

B1. Conceptual and Preliminary Design

This part of the text takes the input information from the previous section and uses this to devise alternative framing systems, that could be used to satisfy the needs of the client and the various other constraints relevant to the project. The section also introduces an air conditioning ducting layout typical of what is likely to be required for the project. This stage of design is relatively non quantitative and may be described as being involved with the “art” of design. This section presents:

- Two fundamentally different conceptual floor framing systems
- Several fundamentally different ways in which horizontal wind loads may be carried to ground
- Preliminary slab design, to determine the maximum unpropped span of the chosen Bondek decking system. This is necessary to allow beam centre line dimensions to be added to the conceptual floor framing systems
- A decision relating to the choice of floor framing and “shear core” systems to be adopted for the project
- A cartoon style representation of the proposed construction sequence for the project that is necessary to understand the use of “erection columns” and the loads for which they must be designed
- Preliminary sizing of steel beams
- Analysis to determine plenum height to accommodate air conditioning ducting and thus allow the total height of the building to be determined
- Preliminary sizing of the columns and core walls

If you are familiar with the design of reinforced concrete multistorey buildings then there may be little new for you in this section except with regard to development of the floor framing system. Some “old fashioned” applications of composite slab systems for low rise applications, involved slab spans of around 5 metres requiring the use of 1 or more rows of props to assist the decking in carrying the load of the wet concrete. Such systems still have their place, but for multistorey buildings, one of the big advantages of composite construction, is the elimination of props. The general objectives in arriving at an economical floor framing system are as follows:

- The number of beams should be minimised, recognising that crane time required to lift each beam into position will represent a dominant time and cost factor for the project
- Minimising the number of beams means maximising the unpropped span of the floor slab. Appendix I illustrates a number of different decking profiles with maximum spans varying from 2 to 6 metres. Around 3 metres span for the slab, appears to represent a “sweet spot” for multistorey construction. To achieve the required 120 min FRL, a minimum slab depth of 120 is required. This same slab depth is about the minimum required to achieve satisfactory stiffness over a 3000 slab span. If a slab span of say 2 metres is used then the slab depth will still have to be 120 to satisfy the FRL requirement – but the 120 will represent more than enough for stiffness. With contemporary long spanning decking systems, unpropped slab spans up around 5 or 6 metres may be appropriate particularly in medium rise applications. Generally they will involve thicker, heavier slabs and heavier loaded, deeper beams, resulting in increased column and footing loads and floor to floor heights, all of which are increasingly disadvantageous as the number of floors increases.
- The system should minimise the clashes between the air conditioning ducts and the floor beams
- All of the standard objectives relating to repetition and simplicity and buildability of detailing. All beam to beam and beam to column connections are likely to be “pinned” connections using either a web side plate or a flexible end plate connection type.
- Secondary beams should be smaller than supporting primary beams to avoid detailing and erection problems

