5. DESIGN APPROACH

5.1 General

The purpose of this section is to explain the design approach adopted in this booklet. Rules for the strength and deflection design of simply-supported bare steel and composite beams incorporating large web penetrations are covered in Section 6. The restrictions applicable to the strength design method are given in Section 6.2.

The overall design approach covering strength and deflection design is illustrated in Fig. 5.1 as a flowchart.

5.2 Overall Design Approach

It is assumed in the overall design approach that a preliminary design of the beam without web penetrations has been completed prior to the web penetration design. Therefore, the basic parameters such as relevant material properties, the size of the steel beam, dimensions of the concrete slab, distribution of shear connectors, etc., are all assumed to be known. It is also assumed that the deflection of the beam without web penetrations has been calculated and that any specific deflection criteria are known.

The aim of the web penetration design procedure is to determine whether the proposed web penetration can be placed at the preferred location without violating the strength and deflection design criteria. An unreinforced penetration is initially tried with the aim of minimising cost.

If the design criteria are not satisfied for a trial size and location of the web penetration, the options available to the designer for improving the design include:

(a) changing the location of penetration;

(b) changing the steel beam size; or

(c) adding penetration reinforcement.

The parts of the overall design approach that are covered by the strength and deflection design methods provided herein are shown below the horizontal dashed line in Fig. 5.1.

5.3 Strength Design

The aim of the strength design procedure presented in this section is to ensure that the strength design criterion given by Eq. 4.1 is not violated in the region of the web penetration.

When multiple web penetrations are made in a beam, the method can be used to design each penetration separately provided the geometric restrictions in relation to the spacing of the web penetrations are satisfied.

The main steps of the strength design procedure are described in the following sub-sections.

Size and Location of Web Penetration

The size and location of the web penetration shall satisfy the geometric constraints given in Section 6.2. These represent the limits of applicability of the strength design method.

Design Action Effects

The design action effects, M^* and V^*, are calculated at the mid-length of the web penetration.

Strength Design Criterion

The strength design criterion for a web penetration is represented by the cubic moment-shear interaction equation given as Eq. 4.1. Therefore, once M^* and V^* are known, the strength design method simply consists of calculating the design moment and shear capacities, $\phi\overline{M}_b$ and $\phi\overline{V}_u$, and checking that Eq. 4.1 is satisfied.

