6. DESIGN RULES

6.1 General

The design rules for the strength and deflection design of simply-supported bare steel and composite beams incorporating large web penetrations are presented in this section. The web penetrations may be circular or rectangular in shape, unreinforced or reinforced, and located either concentrically or eccentrically to the centroid of the steel section.

The restrictions applicable to the strength design rules are given in Section 6.2.

The strength design objectives and criteria are given in Section 6.3.

The design rules for calculating the design moment and shear capacities, $\phi\overline{M}_b$ and $\phi\overline{V}_u$, for composite beams are given in Section 6.4.

The design rules for calculating $\phi\overline{M}_b$ and $\phi\overline{V}_u$ for bare steel beams, a special case of the more general method applicable to composite beams, are given in Section 6.5.

The stability considerations applicable to the strength design are given in Section 6.6, and the detailing requirements are given in Section 6.7.

Design rules for calculating the additional vertical deflection due to a web penetration are given in Section 6.8.

6.2 Application

The proposed size and location of the web penetration must be checked prior to performing the design calculations to ensure compliance with the requirements of the strength design method given in this section. In addition, the size and location of penetrations may also be governed by the stability considerations given in Section 6.6.

Circular Penetrations

The design formulae presented are for rectangular penetrations. However, circular penetrations can be designed using the same formulae by assuming that a circular penetration of diameter D is equivalent to a rectangular penetration of the following dimensions.

(a) $L_0 = 0.45D$.

(b) For unreinforced circular penetrations:

$h_0 = D$ for the calculation of $\overline{M}_b$; and

$h_0 = 0.9D$ for the calculation of $\overline{V}_u$.

(c) For reinforced circular penetrations:

$h_0 = D$ for the calculation of $\overline{M}_b$ and $\overline{V}_u$.

Steel Section

The steel section shall be a doubly symmetric I-section. The design methods are only applicable if the steel beam plate elements are compact or non-compact in accordance with the requirements of AS 2327.1. Only the effective portion of any non-compact plate elements shall be used in the strength and deflection calculations. The steel section shall also conform to the stability considerations given in Section 6.6.

Profiled Steel Sheeting

The profiled steel sheeting shall conform to the requirements of AS 2327.1. For the purposes of design, the sheeting shall be considered to be parallel to the steel beam (i.e. $\lambda = 1.0$) if the angle between the beam and the sheeting ribs is less than or equal to 15 degrees. Otherwise it shall be considered perpendicular (i.e. $\lambda = 0.0$).

Size of Rectangular and Circular Penetrations

Acceptable geometry for a beam incorporating web penetrations is given in Fig. 6.1. The location and dimensions of web penetrations shall be such that:

