4. DESIGN MODELS

4.1 Representation of a Composite Beam at the Strength Limit State

When designing a composite beam for strength, the nominal dead load (*G*) and live load (*Q*) acting over the tributary area (A) (see Fig. 4.1(a)) are used to calculate the design load in accordance with Clause 4.1.4 of AS 2327.1. The effective section and design action effects (M^* and V^*) must be calculated in accordance with Clauses 5.2 and 5.3, respectively, and using an effective span (L_{ef}) determined in accordance with Appendix H of AS 2327.1 (see Fig. 4.1(a)). In the absence of the influence of vertical shear, the design moment capacity (ϕM_b) at a cross-section can be determined by considering equilibrium of the beam as a whole and the free bodies shown in Figs 4.1(b) and (c). Moment-shear interaction may reduce the design moment capacity as explained in Section 3.4, in which case the design moment capacity is represented by ϕM_{bv} (see Section 4.3).

The main features of the design model shown in Fig. 4.1 are:

(a) the beam is simply-supported at both ends;

(b) a "lightly-loaded" cantilever may exist at either end of the beam;

(c) the effective width of the concrete flange is determined, which makes allowance for the shear-lag effect in the slab;

(d) at cross-sections where design moment capacity is calculated, an effective portion of the steel beam section is determined, taking into account any effects of local buckling;

(e) the stress distribution at a cross-section at the strength limit state is determined using rectangular stress block theory; and

(f) when calculating the design moment capacity (ϕM_b) at a cross-section, the shear connectors on the side of the cross-section where nf_{ds} is minimum are assumed to be sufficiently ductile (see Section 4.2) to all sustain their design shear capacity f_{ds} together, provided the compressive force in the concrete $C = nf_{ds}$ does not exceed F_{cc}.

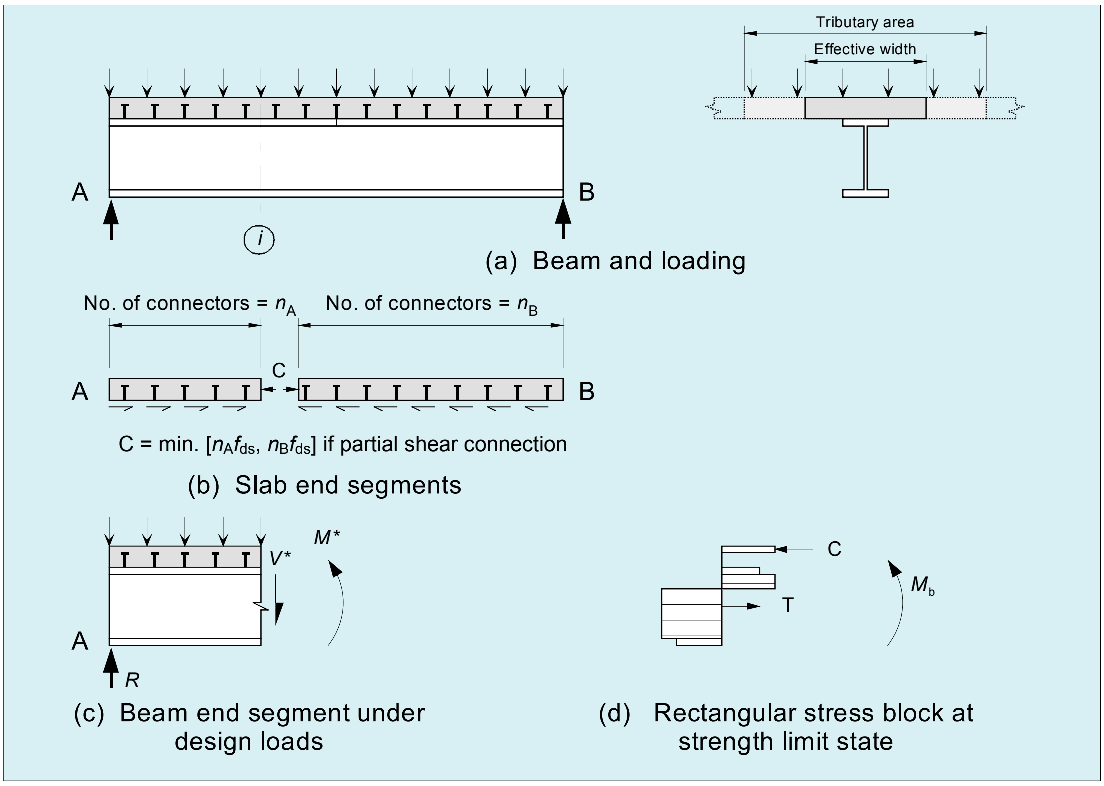

Figure 4.1 Representation of a Composite Beam Ignoring Moment-Shear Interaction at the Strength Limit State

4.2 Ductile Shear Connection Model

The general behaviour of shear connectors is described in Section 3.1. The ductile shear connection model used in the strength design method is shown in Fig. 4.2. It is assumed that shear connectors designed in accordance with Section 8 of AS 2327.1, and reinforced locally in accordance with Section 9 of the Standard have sufficient ductility for the assumption in Fig. 4.2 to be valid. Beam tests have shown that this is a valid assumption even at cross-sections a relatively long distance from the beam ends and with low values of degree of shear connection (β) [5]. The requirement of Clause 6.6.2(a) of AS 2327.1 that the degree of shear connection at the cross-section of maximum design bending moment (β_m) is not to be less than 0.5 is intended to reduce the demand for ductility of the shear connection.

