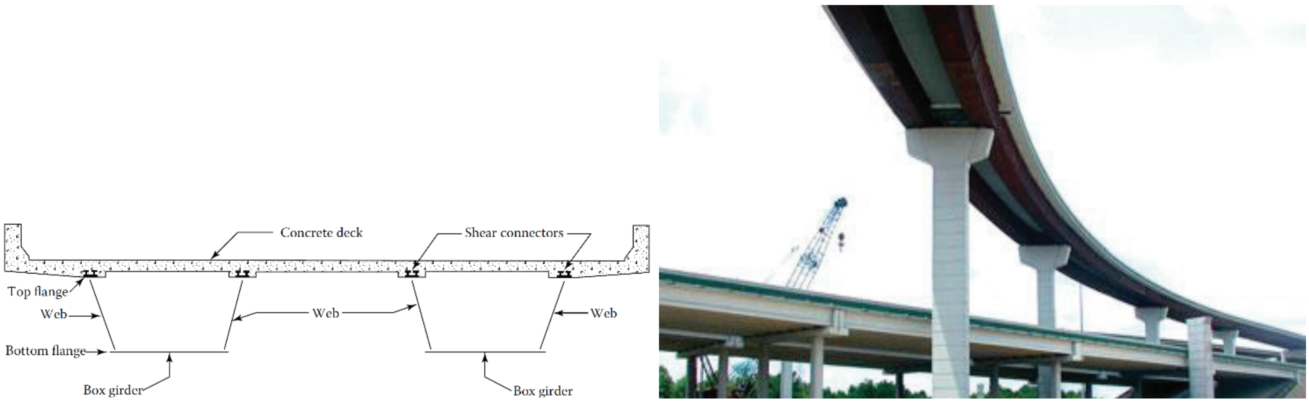

Figure 1.3: Composite Steel Box Girder Bridges

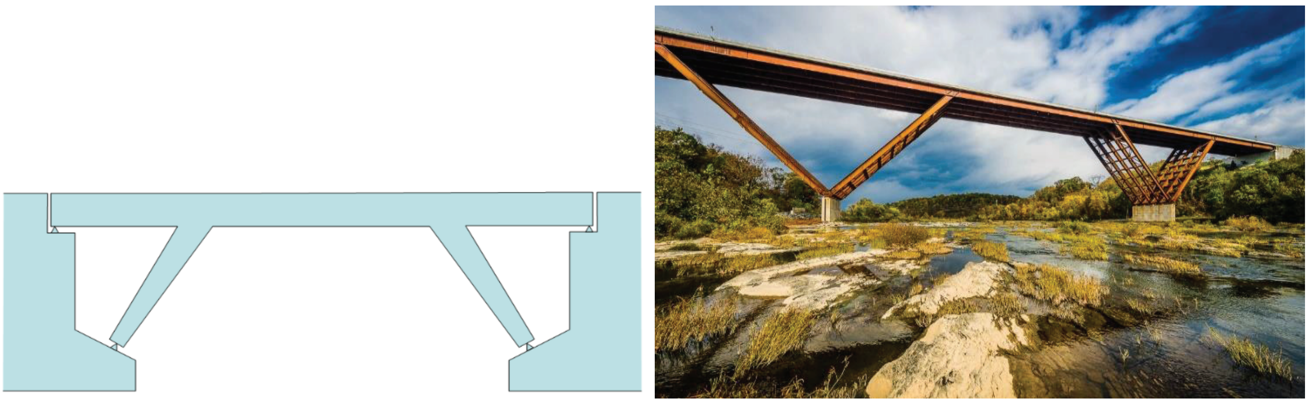

Figure 1.4: Delta Frame Steel Bridges

2. General Considerations for Steel Bridges

2.1. Corrosion Considerations

The corrosion problem is particularly acute when the steel bridge is not protected or maintained properly. The accumulation of salt and water is considered the primary cause of corrosion in highway steel bridges. So, corrosion-resistant steel may be used to mitigate the corrosion problem. There are five main forms of corrosion are identified in steel bridge:

2.1.1. General Corrosion

The common form of corrosion, refers to the general loss of surface material over time, leading to gradual thinning of members. Because this corrosion type can be extreme resulting in the loss of cross-sectional area of the members, the load-carrying capacity is threatened to be lost (Figure 2.1).