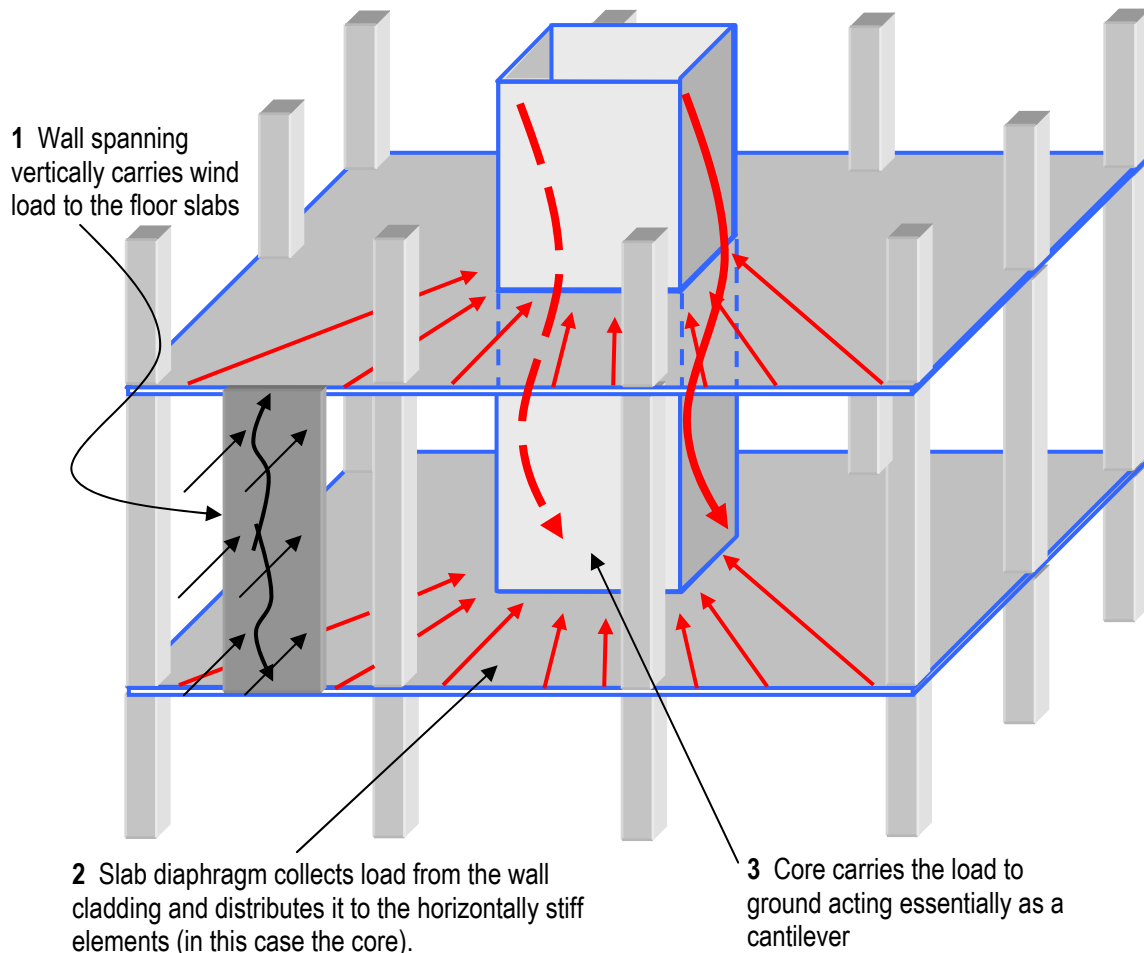
The following alternative floor framing systems anticipate a slab span of around 3 metres but at this conceptual development stage, the focus is on identifying fundamentally different systems rather than considering the details of a particular beam and column layout.



of the columns at each floor level until such time as the concrete is in place.

B1.3 Framing system for horizontal loading – initial distribution of load

The following figure represents the initial distribution of horizontal wind loading from the wall cladding through to, in this case, the shear core. This first stage of distribution of horizontal load is generally applicable to all overall systems for taking horizontal loads to the ground.



General schematic representation of distribution of horizontal wind loading.

The load path as illustrated above is as follows:

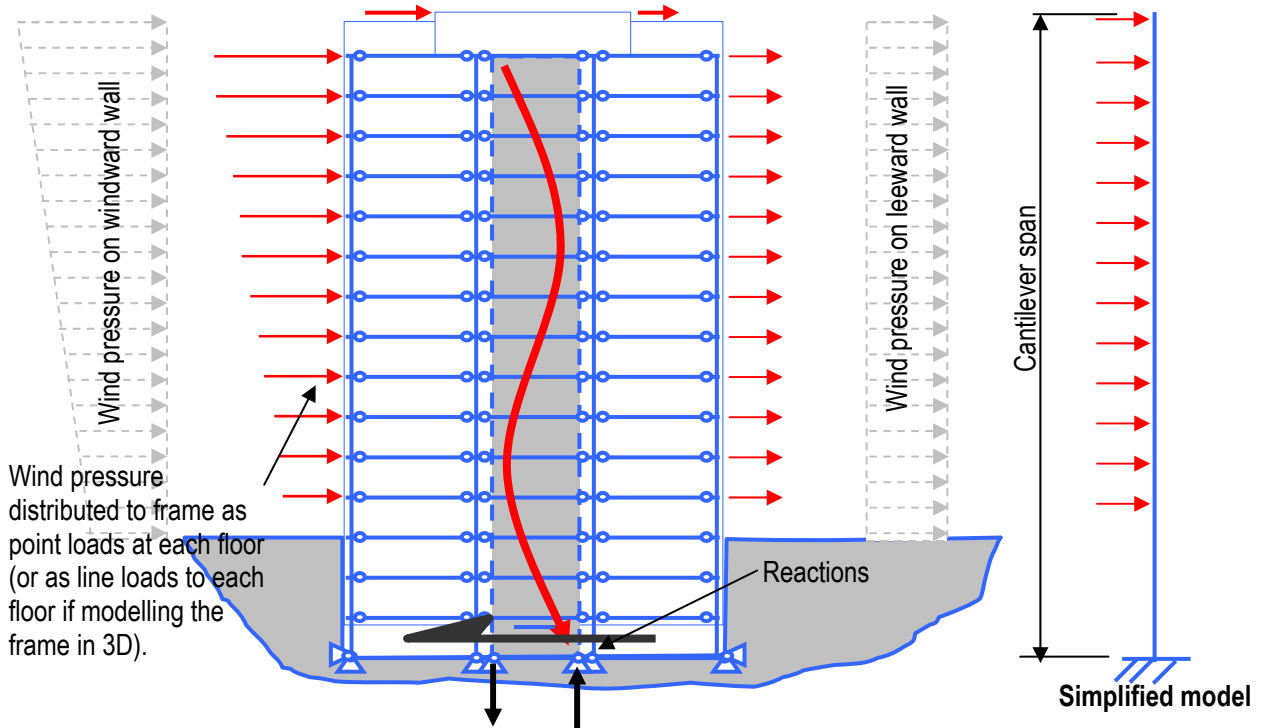
- Curtain walling spans vertically between the floor slabs
- Floor slabs act as diaphragms to distribute the horizontal load to those parts of the structure with significant horizontal stiffness. As illustrated it is assumed that only the central core has significant horizontal stiffness.
- The horizontally stiff elements (in this case the core) carry the horizontal load to ground.