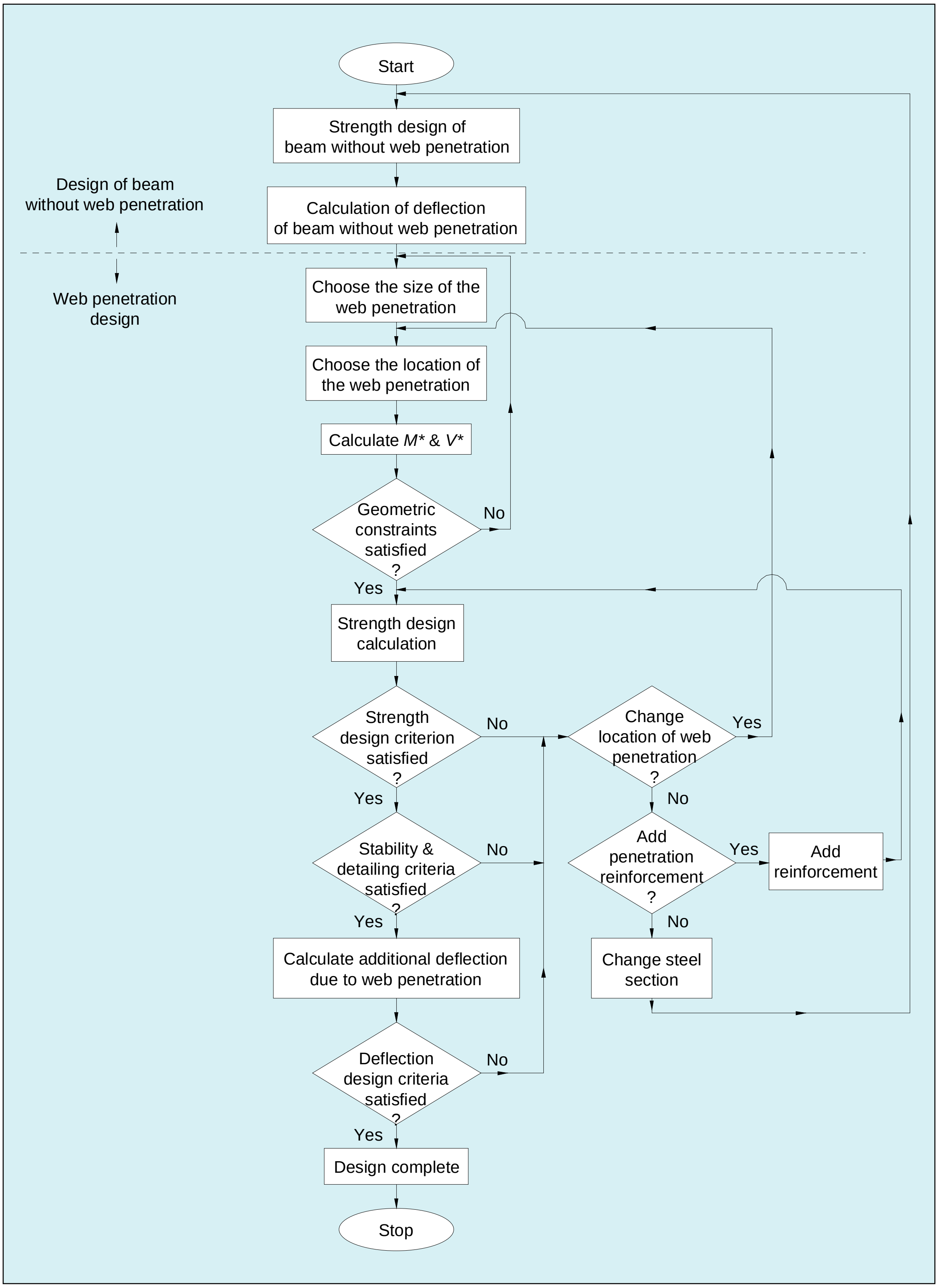

Figure 5.1 Flowchart of the Overall Design Approach

Design Moment Capacity

The design moment capacity, $\phi\overline{M}_b$, is calculated at the *HME* using rectangular stress block theory given in AS 2327.1, while accounting for the height of the web penetration, any web penetration reinforcement present and the degree of shear connection β at the *HME.*

In the calculation of $\phi\overline{M}_b$, it is necessary to know the compressive force in the concrete flange at the *HME*, F_{cH}, which depends on the distribution of shear connectors along the beam, previously determined for the strength design of the beam without any web penetrations.
The shear force, V^*, at the cross-section is assumed to be zero for this calculation. Hence the value of $\phi\overline{M}_b$ represents the point "A" on the moment-shear interaction curve shown in Fig. 4.1.

Design Shear Capacity

The design shear capacity, $\phi\overline{V}_u$, is determined as the summation of the nominal shear capacities of the top and bottom T-sections, V_t and V_b, respectively, times the capacity factor, ϕ. Although the overall bending moment at the penetration is assumed to be zero for this calculation, Vierendeel action due to vertical shear force acting across the penetration is accounted for which gives rise to secondary bending moments. The value of $\phi\overline{V}_u$ represents the point "B" on the moment-shear interaction curve shown in Fig. 4.1.

5.4 Deflection Calculation

The total deflection is calculated as the sum of three components (as shown in Fig. 5.2), viz:

(a) deflection of beam without a web penetration, calculated in accordance with the requirements of AS 2327.1 (Fig. 5.2(a));

(b) deflection due to secondary bending within the length of the penetration (Fig. 5.2(b)); and

(c) deflection due to shear deformation within the length of the web penetration (Fig. 5.2(c)).