(a) $\left(L_0 / h_0\right) \le 3.0$

(b) $h_0 \le 0.7D_s$

(c) $s_t \ge 0.15D_s$

(d) For bare steel beams, $s_b \ge 0.15D_s$; and

for composite beams, $s_b \ge 0.12D_s$

(e) $(L_0 / s_t) \le 12$ and $(L_0 / s_b) \le 12$

(f) For bare steel beams, $(L_0 / h_0 + 6h_0 / D_s) \le 5.6$; and

for composite beams, $(L_0 / h_0 + 6h_0 / D_s) \le 6.0$

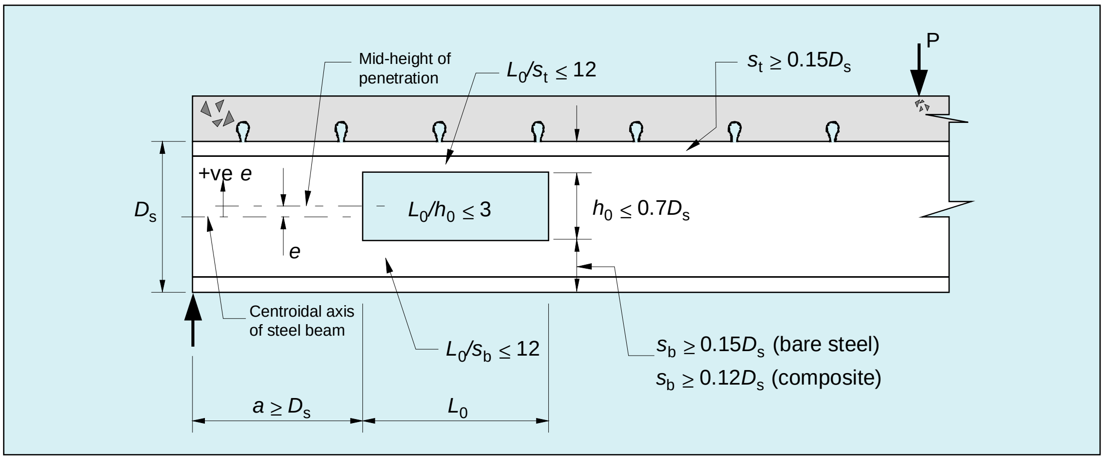

Figure 6.1 Beam Geometry

Proximity to Concentrated Loads and Supports

The distance from the nearer end of the penetration to the edge of a support shall be not less than the overall depth of the beam, D_s. When a beam with a web penetration is subjected to a concentrated load, the following requirements shall also be satisfied.

(a) No concentrated load shall be located within the length of a web penetration.

(b) Bearing stiffeners shall be provided at the loading point when a concentrated load is applied;

- closer than $D_s/2$ to the nearer edge of the penetration unless,

$$\left|\frac{d_1}{t_w}\right|\sqrt{\frac{f_{yw}}{250}} \le 70 \text{ and } \left|\frac{b_f - t_w}{2t_f}\right|\sqrt{\frac{f_{yf}}{250}} \le 9 \tag{6.1}$$

- closer than D_s from the nearer edge of the penetration unless,

$$\left(\frac{d_1}{t_w}\right)\sqrt{\frac{f_{yw}}{250}} \le 87 \text{ and } \left(\frac{b_f - t_w}{2t_f}\right)\sqrt{\frac{f_{yf}}{250}} \le 11 \tag{6.2}$$

The design of bearing stiffeners shall be in accordance with the requirements of Clause 5.14 of AS 4100.

6.3 Strength Design

Design Objectives

The objective of the strength design method is to ensure that the strength design criterion is not violated in the region of the web penetration. It is also necessary to check that the beam is sufficiently strong to resist any local instability of the steel beam plate elements around the penetration, which can cause lateral buckling of the top T-section or flexural-torsional buckling of the beam. The latter two modes of buckling apply only to bare steel beams.

Strength Design Criterion

The strength design criterion is given in the form of a cubic moment-shear interaction equation:

$$\left|\frac{M^*}{\phi \overline{M}_{\mathrm{b}}}\right|^3 + \left(\frac{V^*}{\phi \overline{V}_{\mathrm{u}}}\right)^3 \le 1.0 \tag{6.3}$$

where, M^* and V^* are the design action effects at the mid-length of the penetration; and $\phi \overline{M}_{\mathrm{b}}$ and $\phi \overline{V}_{\mathrm{u}}$ are the design moment and shear capacities at the penetration, respectively. The value of ϕ shall be taken as 0.9.

6.4 Design Moment and Shear Capacities - Composite Beams

Design Moment Capacity

The design moment capacity, $\phi \overline{M}_{\mathrm{b}}$, at the *HME* of the web penetration is calculated using rectangular stress block theory in accordance with AS 2327.1. The design moment capacity of the net section at the penetration, including any web penetration reinforcement, shall not exceed that of the composite cross-section without the web penetration.

The formulae needed to calculate $\phi \overline{M}_{\mathrm{b}}$ are given in Appendix A. The calculation procedure is briefly described below.

(a) Calculate the compressive force in the concrete flange, F_{cH}, and the degree of shear connection, $\overline{\beta}$, using Para. A2.

(b) Determine the depth of the compressive zone in the concrete flange, d_{c}, and the force components in the cross-section using Para. A3.2.

(c) Determine the design moment capacity, $\phi \overline{M}_{\mathrm{b}}$, using the appropriate case given in Para. A3, depending on the depth of the compressive zone in the cross-section, d_{h}.

The formulae given in Appendix A are based on the following assumptions:

(a) the composite beam cross-section is comprised of a concrete flange and a doubly-symmetric steel I-section;

(b) penetrations may be either reinforced or unreinforced;

(c) the reinforcement, if any, above and below the penetration are of the same dimensions and are located horizontally as close as practicable to the edges of the penetration; and

(d) sheeting ribs are deemed to be either perpendicular or parallel to the steel beam.