The following pages illustrate 6 different overall systems that may be used to carry horizontal loads to ground in multistorey construction. Those with experience in multistorey construction will recognise that at least in the Australian context, some form of “shear core” system will be the obvious choice for a 12 storey building. The alternative systems are presented to illustrate with minimal discussion, the different systems that may be applicable for taller buildings.



B1.4 Alternatives for overall distribution of horizontal load to ground

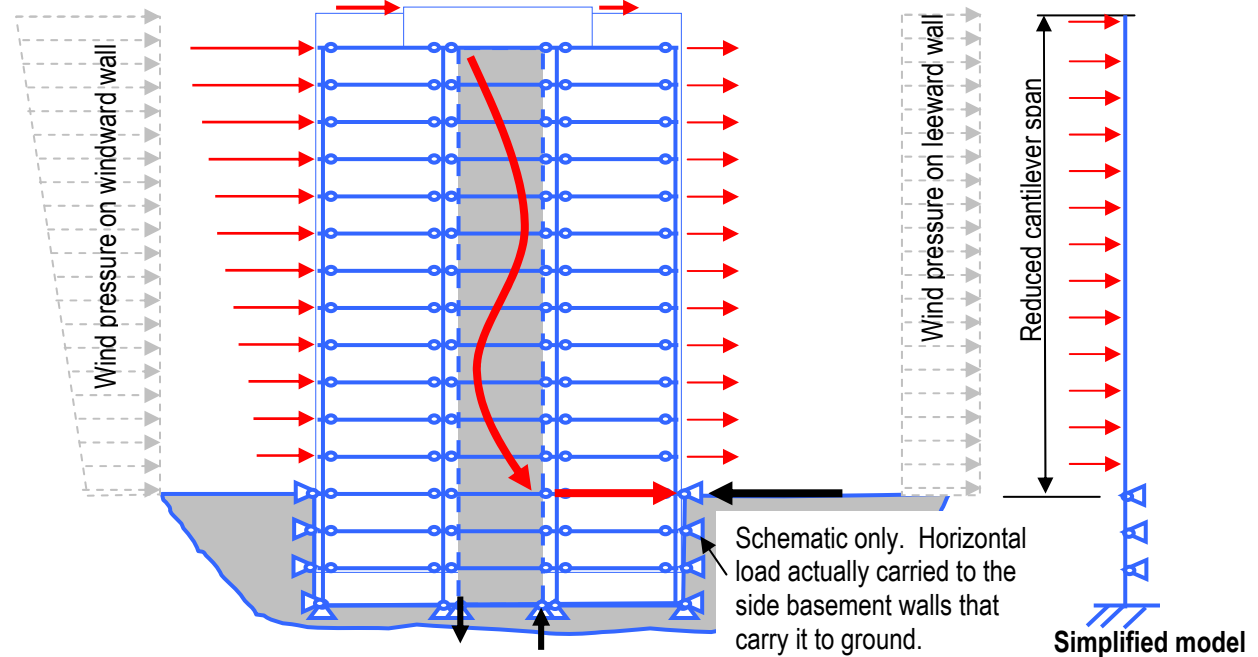
Alternative 1 – shear core alone



Characteristics

- All beam to column (and beam to core) connections are economical pinned connections
- Entire horizontal load is carried by the shear core as a cantilever beam of relatively small width
- High vertical and horizontal reactions at the base of the shear core

