Design of steel and structure engineering essay

A plate girder bridge is a bridge supported by two or more plate girders. The plate girders are typically I-beams made up from separate structural steel plates (rather than rolled as a single cross-section), which are welded or, in older bridges, bolted or riveted together to form the vertical web and horizontal flanges of the beam. In some cases, the plate girders may be formed in a Z-shape rather than I-shape. The first tubular wrought iron plate girder bridge was built in 1846-47 by James Millholland for the Baltimore and Ohio Railroad.[1]

Plate girder bridges are suitable for short to medium spans and may support railroads, highways or other traffic. Plate girders are usually prefabricated, and the length limit is frequently set by the mode of transportation used to move the girder from the bridge shop to the bridge site.[2]

Anatomy of a plate girder.

Generally, the depth of the girder is no less than 1/15 the span, and for a given load bearing capacity, a depth of around 1/12 the span minimizes the weight of the girder. Stresses on the flanges near the centre of the span are greater than near the end of the span, so the top and bottom flange plates are frequently reinforced in the middle portion of the span. Vertical stiffeners prevent the web plate from buckling under shear stresses. These are typically uniformly spaced along the girder with additional stiffeners over the supports and wherever the bridge supports concentrated loads.

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2. 0 PLATE GIRDER CONCEPT

The plate girders are used to carry the loads beyond the capacity of universal beams. They consist of plates and angles riveted together. Plates and angles form an I-section. They are used in building construction and also in bridges. Plate girders are economically used for spans up to 30m.

Plate girders are used in both buildings and bridges. In buildings, when large column-free spaces are designed to be used as an assembly hall, for example, the plate girder is often the economical solution.

Plate girders are used extensively in structures such as bridges. There are 2 types of plate girders that can be selected depending on costs. One type of plate girder has a web so slender that transverse stiffeners must be added. Sometimes, longitudinal stiffeners are added as well. The other type of plate girder would have thicker webs and be unstiffened.

Structural members or systems are formed and selected based on design load requirements and cost effectiveness. Rolled shapes with flanges can be used economically with stiffeners at a certain span and/or load. The distance between flanges must increase as the span and/or load increases in order to efficiently carry loads perpendicular to the longitudinal axis. This is because flanges have the largest proportion of a rolled member’s cross-section so they are placed at the extremities to resist moments. When the range of Rolled shapes exceeds the required flange distance, built-up shapes such as plate girders should be used. Plate girders are built-up flexural members with a slender web. The spanning distance for plate girders is typically 25 to 45 m. When the flange distance for plate girders is exceeded, trusses would be used.

The most common type of plate girder is an I-shaped section built up from two lange plates and one web plate as shown in Fig. A. The moment-resisting capacities of plate girders lie somewhere between those of deep standard rolled wide-flange shapes and those of trusses. Plate girders can be welded (Fig. B & C), riveted, or bolted. Riveted plate girders are practically obsolete. Very few bolted plate girders are designed nowadays. Therefore, we cover only the design In common, section used for plate girders are shown in figure.

Plate Girder Nominal Flexural Strength.

Plate girder in a multi-storey building

Welded Plate girder Built-girder with cover plates up girder with T sections

Welded or box girder Riveted bolted plate girder

Simple Plate Girder (B) Elements of Plate Girder

3. 0 Elements of Plate Girder

A vertical plate of the plate girder is termed as web plate.

The angles connected at the top and bottom of web plate are known as flange angles.

The horizontal plates connected with the flange angles are known as flange plates or cover plates.

4. 0 Depth of Plate Girder

The depth between the outer surfaces of the flanges is termed as overall depth (do) or depth of the plate girder.

In general, depth of the plate girder is kept 1/10th to 1/12thof the span. The distance between C. G of compression flange or C. G. of tension flange is known as effective depth of plate girder (de).

The distance between vertical legs of flange angles at the top and at the bottom is known as clear depth of plate girder (d).

5. 0 Noncompact Web plate Girders

The influence of web slenderness on the strength of plate girders limit is not treated as a separate limit state to be assessed through its own set of requirements. Rather web slenderness comes into play as it influences the flange yielding or flange local buckling strength and the lateral-torsional buckling strength The slenderness parameter of the web is defined as

For a plate girder to be compact

Nominal Flexural Strength Based on Flange Local Buckling.

At the lower limit for a noncombat web,

Nominal Flexural Strength Based on Unbraced Length

6. 0 Slender Web Plate Girders.

They are built up members with web slenderness exceeding the limit

The strength of a plate girder as a function of flange slenderness is shown in Figure

7. 0 Homogenous Plate Girder in Bending and Shear

Plate girders are usually subjected simultaneously to bending and shear. In these cases the load-carrying capacity depends on the efficiency of bending and shear loading. Generally, the effect of bending loading is mostly decisive. But in some cases the effect of shear loading can be also significant or even decisive. Therefore, the bending-shear load-carrying capacity should be calculated and taken into consideration for the safety and economical design of plate girders. The bending-shear load-carrying capacity of plate girders depends on several parameters. Besides of loading and static scheme, the geometrical dimensions and material properties are very important. These parameters influence the behaviour and failure of plate girders in significant measure. Therefore, they influence also determination of the bending-shear load-carrying capacity of different plate girders.