Design Shear Capacity

The design shear capacity in the region of a web penetration in a composite beam is given as:

$$\phi \overline{V}_{\mathrm{u}} = \phi (V_{\mathrm{t}} + V_{\mathrm{b}}) \tag{6.4}$$

where V_{t} and V_{b} are the nominal shear capacities of the top and bottom T-sections, respectively. The nominal shear capacity, $\overline{V}_{\mathrm{u}}$, shall satisfy the conditions given in Eqs 6.37 or 6.41, as applicable.

The nominal shear capacity of the bottom T-section, V_{b}, is calculated as follows:

$$V_b = \frac{\sqrt{6}+\mu_b}{\nu_b+\sqrt{3}} V_{pb} \le V_{pb} \tag{6.5}$$

where,

$$\mu_b = \frac{2F_r d_r}{V_{pb} s_b} \tag{6.6}$$

$$s_b = (D_s - h_0)/2 + e_0 \tag{6.7}$$

$$\nu_b = \frac{L_0}{\bar{s}_b} \tag{6.8}$$

$$\bar{s}_b = s_b \text{, or} \tag{6.9}$$

$$= s_b - A_r/(2b_f) \text{ [when the penetration is reinforced and } \frac{\sqrt{6}+\mu_b}{\nu_b+\sqrt{3}} \le 1\text{]}$$

$$V_{pb} = 0.6 f_{yw} s_b t_w \tag{6.10}$$

The nominal shear capacity of the top T-section, V_t, is calculated as follows:

$$V_t = \frac{\sqrt{6}+\mu_t}{\nu_t+\sqrt{3}} V_{pt} \le V_{pt} + 0.29\sqrt{f_c'} A_{vc} \tag{6.11}$$

where,

$$\mu_t = \frac{2F_r d_r + F_{ctH} d_{ctH} - F_{ctL} d_{ctL}}{V_{pt} s_t} \tag{6.12}$$

$$s_t = (D_s - h_0)/2 - e_0 \tag{6.13}$$

$$\nu_t = \frac{L_0}{\bar{s}_t} \tag{6.14}$$

$$\bar{s}_t = s_t \text{, or} \tag{6.15}$$

$$= s_t - A_r/(2b_f) \text{ [when the penetration is reinforced and } \frac{\sqrt{6}+\mu_t}{\nu_t+\sqrt{3}} \le 1\text{]}$$

$$V_{pt} = 0.6 f_{yw} s_t t_w \tag{6.16}$$

$$F_r = f_{yr} A_r \tag{6.17}$$

$$F_{ctH} = \min.(F_c, n_H f_{ds}, (F_{tf} + F_{tw} + F_r)) \tag{6.18}$$

The distance d_{ctH} from the top of the steel cross-section to the line of action of F_{ctH} is determined as:

$$d_{ctH} = D_c - \frac{F_{ctH}}{1.7 f_c' b_{cf}} \tag{6.19}$$

$$F_{ctL} = F_{ctH} - (n_H - n_L) f_{ds} \tag{6.20}$$

where, f_{ds} is calculated in accordance with AS 2327.1 based on n_H shear connectors.

The distance from the top of the steel section to the line of action of F_{ctL} is determined as:

$$d_{ctL} = (1-\lambda) h_r + \frac{F_{ctL}}{1.7 f_c' b_{cf}} \tag{6.21}$$

If $\frac{\sqrt{6}+\mu_t}{\nu_t+\sqrt{3}} > 1.0$ in Eq. 6.11, then the nominal shear capacity of the top T-section, V_t, shall be limited by the following condition:

$$F_{ctH} \le f_{yf} t_f (b_f - t_w) + A_r f_{yr} \tag{6.22}$$

In this case, d_{ctH}, F_{ctL}, and d_{ctL} are all to be recalculated based on the value of F_{ctH} in Eq. 6.22, and μ_t shall be recalculated from Eq. 6.12. The nominal shear capacity of the top T-section is then determined as:

$$V_t = \frac{\mu_t}{\nu_t} V_{pt} \tag{6.23}$$

but limited by,

$$V_{pt} \leq V_t \leq V_{pt} + 0.29\sqrt{f_c'}A_{vc} \tag{6.24}$$

where,

$$A_{vc} = 3D_c\left(D_c - (1-\lambda)h_r\right) \tag{6.25}$$

6.5 Design Moment and Shear Capacities - Bare Steel Beams

The design rules given in this section for bare steel beams have been derived using the more general rules for composite beams given in Section 6.4.

