SECTION I

STRESS CONCENTRATION DUE TO SHEAR LAG IN SIMPLY SUPPORTED BOX GIRDERS WITH LONGITUDINAL STIFFENERS AND CONTINUOUS BOX GIRDERS

CHAPTER 1

INTRODUCTION

1.1 General

The use of thin-walled components in structural applications has increased steadily due to their efficiency both on load-carrying capacity and economization. In particular, thin-walled components are extremely useful structures for supporting and distributing loads. The advantage of thin-walled structures is that the material is efficiently used both in flexure and torsion, and thus leading to considerable saving in material, particularly when self-weight is important. Girders such as box, I- and other rolled sections have long been used in structural engineering, and it is generally assumed that the magnitude of the normal stresses in longitudinal direction does not vary over the width of the flange at a given cross section.

With the development of light-weight constructions of different kinds, there is, however, at present a definite trend toward the use of I-, T-, box, and other sections of considerable width and rather small thickness. Structural members of such kind are therefore widespread in modern buildings and bridges. In connection with the welding technique, the construction of this class of structures, which needs the connection between flange and web becomes more convenient. In real behavior, due to such connections, the complication of stress state takes place.

Several investigations have been undertaken to ascertain weather in such cases the normal stress still probably assumed to be uniformly distributed over the width of the flange. It was found that in wide-flange girders the normal stress distribution considerably deviates from uniformity. The elementary beam theory, which assumes the uniform stress distribution over the width of the flange is no longer able to describe this occurrence. The elementary beam theory cannot be used to represent actual behaviors not only for the stress but also the deflection in this class of structures. This non-uniformity in both stresses and deflections must be studied and should be taken into account for a reasonable design of such structures.

1.2 Problem Statement

In the elementary beam theory, the normal stress in the longitudinal direction (σ_Y) produced by bending deformation is assumed to be proportional to the distance from the neutral axis and therefore uniform across the flange width. However, as a flange gets wider, this assumption becomes invalid: the normal stress distribution is not uniform in the wide flange, but the stress is maximum in general at the flange-web intersection, decreasing toward the middle of the flange. This phenomenon is called the shear lag as shown in Figure 1.1. In the elementary beam theory, σ_Y produced by bending deformation is assumed to be proportional to the distance from the neutral axis and therefore uniform across the flange width. In thin-walled structures, as a flange gets wider, this assumption becomes invalid. Accordingly, the elementary beam theory cannot be used to predict σ_Y correctly.

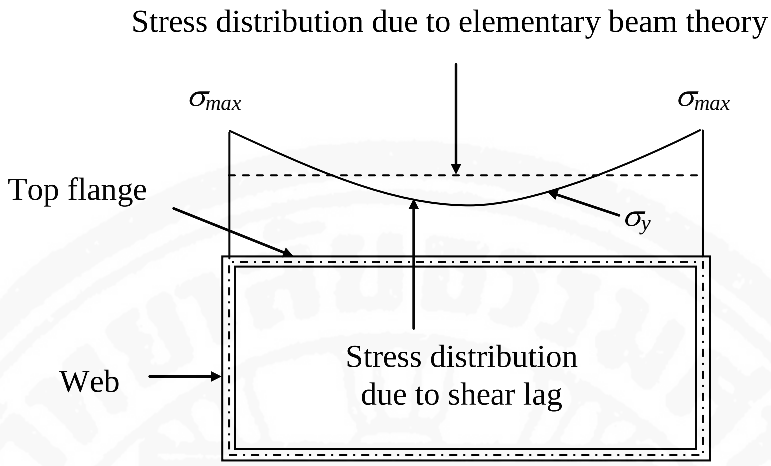

Figure 1.1 Stress distribution due to shear lag

Shear lag effects are usually very large, especially near points of high concentrated load or at reaction points in short span beams with thin-wide flanges. In particular, shear lag effects may be significant in light-gauge, cold-formed sections and in stiffened box girders. Shear lag has no serious consequences in a ductile structure, in which any premature local yielding leads to a favorable redistribution of stress. However, the increased stress due to shear lag may induce in a tension flange, which is liable to brittle fracture or fatigue damage, or in a compression flange whose strength is controlled by its resistance to local buckling (Trahair and Bradford 1988).