Alternative 2 – modified shear core alone (SUBSEQUENTLY ADOPTED SYSTEM)



Characteristics

- All beam to column (and beam to core) connections are economical pinned connections
- Entire horizontal load is carried by the shear core as a cantilever beam of relatively small width
- Reduced vertical reactions at the base of the shear core
- High horizontal loads in floor diaphragm at ground floor level and high horizontal loading to basement walls
 - Significantly reduced cantilever core span with distribution of horizontal load to basement walls

Composite Design Example for Multistorey Steel Framed Buildings

Copyright © 2007 by AUSTRALIAN STEEL INSTITUTE

Published by: AUSTRALIAN STEEL INSTITUTE

All rights reserved. This book or any part thereof must not be reproduced in any form without the written permission of Australian Steel Institute.

Note to commercial software developers: Copyright of the information contained within this publication is held by Australian Steel Institute (ASI). Written permission must be obtained from ASI for the use of any information contained herein which is subsequently used in any commercially available software package.

FIRST EDITION 2007 (LIMIT STATES)

National Library of Australia Cataloguing-in-Publication entry:

Durack, J.A. (Connell Wagner)

Kilmister, M. (Connell Wagner)

Composite Design Example for Multistorey Steel Framed Buildings

1st ed.

Bibliography.

ISBN 978-1-921476-02-0

1. Steel, Structural—Standards - Australia.
2. Steel, Structural—Specifications - Australia.
3. Composite, (Engineering)—Design and construction.
 - I. Connell Wagner
 - II. Australian Steel Institute.
 - III. Title

Disclaimer: The information presented by the Australian Steel Institute in this publication has been prepared for general information only and does not in any way constitute recommendations or professional advice. The design examples contained in this publication have been developed for educational purposes and designed to demonstrate concepts. These materials may therefore rely on unstated assumptions or omit or simplify information. While every effort has been made and all reasonable care taken to ensure the accuracy of the information contained in this publication, this information should not be used or relied upon for any specific application without investigation and verification as to its accuracy, suitability and applicability by a competent professional person in this regard. Any reference to a proprietary product is not intended to suggest it is more or less superior to any other product but is used for demonstration purposes only. The Australian Steel Institute, its officers and employees and the authors, contributors and editors of this publication do not give any warranties or make any representations in relation to the information provided herein and to the extent permitted by law (a) will not be held liable or responsible in any way; and (b) expressly disclaim any liability or responsibility whatsoever for any loss or damage costs or expenses incurred in connection with this publication by any person, whether that person is the purchaser of this publication or not. Without limitation, this includes loss, damage, costs and expenses incurred as a result of the negligence of the authors, contributors, editors or publishers.

The information in this publication should not be relied upon as a substitute for independent due diligence, professional or legal advice and in this regards the services of a competent professional person or persons should be sought.