2.1.2. Pitting Corrosion

This corrosion type of also causes loss of material, although it is localized and restricted to small areas. Pits can be characterized as rolled-in imperfections that can be dangerous, for they inconspicuously extend into the metal. Their presence in high-stress regions becomes a source of stress concentration.

2.1.3. Galvanic Corrosion

This corrosion occurs when two dissimilar metals are electrochemically coupled. For example, in welded or bolted connections, the bolt metal is different from the weld metal. The iron oxide forms on structural steel after hot rolling can galvanically encourage corrosion of the underlying base metal.

2.1.4. Crevice Corrosion

Refers to corrosion that occurs in small confined areas such as peeling paint between faying surfaces or at pit locations.

2.1.5. Stress Corrosion

Refers to tensile loading of metal in a corrosive environment. An existing crack on a metal's surface spreads gradually under repetitive loading (fatigue). However, formation of rust at the crack tip accelerates this spreading of the crack.

Figure 2.1: Corrosion of Structural Steel in Bridges

2.2. Construction Considerations

Bridges should be designed in a manner guarantees that fabrication and erection can be performed without probability of failure or deformed in degree out of the acceptable levels of deflection, strength of materials and stability during construction.

2.2.1. Shored Construction

In beam-type of steel bridges, the beams are installed between the end supports and supported at intermediate points by temporary shores placed at close intervals. The temporary shores keep these beams in almost undeformed condition during construction and hardening period of fresh concrete poured to produce the deck slab. While shored construction is permitted according to LRFD Specifications, its use is not recommended due to further costs.

2.2.2. Unshored Construction

In this way of construction, the beams are installed between the end supports, and concrete is poured. Until the concrete hardens, the loads due to dead weight of the beams and concrete are resisted by the steel section alone. Permanent loads and live load applied after hardening of concrete are assumed to be resisted by the composite section of the deck slab and supporting beams.

2.3. Mechanical Properties of Steel for Highway Bridges

The following design properties shall be used for all grades of structural steel used in design of:

- Modulus of Elasticity

$$E_s = 29\text{x}10^3 \text{ ksi}$$

- Coefficient of Thermal Expansion

$$\alpha_s = 6.5\text{x}10^{-6}\ /°\text{F}$$

- Tensile Strength

Specified yield strength (F_y) also called as steel grade and the specified minimum ultimate or tensile strength (F_u) are tubulated below.

Table 2.1: Minimum Tensile Strength of Structural Steel [AASHTO LRFD Table 6.4.1-1]

Designation		Grade	F_y ksi	F_u ksi
AASHTO	Equivalent ASTM			
M 270M/M 270	A709/A709M	36	36	58
		50	50	65
		50S	50	65
		50W	50	70
		HPS 50W	50	70
		HPS 70W	70	85
		HPS 100W	90	100
			100	110

2.4. Noncomposite and Composite Sections

The basic layout for a slab-steel girder bridge consists of a concrete deck slab supported over steel beams. From the manner of how the basic steel girder is connected to its supported concrete deck slab, the entire section act as composite or noncomposite.

2.4.1. Noncomposite Sections

When the deck is not physically connected to the girders by shear connectors, the deck merely sits on girders and transfers loads by bearing on them. In this case, steel girders are alone designed to carry the entire gravity load on the bridge and referred to as noncomposite sections. Noncomposite sections are not recommended because they demand larger sections and they are relatively uneconomical.

2.4.2. Composite Sections

When the top flanges of steel girders are provided with welded shear connectors that embedded in the bottom of the concrete deck during pouring. The dead load of the deck is resisted by the steel girders alone by bearing. After the concrete hardens, subsequent loads (superimposed dead load and the live load) on the superstructure are resisted by the girders and the deck acting as a unit. In such case, girder sections are designed and referred to as composite section.