In view of geometrical dimensions the cross-sections of plate girders can be compact or slender. In the case of plate girders with compact cross-sections can be utilized the plastic or elastoplastic load-carrying capacity. In the case of plate girders with slender cross-section the elastic or elastoplastic post-critical load-carrying capacity can by utilized. It is advantageous to design the plate girders with compact compression flange and slender – thin web, stiffened in adequate measure by transverse or transverse and longitudinal stiffeners. Regarding material properties the cross-sections of plate girders can be homogeneous or combined from different steels. It is economical advantage to design the hybrid plate girders with flanges from higher strength steels and compact or thin web from middle steel. In the case of plate girders with hybrid compact cross-sections there can be utilized the plastic or elastoplastic load-carrying capacity. In the case of hybrid plate girders with compact compression flange and stiffened thin web the elastoplastic post-critical load-carrying capacity can by utilized.

Plate girders basically carry the loads by bending. The bending moment is mostly carried by flange plates. In order to reduce the girder weight and possibly achieve maximum economy, hybrid plate girders are sometimes used. In a hybrid girder, flange plates are made of higher strength steel than that of the web. Or, in a tee-built-up plate girder, Allowable bending stress for hybrid girders is limited to 0. 60Fy (ASD F1).

8. 0 Preliminary Proportioning

A preliminary design of a plate girder takes the weight of steel and the amount of fabrication into main consideration. Knowing the factored moment and factored shear, and selecting a preliminary yield stress (Fy) and ultimate shear stress (Fs), a designer can first estimate the optimum web depth (h), the area of a flange (Af), and the web thickness (w). Equations1. 1 to 1. 2 are used for this preliminary design.

Equation 2. 1 is used to calculate the optimum web depth based on the factored moment designed for the section.

(1. 1)

Where, h = optimum web depth (mm)

Mf = maximum factored moment (kNm)

Fy = yield stress (MPa)

Equation 1. 2 is used to calculate the area of the flange at the top or bottom of the section. Several assumptions should be noted when selecting this

Preliminary flange size:

Flange material will be able to reach yield.

Web contribution to bending resistance is neglected.

Lateral-torsion buckling will not govern design. Therefore, lateral support is assumed to be at close enough intervals. Flange areas are concentrated at the top and bottom of the web.

(1. 2)

Where, Af = area of flange (m2)

h = optimum web depth (m)

Mf = maximum factored moment (kNm)

Fy = yield stress (MPa)

Equation 1. 3 is used to calculate the area of web (Aw), and hence the web

thickness. The slenderness of the web would usually have the plate girder

fall into Class 3 cross-section category. One assumption to be noted is that

the web carries all the shear (as in rolled shapes)

(1. 3)

Where, w = web thickness (m)

Vf = factored shear force (kN)

Ï† = resistance factor

Fs = ultimate shear stress (MPa)

Fs is function of: 1. Web slenderness (h/w).

9. 0 Stiffeners For Plate Girders

When stiffeners are required for a plate girder, they can be either intermediate stiffeners or bearing stiffeners. Intermediate stiffeners purpose is to increase girder shear strength, either by controlling the buckling strength of the girder web or by permitting the post buckling strength to be reached. These stiffeners are distributed along the girder length and result in panel sizes with aspect ratios that impact girder shear strength. Bearing stiffeners usually occur at the locations of concentrated loads or reactions. They permit the transfer of concentrated forces that could not already be transferred through direct bearing on the girder web.

10. 0 Design For Stiffeners

Stiffeners in plate girders have two major roles.

1. They act as posts to provide tension field action. These are called intermediate transverse stiffeners.

2. They prevent local instability caused by concentrated loads. These stiffeners are known as bearing stiffeners.

11. 0 Intermediate Stiffeners

The only other size requirement for intermediate stiffeners in nontension field girders is a limit on their moment of inertia.

Web Stiffener Minimum Moment of Inertia

12. 0 Bearing Stiffeners

Bearing stiffeners are required when the strength of the girder web is not sufficient to resist the concentrated forces exerted on it. Although bearing stiffeners can be require for rolled l-shaped members, they are much more likely to be required for plate girders. Particularly at the girder supports.. Normally the forces to be resisted are compressive in nature. For those cases, the limit states of web local yielding, web crippling, and web side sway buckling must be checked. when the applied load is tensile, web local yielding and flange local bending must be considered. If the strength of the web is insufficient to resist the applied force, bearing stiffeners can be used. The relationship between available strength and nominal strength varies for each limit state associated with web strength. Thus, either design strengths or allowable strength they must be compared, not nominal strengths, to determine the minimum web strength. The appropriate resistance factors and safety factors are given with the following discussion of limit states.

13. 0 Web Local Yielding

When a single concentrated force is applied to a girder, as shown Figure the force is assumed to be delivered to the girder over a length of bearing, and is then distributed through the flange and into the web. The narrowest portion of the web is the critical section . This occurs below the web to flange weld, dimensioned as ft in. The distribution takes place along a line with a slope of 1: 2. 5. So when the critical section is reached. the force has been distributed over a length plus 2. 5k in each direction. If the concentrated force is applied so that the force distributes along the web in both directions, this distribution increases the bearing length by 5ft as shown in Figure 1 . 19b. If the bearing is close or the end of the member, distribution takes place only in one direction, toward the mid span. The Specification defines " close to the member end" as being within the member depth from the end. Thus, the available length of the web is (1/ + 2. 5k), as shown in Figure.

Single Concentrated Force Applied to Beam.

The nominal strength of the girder web when the concentrated force to be resisted is applied at a distance from the member end that is greater than the depth of the member,

When the concentrated force to be resisted is applied at a distance from the member end that is less than or equal to the depth of the member, d, the nominal strength is

14. 0 Web Crippling

The criteria for the limit state of web crippling also depend on the location of the force with respect to the end of the girder. When the concentrated compressive force is applied at a distance from the member end that is greater than d/2