Design Moment Capacity

The design moment capacity, $\phi\overline{M}_b$, at the *HME* of the penetration is based on the net section at the penetration and determined using rectangular stress block theory. The value of $\phi\overline{M}_b$ shall not exceed the design moment capacity of the steel section without the penetration.

The formulae presented in Appendix B for the calculation of $\phi\overline{M}_b$ are only applicable when the following requirements are satisfied:

(a) the steel beam is a doubly-symmetric I-section; and

(b) the reinforcement, if any, above and below the penetration is of the same dimensions and is located as close as practicable to the horizontal edges of the penetration.

Design Shear Capacity

The design shear capacity, $\phi\overline{V}_u$, of a bare steel beam in the region of a web penetration is determined by evaluating the geometric parameters μ_t, ν_t, μ_b and ν_b for the top and bottom T-sections, and summing the components V_t and V_b, whereby;

$$\phi\overline{V}_u = \phi(V_t + V_b) \tag{6.26}$$

where V_t and V_b are the nominal shear capacities of the top and bottom T-sections, respectively.

The nominal shear capacity of the bottom T-section shall be calculated as follows:

$$V_b = \frac{\sqrt{6} + \mu_b}{\nu_b + \sqrt{3}} V_{pb} \leq V_{pb} \tag{6.27}$$

where,

$$\mu_b = \frac{2F_r d_r}{V_{pb} s_b}; \tag{6.28}$$

$$s_b = \left(D_s - h_0\right)/2 + e_0 \tag{6.29}$$

$$V_{pb} = 0.6 f_{yw} s_b t_w \tag{6.30}$$

$$F_r = f_{yr} A_r \tag{6.31}$$

and

$$\nu_b = \frac{L_0}{\overline{s}_b}; \tag{6.32}$$

$$\overline{s}_b = s_b \text{, or} \tag{6.33}$$

$$= s_b - A_r/(2b_f) \text{ [when the penetration is reinforced and } \frac{\sqrt{6} + \mu_b}{\nu_b + \sqrt{3}} \leq 1 \text{]}$$

The nominal shear capacity of the top T-section, V_t, can be calculated using Eqs 6.27 to 6.33 with V_t, μ_t, ν_t, V_{pt} and $\bar{s}_t$ substituted for V_b, μ_b, ν_b, V_{pb} and $\bar{s}_b$, respectively.

6.6 Stability Considerations

Web Buckling

The strength design method is generally applicable to the design of web penetrations in beams for which,

$$\left|\frac{d_1}{t_w}\right|\sqrt{\frac{f_{yw}}{250}} \leq 87 \tag{6.34}$$

More specifically,

(a) for beams where,

$$\left(\frac{d_1}{t_w}\right)\sqrt{\frac{f_{yw}}{250}} \leq 70 \tag{6.35}$$

then $$\frac{L_0}{h_0} \leq 3.0 \tag{6.36}$$

and $$\bar{V}_u \leq 0.4 f_{yw} t_w D_s + V_c \tag{6.37}$$

where, $$V_c = \min.(V_{pt}(\mu / \upsilon - 1) \geq 0,\ 0.29\sqrt{f_c^{'}}A_{vc}) \tag{6.38}$$

for composite beams, and

$= 0$ for bare steel beams.

(b) for beams where,

$$70 < \left(\frac{d_1}{t_w}\right)\sqrt{\frac{f_{yw}}{250}} \leq 87 \tag{6.39}$$

then $$\frac{L_0}{h_0} \leq 2.2 \tag{6.40}$$

and $$\bar{V}_u \leq 0.27 f_{yw} t_w D_s \tag{6.41}$$

Buckling of Top T-sections

For rectangular penetrations where $M^* / (V^* D_s) > 20$ and $\nu_t > 4$, the top T-section of a bare steel beam shall be designed as a compression member with an effective length equal to L_0, in accordance with the requirements of AS 4100. Buckling is unlikely to occur in the top T-section of a composite beam or in reinforced T-sections.

Flexural-Torsional Buckling

In the case of bare steel beams, the effect of the penetration on flexural-torsional buckling of the member shall be considered. No specific guidelines are provided in this document.

Note: Some guidance on buckling of beams with web penetrations can be found in [18].

