Project Summary

Texas Department of Transportation

0-4307: Steel Trapezoidal Girders: State of the Art

Background

Since 1995, the Texas Department of Transportation (TxDOT) has funded several studies on trapezoidal box girders. The research in these studies was some of the first detailed work on curved box girders that had been carried out in nearly twenty years. Although the studies considered the fundamental behavior of the girders themselves, the primary focus of the work was dedicated towards improving the understanding of bracing systems for the box girders. While significant progress was made to that end, there were still a number of issues related to the design and behavior of box girder systems that were not well understood. In addition, much of the material was summarized in lengthy research reports that included laboratory testing, field measurements, and finite element analytical parametric investigations. While there was a wealth of material in these reports, the bulky sizes of the reports were not conducive for use by first-time designers of curved box girders.

What the Researchers Did

The impetus for project 0-4307 was to consolidate the previous research reports into a more concise document, as well as to develop design procedures for some of the elements of curved box girders that were not yet well understood. While the previous studies included laboratory testing, field monitoring, and finite element analytical (FEA) investigations, additional work on this project was to be completed with parametric FEA studies. Based on the synthesis and analysis of previous studies, the researchers produced a design guide consisting of five chapters that should provide assistance to designers in preliminary sizing of the box girders. In addition, suggested details are discussed throughout the document based upon the experiences of researchers and TxDOT designers over the past decade.

The design guide provides a concise overview of many of the important issues that designers need to consider, and contains recommended details. It consists of the following:

Chapter 1: Provides an overview of the geometry of box girders, as well as a discussion of the different types of bracing that are utilized in box girder construction. The chapter also provides a brief overview of torsional theory and defines the scope of the design guide.

Chapter 2: Provides a brief overview of the common analytical methods that are used for box girder systems. The simplest method is the M/R method that modifies the analysis results for an equivalent straight bridge. The basic techniques that are applied in grid models are then discussed. Most commercially available programs for curved girders are based upon simplified grid techniques.

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The most accurate method of analysis generally employs three-dimensional finite element techniques in which the girder cross-section and the braces are specifically modeled. The overview of three-dimensional modeling primarily focuses on the use of the program UTrAp, which was developed on a TxDOT supported project and is free for engineers to download. The software includes a graphical user interface (GUI) to simplify the modeling.

Chapter 3: Focuses on the role of the top flange lateral truss at improving the torsional stiffness of the steel girders during erection and construction. The equivalent plate method that is used to convert the girders to a quasi-closed box for the analysis is discussed. In addition, an overview of the effects of vertical bending on the truss is presented and the pros and cons of different details are discussed.

Chapter 4: Discusses the purpose and behavior of internal K-frames. The chapter begins by providing an overview of box girder distortion and then presents equations that can be used to determine design forces in the internal K-frames. Recommendations for the suggested K-frame detailing are provided, such as the spacing that generally leads to the best behavior in the internal bracing systems.

Chapter 5: Reviews the behavior and purpose of external diaphragms that are provided at the supports, as well as at intermediate locations along the girder length. A discussion of deformational behavior of the girders without external intermediate braces is provided, as well as the development of an approximate expression that can be used as a guide to determine spacing requirements for the intermediate external braces. Equations are also provided for the forces in the external K-frame. Expressions are also given for the sizing of solid plate diaphragms located at the supports of the box girders. Both stiffness and strength requirements were developed for the external braces.

What This Means

The design guide provides a concise reference for designers to understand the behavior of trapezoidal box girders and obtain critical information regarding necessary design details.

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