2.5. Hybrid Steel Girders

A hybrid girder is a girder fabricated from two different grades of steels, typically with a web of lower-grade steel and one or both flanges of higher-grade steel. It is recommended that the difference in the specified minimum yield strengths of the web and higher-strength flange preferably be limited to one steel grade. Such girders are believed to possess greater design efficiency.

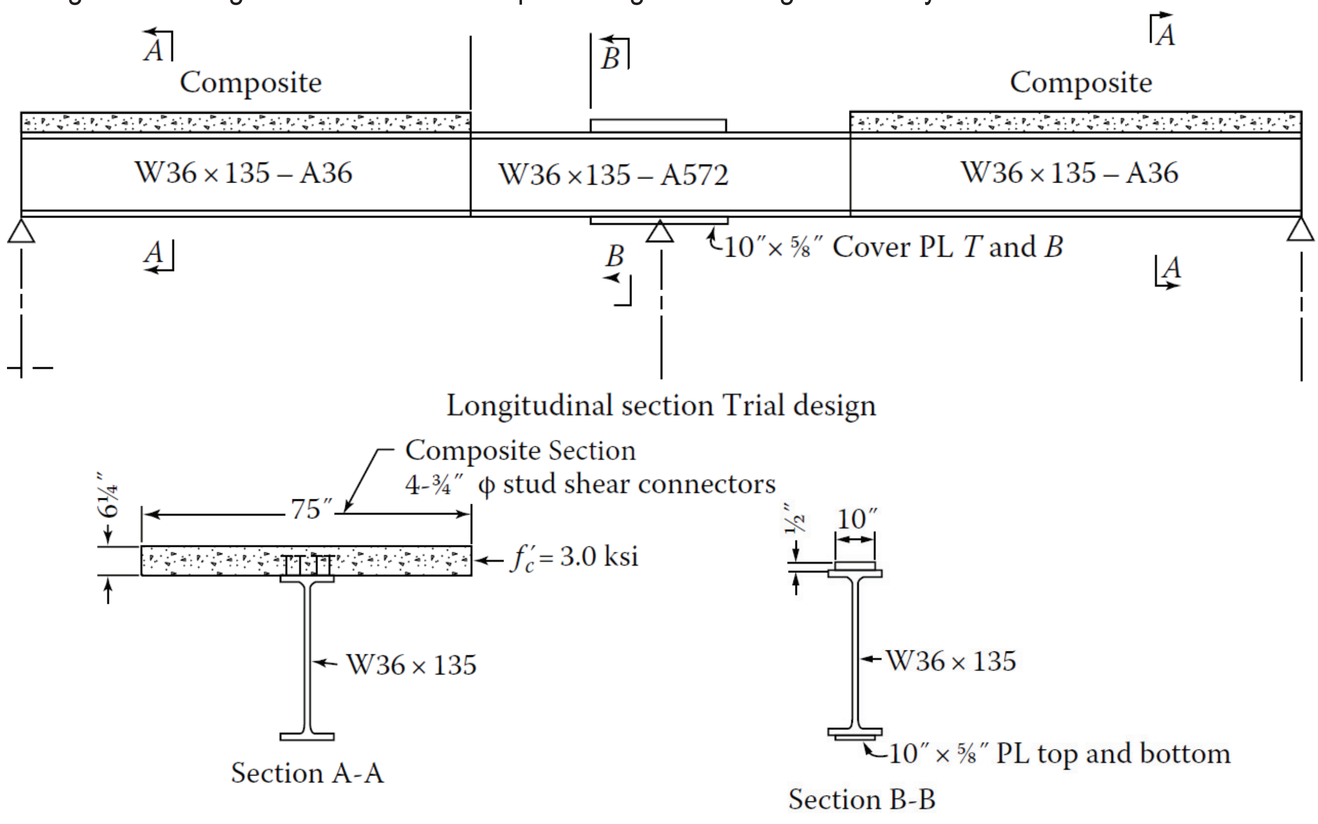

Figure 2.2: Hybrid Steel Girder