6.7 Detailing

Spacing Between Multiple Penetrations

To be treated as an individual penetration, the clear spacing, S, between multiple penetrations in both composite and bare steel beams shall satisfy the following requirements.

For rectangular penetrations:

$$S \geq \max.\left[h_0, L_0\left(\frac{\dfrac{V^*}{\phi V_u}}{1-\dfrac{V^*}{\phi V_u}}\right)\right] \tag{6.42}$$

For circular penetrations:

$$S \geq max.\left[1.5D, D\left(\frac{\dfrac{V^*}{\phi V_u}}{1-\dfrac{V^*}{\phi V_u}}\right)\right] \tag{6.43}$$

where, V_u is the nominal shear capacity of the steel beam without a penetration and D is the diameter of the penetration.

The spacing between multiple penetrations in composite beams shall also satisfy,

$$S \geq \max.\left[L_0, 2D_s\right] \tag{6.44}$$

When these criteria are not satisfied, the possible reduction in the strength of the member due to interaction between penetrations shall be considered. However, no guidelines are provided in this document for this assessment.

Penetration Reinforcement

Typical reinforcement details are shown in Fig. 4.2. The reinforcement shall be provided in accordance with the following requirements.

(a) The outstand of the reinforcement shall be compact in accordance with the requirements of AS 4100.

(b) The reinforcement shall be continuously welded parallel and as close as practicable to the horizontal edges of the penetration.

(c) The area of reinforcement along each edge of the penetration shall satisfy the condition:

$$A_r \leq 0.3 t_w L_0 \left| \frac{f_{yw}}{f_{yr}} \right| \tag{6.45}$$

(d) The reinforcement shall be extended beyond each end of the penetration by a distance not less than $L_0 / 4$ or $(0.87 A_r) / t_w$, whichever is greater.

(e) The design capacity of the weld within the length of the penetration shall not be less than twice the nominal tensile capacity of the reinforcement.

(i.e. design capacity of weld $\geq 2 \times f_{yr} \times$ cross-sectional area of one reinforcement plate or flat bar.)

(f) The design capacity of the weld beyond each end of the penetration shall not be less than the nominal tensile capacity of the reinforcement.

(i.e. design capacity of weld $\geq f_{yr} \times$ cross-section area of reinforcement.)

(g) Reinforcement shall be provided equally along the top and bottom horizontal edges of the web penetration.

A single-side reinforcement arrangement shall not be used unless all of the following conditions are satisfied:

$$A_r \leq \frac{A_f}{3} \tag{6.46}$$

$$\frac{L_0}{h_0} \le 2.5 \tag{6.47}$$

$$\frac{s_t}{t_w}\sqrt{\frac{f_{yw}}{250}} \le 23 \tag{6.48}$$

$$\frac{s_b}{t_w}\sqrt{\frac{f_{yw}}{250}} \le 23 \tag{6.49}$$

and

$$\frac{M^*}{V^* D_s} \le 20 \text{ at the mid-length of the penetration.} \tag{6.50}$$

Slab Reinforcement

It is recommended that DECKMESH™ be provided in region of the web penetration when the sheeting ribs are deemed perpendicular to the steel beam (see Fig. 6.2), to control the diagonal cracking shown in Fig. 3.1. Only one panel width (450 mm) is required.

