PLATE GIRDER

Introduction

Beams of long span subjected to heavy loads are encountered in buildings and bridges. For these beams, readymade I-sections are not suitable since their depth is limited due to buckling of web. In this situation, the girders are to be fabricated using flange and web plates as per the requirement. Usually, the flange and web plates are connected by welding. Girders fabricated in this manner are known as welded plate girders. The plate girder is a deep flexural member used to carry heavy loads over long spans. Their depth to web thickness ratio is kept at around 400. Because of this higher ratio, the buckling of web becomes the major problem. Hence, to overcome this problem, different types of stiffeners are provided.

Elements

Various components of welded stiffened and unstiffened plate girders are as follows:

- Web plate (WP)
- Flange plate with or without cover plates (with curtailment of cover plate) (FP)
- Bearing stiffeners or end post (EP)
- Intermediate transverse stiffeners (ITS)
- Longitudinal stiffeners (LS)
- Web splices (WS)
- Flange splices (FS)
- Connection between flange and web
- End bearing or end connections

Codal Provisions

1. Selection of web

Depth of the girder, i.e. the depth of the web, ignoring the thickness of the flange plates is proportional with the span mainly to control the deflection and the economical flange area. The recommended span to depth ratios are as follows:

- Constant depth in case of simply supported girder: 12 to 20
- Constant depth in case of continuous girder: 15 to 20
- Constant depth in case of simply supported crane girder: 10 to 15

Girders having span/depth ratio less than 12 are deep beams.

2. Depth to thickness ratio of web

Selection of web is also governed by limiting depth to thickness ratio of web in different conditions of stiffener arrangements. In case of rolled steel section, ratio $d/t_w$ is less than $67\varepsilon$ and hence the web is plastic and capable of offering shear buckling resistance for its fullest capacity. With increase in ratio, the tendency of buckling of the web develops due to following situation:

- Under concentrated load and at support
- Diagonal compression at the neutral axis
Buckling of the compression flange into the web

Codal provisions guarding these situations for the plate girder with transverse stiffeners only are as follows:

(a) cl. 8.4.2.1 (p.59)
In case of plate girder with stiffener, resistance to shear buckling is to be verified when
\[ d/t_w > [67\varepsilon \sqrt{K_v/5.35}], \quad K_v = \text{shear buckling coefficient} \]

(b) Serviceability requirement (cl. 8.6.1.1, p.63)
When only transverse stiffeners are provided along the depth of the web,
\[ d/t_w \leq 200 \varepsilon_w, \quad \varepsilon_w = \sqrt{250/f_{yw}} \]
for web
\[ f_{yw} \text{ relates to the yield strength of the web material} \]

(c) Compression flange buckling requirement (cl. 8.6.1.2, p.64).
In order to avoid the buckling of the compression flange into web and when only transverse stiffeners are provided, for \( c < 1.5d \), where \( c \) = spacing of the transverse stiffeners and \( d \) = depth of web,
\[ d/t_w \leq 345\varepsilon_f, \quad \varepsilon_f = \sqrt{250/f_{fy}} \]
for flange
This situation occurs when the flange is semi-compact, being vulnerable to buckle before the yield takes place.
Since \( d/t_w \) is restricted to 200 for the serviceability requirement of flange, the buckling into web is automatically controlled for identical yield strength of the flange and the web. In general,
When \( d/t_w \leq 67 \varepsilon_w \), no stiffeners are required;
When \( 200 \varepsilon_w \geq d/t_w \geq 67 \varepsilon_w \), only transverse stiffeners are required; and
When \( d/t_w > 200 \varepsilon_w \), transverse as well as longitudinal stiffeners are required.
In plate girder, the web is always slender, as \( d/t_w > 126 \varepsilon_w \), and therefore it needs stiffening.

3. Flange Design

Flange is a solid plate of width \( b \) and thickness \( t_f \). The curtailment of the thicker plate is made by reducing thickness \( t_f \), keeping \( b \) the same. The width of the flange plate \( b \), is generally 0.3 times the depth of the web. The ratio \( b/2t_f \) must be less than 8.4\( \varepsilon \). The flange plate area is obtained by assuming that the flanges resist only B.M., so that,
\[ \text{BM} = (A_f f_s d)/\gamma_{mo}, \quad \text{Therefore, } A_f = (\text{BM} \times \gamma_{mo})/f_s d \]

4. The web strength is increased due to transverse stiffeners. Vertical stiffeners guards against buckling by diagonal compression due to shear. After the shear buckling of the web panel in between the stiffeners, the web resists further additional shear due to tension field action. This tension field anchors against the top and bottom flanges and against the adjacent transverse stiffeners on either side of the web panel. The web offers resistance to shear in two ways:
- By shear buckling due to diagonal compression
- Post-buckling resistance by tension field action
Thus tension field action takes place under the following conditions:
- When factored shear is more than shear buckling resistance;
- Ratio \( c/d > 1 \), cl. 8.4.2.2(b), p.60;
- Enough anchorage is available by means of the adjacent web panels or the stronger end stiffener of the girder.

5. Salient Codal Provisions

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<td>Minimum moment of inertia of ITS</td>
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### Design Steps

1. Assume the self weight of the girder. (The self weight $w$ may be assumed as equal to $W/200$ where $w$ is in kN/m and $W$ is the total factored load applied to the girder in kN). Estimate the live loads. Calculate the maximum bending moment and shear force in the plate girder.

2. Decide whether to use the transverse stiffeners or not, assume depth of the web as $d = (Mk/f_y)^{0.33}$ and thickness of web as $t_w = [M/(f_yk^2)]^{0.33}$. Assume the value of $k$ i.e. $dlt_w$. Also check the web thickness as per clause 8.6.1.1 and 8.6.1.2 of the code and adopt a suitable web thickness.

3. Select suitable flange plate thickness and width (approximately 0.3 times the depth of web). The flange plate area should be so proportioned that $b_f/t$ satisfies the requirements of plastic/compact/semi-compact section. Flange thicknesses may be varied at suitable length along the span, to take care of the varying moment. The flange area may be computed as $A_f = M/(D \times f_y/\gamma Mo)$, where $M$ is the factored moment. Flange width $b_f$ may be assumed as total depth/3 and the flange thickness may be taken as $t_f = A_f/b_f$.

4. Check for moment capacity as per the clause 8.2.1 or 8.2.2 depending on whether the plate girder is laterally supported or unsupported. It is generally advantageous to provide lateral support at sufficiently close intervals such that lateral torsional buckling will not govern the design.
For laterally supported girder, \( M_d = \beta_b Z_p f_y \gamma_{mo} \)
For laterally supported girder, \( M_d = \beta_b Z_p f_{bd} \)

5. Check for shear resistance of the web. One may use either clause 8.4.2.2(a) simple post-critical method or clause 8.4.2.2(b) by considering tension field method.
6. Design of the weld connection between the flange plate and the web plate.
7. Design of bearing stiffeners and their connections (clause 8.7.4, 8.7.5, and 8.7.9 of the code).
8. Design of load carrying stiffeners; if required (clause 8.7.5) and their connections.
9. Design of intermediate stiffeners, if required (clauses 8.7.2 and 8.7.1.2) and their connections (clause 8.7.2.6).
Design of Bridge Splice and its Connections.

(a) Riveted Plate Girder

(b) Welded Plate Girder

Plate Girders

(c) Unstiffened

(d) Stiffened

SECTIONS

ITS = Intermediate Transverse Stiffener; LS = Longitudinal Stiffener;
EP = End Post

Unstiffened and Stiffened Plate Girders.
Details of Welded Plate Girder - Span 30 m