The design method has been formulated assuming only one web penetration in the beam. However, deflections from multiple penetrations may be superimposed as linear elastic behaviour is assumed.

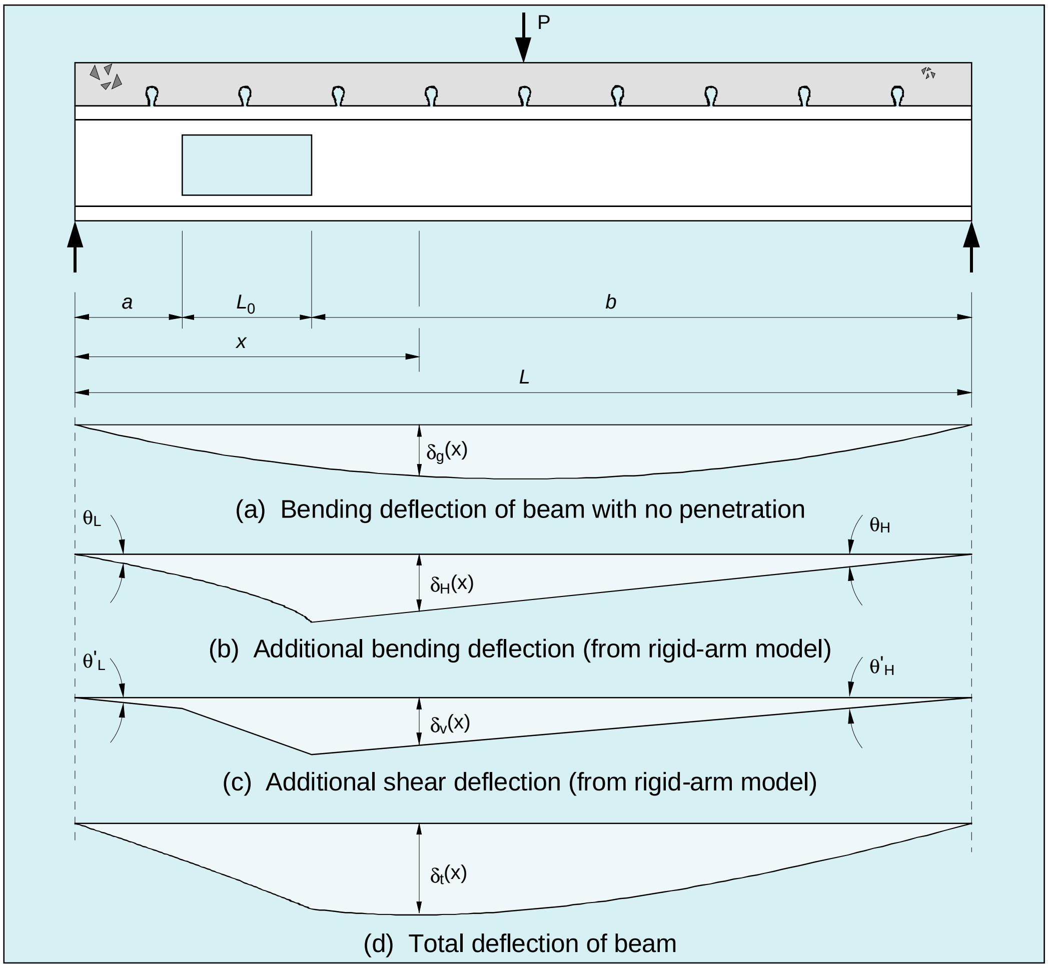

Figure 5.2 Deflection Components of Beam

Design of Simply-Supported Composite Beams with Large Web Penetrations

Design Booklet DB1.3

OneSteel Market Mills

Composite Structures Design Manual

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Disclaimer

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.

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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.