1. SCOPE AND GENERAL

1.1 Scope

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 steel beam must be a doubly-symmetric I-section.

The overall beam design for the bare steel and composite states is assumed to have been carried out in accordance with AS 4100 [1] and AS 2327.1 [2], respectively.

The penetrations may be (see Fig. 1.1):

- rectangular or circular in shape (within the specified limitations);
- unreinforced, or reinforced (in accordance with the specified details) ; and
- concentric or eccentric to the centroid of the steel section.

The application of the strength design method is defined by the conditions given in Section 6.2.

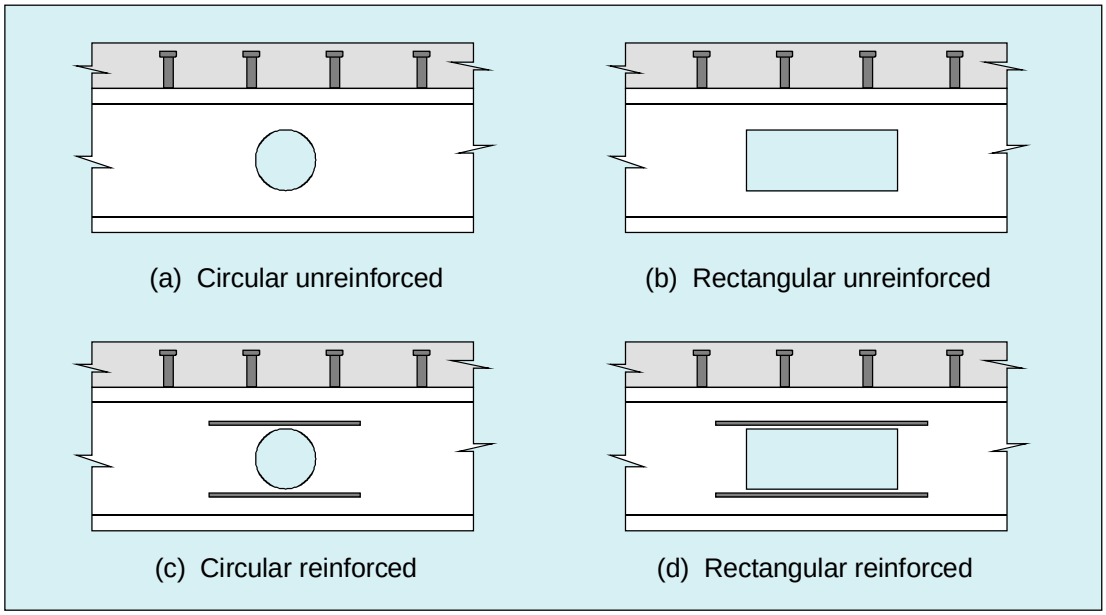

Figure 1.1 Acceptable Types of Web Penetrations

This document should be read in conjunction with the design booklet Design of Simply-Supported Composite Beams for Strength, DB1.1 [3] and AS 2327.1, noting that some relevant material from these documents has not been duplicated herein.

In accordance with Clause 5.2.3.1 of AS 2327.1, the effect of holing of the steel beam due to a web penetration may be ignored provided the greatest internal dimension of the penetration is not greater than 0.1 times the clear depth of the web. It follows that penetrations larger than this should be considered as large, and their effect determined in accordance with the information provided in this document.

1.2 General

The strength design method presented herein is based on a method recommended by an ASCE Task Committee [4]. The method has been verified with some experimentally-based investigations conducted in Australia, and modified to suit Australian design practice and conform to relevant Australian Standards. Further details about the development of the strength design method can be found elsewhere [5,6].

The deflection design method has been developed from work originally presented by Tse and Dayawansa [7]. Further information about this method can be found in [5].

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 web penetrations weaken a composite beam locally and reduce its overall flexural stiffness. Neither the Steel Structures Standard AS 4100 nor the Composite Beam Standard AS 2327.1 contains design provisions for large web penetrations.

The strength design method was adopted after a detailed review of four proposed methods, viz. ASCE Task Committee [4], Redwood and Cho [8], Lawson [9] and Oehlers and Bradford [10]. The method adopted for Australian design practice, proposed by ASCE Task Committee [4], has been modified to conform to the relevant Australian Standards. The suitability of the modified method has been verified on the basis of an Australian experimental program. A reliability analysis has been conducted using the results of the experimental program and other experimental data available from overseas literature, to determine an appropriate value for the strength factor, ϕ [11]. In this regard, consideration has also been given to the improved performance of a composite beam that can be derived by placing DECKMESH™ [12] in the region of a penetration [13]. Accordingly, it is recommended herein that this reinforcing product is used in the region of each web penetration when the profiled steel sheeting is deemed perpendicular to the steel beam. (Note: this product is not suitable to be used in situations when the sheeting is parallel to the steel beam – refer to design booklet DB1.2 for further guidance.)

The cost implications of choosing between reinforced or unreinforced web penetrations is an important consideration during the design stage, noting that the intention of using penetrations is not only to obtain an acceptable floor-to-floor height, but also a more cost-effective structure. For this purpose, it is recommended that a rational method of costing steelwork is used which takes into account the specific labour and material costs involved in fabricating the penetrations including any steel plate reinforcement [14].

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.

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.