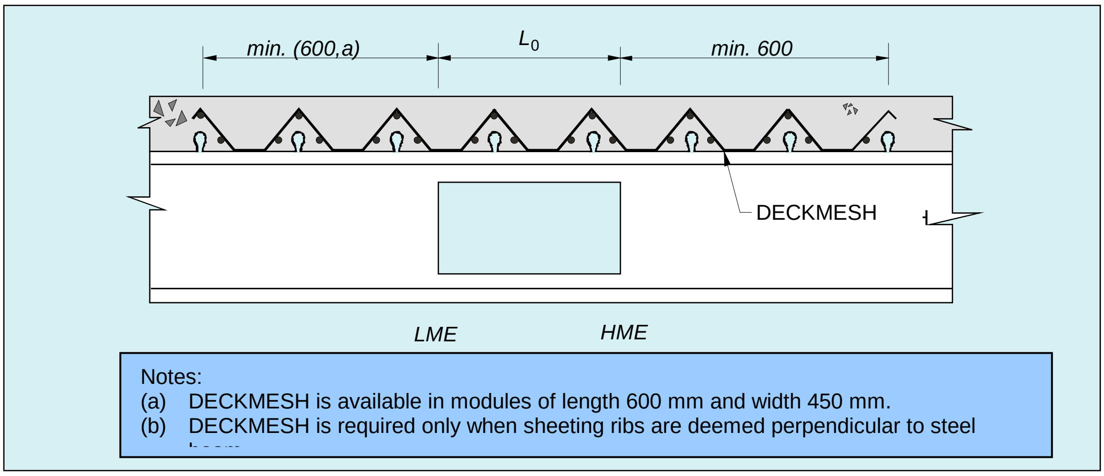

Figure 6.2. DECKMESH™ Recommended in the Region of a Web Penetration.

Corner Radii

The corner radii of a rectangular penetration shall be not less than $2t_w$ or 16 mm, whichever is greater.

6.8 Deflection Calculation

General

The total deflection $\delta_t(x)$ at a point x (see Fig. 5.2) on the beam is expressed as:

$$\delta_t(x) = \delta_g(x) + \delta_b(x) + \delta_v(x) \tag{6.51}$$

where,

$\delta_g(x)$ = deflection at point x of the beam without the penetration;

$\delta_b(x)$ = deflection at point x due to bending from Vierendeel action within the length of the penetration; and

$\delta_v(x)$ = deflection at point x due to shear deformation within the length of the penetration.

Shear Force Carried by Top T-Section

The design shear force, V^*, is assumed to be shared between the top and bottom T-sections as V_t^* and V_b^*, respectively. For bare steel and composite beams, V_t^* shall be determined as follows:

(a) For concentric penetrations in bare steel beams:

$$V_t^* = \frac{V^*}{2} \tag{6.52}$$

(b) For eccentric penetrations in bare steel beams:

$$V_t^* = \frac{V^*}{(1+R)} \tag{6.53}$$

where,
$$R = \left| \frac{\dfrac{L_0^3}{12EI_b} + \dfrac{k_B L_0}{G t_w s_b}}{\dfrac{L_0^3}{12EI_t} + \dfrac{k_T L_0}{G t_w s_t}} \right| \tag{6.54}$$

k_T and k_B are the appropriate shear coefficients for top and bottom T-sections. A value for R of 1.2 is considered suitable for I-sections used in practice.

(c) For composite beams:

$$V_t^* = V^* \tag{6.55}$$

Additional Bending Deflection

The additional deflection due to secondary bending occurs as a result of the rotations of the rigid arms as shown in Fig. 4.3(c) and 4.3(d).

To determine these rotations, the differential primary moment across the penetration and the secondary moment due to Vierendeel action must first be determined.

The differential design bending moment, M_d^*, acting across the web penetration is calculated as:

$$M_d^* = M_H^* - M_L^* \tag{6.56}$$

where, M_H^* and M_L^* are the design bending moments at the high and low moment ends, respectively.

The secondary moment induced by Vierendeel action across the web penetration is defined as:

$$M_{se}^* = -\frac{V_t^* L_0}{2} \tag{6.57}$$

where V_t^* is the shear force carried by the top T-section, and is calculated using Eqns 6.52, 6.53 or 6.55, as appropriate.

Hence, the rotations at the low and high moment ends of the web penetration are given as:

$$\theta_L = \left| \frac{M_{se}^* I_0 \left(L_0^2 - 2L_0(3b + 2L_0)\right) - M_d^* I_t L_0 (3b + 2L_0)}{6EI_0 I_t L} \right| \tag{6.58}$$

$$\theta_H = -\left| \frac{\left(M_d^* I_t + 2M_{se}^* I_0\right) L_0}{2EI_0 I_t} \right| - \theta_L \tag{6.59}$$

where I_0 is the second moment of area of the gross cross-section including the web penetration, I_t is the second moment of area of the top T-section, and b and L are the dimensions shown in Fig. 4.3(a).