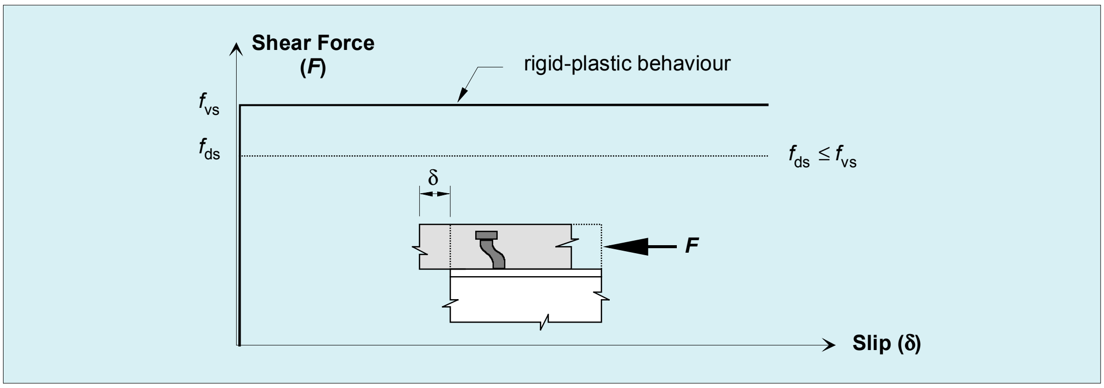

Figure 4.2 Ductile Shear Connection Model

4.3 Moment-Shear Interaction Model

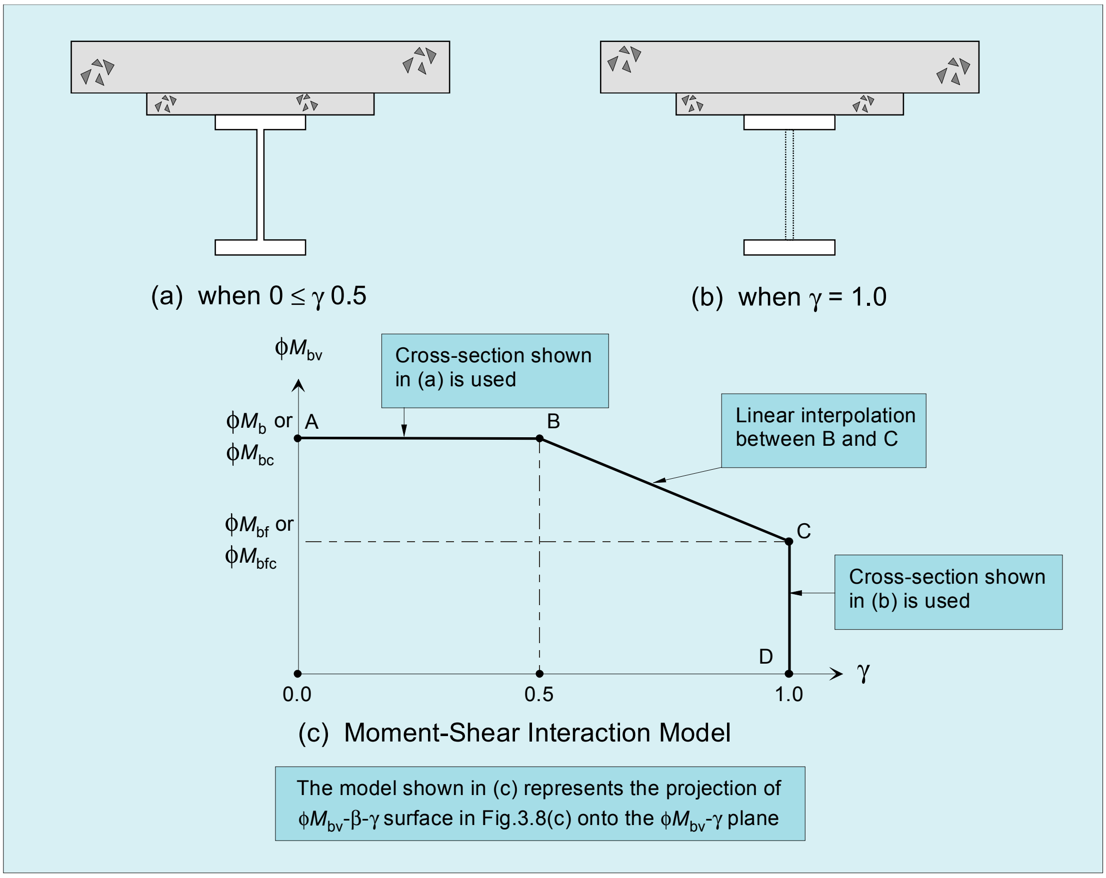

Figure 4.3 Moment-Shear Interaction Model

A detailed description of the moment-shear interaction behaviour is given in Sections 3.4 and 3.5. The basis of the design model used is given below.