Table of contents

Table of contents	iii
Preface	v
Section A: INPUT INFORMATION	1
A1. Client and Architectural Requirements	2
A2. Site Characteristics	4
A3. Statutory Requirements	5
A4. Serviceability	8
A5. Design Loads	9
A6. Materials and Systems	10
A7. Design Aids and Codes	11
Section B: CONCEPTUAL AND PRELIMINARY DESIGN	12
B1. Conceptual and Preliminary Design	13
B1.1 Consideration of alternative floor framing systems– Scheme A	14
B1.2 Consideration of alternative floor framing systems– Scheme B	15
B1.3 Framing system for horizontal loading – initial distribution of load	16
B1.4 Alternatives for overall distribution of horizontal load to ground	17
B2. Preliminary Slab Design	21
B3. From Alternatives to Adopted Systems	22
B3.1 Adopted floor framing arrangement	22
B3.2 Adopted framing arrangement for horizontal loading	23
B4. Indicative Construction Sequence and Stages	24
B4.1 The importance of construction stages in composite design	24
B4.1 Indicative construction sequence and construction stages	25
B4.2 Adopted construction sequence for design of erection columns	27
B4.3 Core construction alternatives	27
B4.4 Adopted construction method for the core	27
B5. Preliminary Sizing of Primary and Secondary Beams	28
B6. Plenum Requirements and Floor to Floor Height	30
B7. Preliminary Column Sizes and Core Wall Thickness	33
Section C: DETAILED DESIGN	35
C1. Detailed Design - Introduction	36
C2. Design Stages and Construction Loading	37
C3. Detailed Load Estimation After Completion of Construction	38
C3.1 Vertical loading	38
C3.2 Wind loading	39
C3.3 Seismic loading Not considered	40
C4. Erection Column Design	41
C4.1 Load distribution for erection column design	42
C4.2 Side Column C5 (typical of C5 to C10)	43
C4.3 End column C2 (typical of C2, C3, C12 and C13)	44
C4.4 Corner column C1 (typical of columns C1, C4, C11 and C14)	44
C5. Floor Beams – Construction Stage 1	45
C5.1 Secondary beams Group S1(11 050, 2800) (Beams B22 – B41, B43 – 48)	45
C5.2 Primary beams Group P1(9800, 5725) (Beams B1, B7 to B12, B18,	46
B19 – 21, B49 – 51 and B42)	46
C5.3 Primary beams Group P2(9250, 6600) (B2, B6, B13 and B17)	47
C6. Floor Beams – Construction Stage 3	48
C6.1 Secondary beams Group S1(11 050, 2800) (Beams B22 – 41, B43 – 48)	48
C6.2 Primary beams Group P1(9800, 5725) (Beams B1, B7 - B12, B18 – 21,	49
B49 – 51 and B42)	49
C6.3 Primary beams Group P2(9250, 6600) (Beams B2, B6, B13, B17)	49
C7 Floor Beam Design for Occupancy Loading	50
C7.1 Secondary beams Group S1(11 050, 2800) (Beams B19, B21, B22 - B41,	51
B43 – B49 and B51)	51



C7.2	Primary beams Group P1(9800,5725) (Beams B1, B7 to B12, B18)	58
C7.3	Primary beams group P2(9050, 6600) (Beams B2, B6, B13, B17)	63
C8.	Assessment of Dynamic Performance of Floor System	69
C8.1	Definition of the dynamic assessment process	69
C8.2	Application of the dynamic assessment process	73
C9	Final Slab Design	79
C9.1	Slab design for the office areas	79
C9.2	Slab design for the compactus areas	80
C10.	Longitudinal Shear Reinforcement Design	81
C10.1	Introduction	81
C10.2	Proprietary longitudinal shear reinforcement products	83
C10.3	Secondary beams group S1, B22 typical – longitudinal shear design	84
C10.4	Internal primary beams group P2, (B2 typical) longitudinal shear design	85
C10.5	Primary beams P1, (B1 typical) – longitudinal shear design	87
C10.6	Perimeter beams B19 to 21 and B49 to 51	88
C11.	Floor System Design Review and Final Decisions	89
C11.1	Floor design review	89
C11.2	Final floor framing plan and deck reinforcement	90
C12.	Final Design of RC Columns	91
C13.	Detailed Design of the Core	91
C13.1	Preliminary discussion and statement of limitations of this section	91
C13.2	Basic modelling of the core using beam elements	92
C13.3	The Space Gass Analysis Model	96
C13.4	Model verification and static deflections for W_s	97
C13.5	Dynamic analysis for natural frequency of building	98
C13.6	Interpretation and application of stress resultants from Space Gass	100
C13.7	Further investigation of the core using a Strand7 finite element model	102
C13.8	Review of core investigations	105
C14.	Steel Connection Design	106
C14.1	Can it be built?	106
C14.2	Representative connections	108
C14.3	Web side plate connection design for $V^* = 142$ kN	108
C14.4	Flexible end plate connection for $V^* = 279$ kN	112
C14.5	B2 to core web side plate connection for $V^* = 308$ kN	113
C14.6	Column splice for a load of $N^* = 1770$ kN	114
C14.7	Column base plate for a load of $N^* = 1770$ kN	115
C15.	Web Penetrations	116
C16.	Some Final Thoughts and Disclaimers	117
Appendix I	Theory and discussion – composite slabs	119
Appendix II	Theory and discussion - composite beams	133
Appendix III	Dynamic assessment of the floor system	149
Appendix IV	Theory and discussion steel connections	163
Appendix V	Corrosion and fire protection	175