The early studies on shear lag are based on analytical approach. Timoshenko and Goodier (1970) have documented one of the earliest researches due to Von Karman (1924). Reissner (1941, 1946) used the principle of minimum potential energy to formulate the governing differential equation and boundary conditions. The previous study confirmed by the present FEA that the shear lag depends on loadings conditions (Reissner, 1941, Moffatt and Dowining 1975, Song and Scordelis 1990, Lertsima et al. 2004, Yamaguchi et al. 2008). Although many research focus on shear lag problem, there are only a few research on the shear lag in stiffened box girder. Tenchev (1996) and Eurocode 3 (2003) presented the solution for shear lag effect on plates with stiffeners. The concept of effective width ratio was used to take care of the effect of shear lag. Tenchev (1996) analyzed the shear lag in orthotropic beam flanges and plates with stiffeners by using two-dimensional plane stress finite element model. The empirical formula of shear lag coefficient was obtained in term of ratios of half flange width to half length of beam, Young’s modulus to shear modulus of flange, and thickness of flange to thickness of web. Longitudinal flange stiffener has been accounted for by modifying the ratio of Young’s modulus to shear modulus. Similarly Eurocode 3 (2003) also gave the design of effective width factor in term of the ratios of half the width to span length, and the ratio of stiffener area to flange area.

In addition, continuous girders are quite common structures in practice. Engineers dealing with ordinary box girders for highway bridges and buildings need not be daunted by the stress concentration due to shear lag. However, there are indeed some special cases of short stocky members, so that design codes provide formulas to account for the shear lag effect. Nevertheless, there appears to be very few research results available in the literature on the shear lag effect of continuous girders. Besides, Japan (2002) and Eurocode 3 (2003) yield very different shear lag effects, which will be shown later in Chapter 4.

1.3 Objectives and Scope of the Study

This study aims to investigate the shear lag effect on stress concentration at the mid-span of simply supported box girder with longitudinal stiffener and continuous box girders. The stress concentration due to shear lag effect is presented in term of *Kc* which stands for the stress concentration factor defined by the ratio of the maximum normal stress in the flange to that of the elementary beam theory. In the finite element analysis, three-dimensional shell element is used. The local effects due to boundary and loading conditions are carried out. Various values of geometric properties of a box girder are also considered. MARC (1994), a finite element program is used in this finite element analysis. Based on the numerical results, empirical formulas are presented to simplify the shear lag effect and to make them useful to the design engineer.

The objectives of this study can be summarily written as

1. To apply the finite element analysis to study the stress concentration due to shear lag in simply supported box girder with longitudinal stiffener.
2. To apply the finite element analysis to study the stress concentration due to shear lag in continuous box girders.
3. To study the effects of the geometric properties of box girder, i.e., half flange width (B), span length (L), height of web (H), thickness of flange (T_f), thickness of web (T_w), cross sectional area of the stiffeners (A_s), and cross sectional area of the flange (A_f).
4. To propose the empirical formula to compute stress concentration due to shear lag effect in simply supported box girder with longitudinal stiffener.
5. To propose the empirical formula to compute stress concentration due to shear lag effect in continuous box girders.

In chapter 3 and 4, 3D FEA of simply supported box girders with longitudinal stiffeners and continuous box girder with different geometries by shell elements are carried out. In both chapters, multi-mesh extrapolation method is used to improve the solution accuracy. Two loading conditions of concentrated load at the mid span and uniformly distributed load along the girder length are employed for simply supported box girders with longitudinal stiffeners. Multiple ways to apply those loads are considered. The shear lag effect on stress in simply supported box girder with longitudinal stiffeners depends upon the geometric properties of box girders in term of H/L, B/H, T_f/T_w, and A_s/A_f. For the continuous box girder, a uniformly distributed load is applied as a line load along the centerline of the web. The geometric properties are considered in term of H/L, B/H, T_f/T_w, and α.