(a) Unless it can be demonstrated that the concrete slab contributes to the vertical shear capacity, the web of the steel beam is assumed to carry the entire shear force.

(b) When the shear ratio (γ) is in the range $0 \leq \gamma \leq 0.5$, the nominal moment capacity (M_b or M_{bc}) of a cross-section is not affected by shear force, and the entire web of the effective portion of the steel beam is available to resist bending (i.e. between points A and B in Fig. 4.3(c)).

(c) When the shear ratio (γ) is equal to 1.0, the entire steel web is utilised carrying shear, and hence, the nominal moment capacity (M_{bf} or M_{bfc}) is calculated assuming the web is omitted (i.e. point C in Fig. 4.3(c)).

(d) Linear interpolation is used when the shear ratio (γ) is between 0.5 and 1.0 (i.e. between points B and C in Fig. 4.3(c)).

The moment-shear interaction diagram shown in Fig. 4.3(c) is a condensed two-dimensional form of the three-dimensional surface shown in Fig. 3.8.

Design of Simply-Supported Composite Beams for Strength

(To Australian Standard AS 2327.1–1996)

Design Booklet DB1.1

OneSteel Market Mills
Composite Structures Design Manual

February 2001

Published by

OneSteel Manufacturing Limited

ABN 42 004 651 325

Produced by the

Centre for Construction Technology & Research

University of Western Sydney

Contributors

Dr. Mark Patrick *
Centre for Construction Technology & Research

Dr. Daya Dayawansa *
Mr. Rodney Wilkie *
* Formerly BHP Melbourne Research Laboratories

Reviewed by

Prof. Russell Bridge
Centre for Construction Technology & Research

Mr. Mark Sheldon
Connell Wagner

Mr. Ken Watson
Formerly BHP Integrated Steel

Edition 1.0 - May 1998

Edition 2.0 - February 2001

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 Composite Beams for Strength” was one of the first two design booklets 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.

Simply-supported composite beams have been favoured in the construction of composite steel-frame buildings in Australia. This is essentially because simple steel connections such as the web-side-plate connection (see design booklet DB5.1 – Design of the Web-Side-Plate Steel Connection) are very economical to use when the steel frame is erected.

This design booklet contains important explanatory information and worked examples about the strength design method in Section 6 of Australian Standard AS 2327.1-1996, Composite Structures, Part 1: Simply Supported Beams. It is intended that this information will assist structural design engineers to understand the engineering principles on which the design method is based. The coverage of the strength design method is continued in design booklet DB1.2 – Design of the Shear Connection of Simply-Supported Composite Beams (To Australian Standard AS 2327.1-1996).

Design aids have already been prepared to support the use of the design method, and are included in the Composite Beam Design Handbook (in Accordance with AS 2327.1-1996) [2] published jointly by the AISC and Standards Australia. These comprise Design Tables (Appendix A) and computer software (COMPBEAM™). Although these design aids are intended to make the design process more efficient, it is essential that the users have a clear understanding of the design concepts and design rules prior to using them.

The strength design method in AS 2327.1 is based on partial shear connection strength theory and rectangular stress block theory, and is applicable to the design of composite beams with compact steel sections and ductile shear connection. Non-compact steel sections can be catered for by representing them in design as equivalent compact sections. Slender steel sections are not permitted. Details for ensuring that ductile shear connection is achieved are given in Sections 8 and 9 of AS 2327.1, and explanatory information about these rules can be found in design booklet DB1.2. Computer program COMPSHEAR™ can be used in association with COMPBEAM™ to design the shear connection in accordance with DB1.2.

The method of strength design presented for simply-supported composite beams has also been extended to cover the design of continuous composite beams, noting that very similar principles apply. The reader is referred to design booklet DB2.1 – Design of Continuous and Semi-Continuous Composite Beams with Rigid Connections for Strength, and an associated computer program COMPSECT™. Partial shear connection strength theory is also applicable to the design of composite slabs with ductile shear connection, which is also covered in a separate design booklet DB3.1 – Design of Composite Slabs for Strength. Finally, it is important to point out that the strength design method in AS 2327.1 is in harmony with leading overseas Codes, Standards and Design Specifications which address the design of composite beams.

Edition 1.0 was published by BHP in May 1998. Edition 2.0 contains some minor corrections to the first edition, and is published by OneSteel.