The additional bending deflection, δ_b, of the beam due to the web penetration is given as:

For $x \le a$;

$$\delta_b(x) = x\theta_L \tag{6.60}$$

For $x \geq a + L_0$;

$$\delta_b(x) = (L - x)\theta_H \qquad (6.61)$$

Additional Shear Deflection

The additional deflection due to shear deformation in the T-sections causes the rigid arms to rotate as shown in Fig. 4.3(c) and (d). These rotations, $\theta_L^{'}$ and $\theta_H^{'}$, are calculated as follows:

$$\theta_L^{'} = \frac{2L_0\delta_s^{'}}{3bL} \qquad (6.62)$$

$$\theta_H^{'} = \left|\frac{\delta_s^{'}}{b}\right| - \theta_L^{'} \qquad (6.63)$$

where the additional shear deflection ignoring geometric continuity (see Fig. 4.3(c)) is given by:

$$\delta_s^{'} = \frac{kV_t^{*}L_0}{Gs_t t_w} \qquad (6.64)$$

The additional deflection, δ_v, of the beam due to the web penetration is given as:

For $x \leq a$;

$$\delta_v(x) = x\theta_L^{'} \qquad (6.65)$$

For $x \geq a + L_0$;

$$\delta_v(x) = (L - x)\theta_H^{'} \qquad (6.66)$$

Design of Simply-Supported Composite Beams with Large Web Penetrations

Design Booklet DB1.3

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Foreword

OneSteel is a leading manufacturer of steel long products in Australia after its spin-off from BHP Pty Ltd on the 1st November 2000. It manufactures a wide range of steel products, including structural, rail, rod, bar, wire, pipe and tube products and markets welded beams.

OneSteel is committed to providing to design engineers, technical information and design tools to assist with the use, design and specification of its products. This design booklet “Design of Simply-Supported Beams with Large Web Penetrations” was the third design booklet of the Composite Structures Design Manual, which is now being completed and maintained by OneSteel.

The initial development work required to produce the design booklets was carried out at BHP Melbourne Research Laboratories before its closure in May 1998. OneSteel Market Mills is funding the University of Western Sydney’s Centre for Construction Technology and Research in continuing the research and development work to publish this and future booklets.

The Composite Structures Design Manual refers specifically to the range of long products that are manufactured by OneSteel and plate products that continue to be manufactured by BHP. It is strongly recommended that OneSteel sections and reinforcement and BHP plate products are specified for construction when any of the design models in the design booklets are used, as the models and design formulae including product tolerances, mechanical properties and chemical composition have been validated by detailed structural testing using only OneSteel and BHP products.

To ensure that the Designer’s intent is met, it is recommended that a note to this effect be included in the design documentation.

Contents

Preface

This design booklet forms part of a suite of booklets covering the design of simply-supported and continuous composite beams, composite slabs, composite columns, steel and composite connections and related topics. The booklets are part of the OneSteel Market Mills' Composite Structures Design Manual which has been produced to foster composite steel-frame building construction in Australia to ensure cost-competitive building solutions for specifiers, builders and developers.

The additional design information necessary to allow large web penetrations to be incorporated into simply-supported bare steel and composite beams is presented in this booklet. Design issues with respect to strength and deflection control are addressed. The non-composite bare steel state arises during construction prior to the concrete hardening.

Large rectangular and circular penetrations are often made in the steel web of composite beams for the passage of horizontal building services. This allows the plenum height to be reduced when using economical, standard UB and WB steel sections. However, large penetrations weaken a composite beam locally and reduce its overall flexural stiffness, and therefore their effect must be considered in design.

Neither the Steel Structures Standard AS 4100 nor the Composite Beam Standard AS 2327.1 contains design provisions for large web penetrations. The rules provided in the booklet for designing bare steel beams with large penetrations are compatible with AS 4100. For the composite state, the rules are compatible with AS 2327.1, and have been proposed as an acceptable method of design to be referred to in Amendment No. 1 of this Standard expected to be published this year.

Information is also given to assist design engineers to understand the engineering principles on which the design methods are based. This includes:

(a) explanatory information on important concepts and models;

(b) the limits of application of the methods; and

(c) worked examples.

Design capacity tables are given in Appendix C to simplify the strength design process. The information provided can be used to design for either the bare steel or composite states. The tables cover a range of situations involving 300PLUS® UB and WB steel sections supporting a composite slab and incorporating large web penetrations. A spreadsheet program named WEBPEN™ is available to assist with the strength design calculations.

Although these design aids are intended to make the design process more efficient, it is essential that the user obtain a clear understanding of the basis of the design rules and the design approach by working through this document and the relevant parts of associated design Standards such as AS 4100 and AS 2327.1.