ZEGO®

Fire Form™

Engineering User Manual

for Commercial Building

The Fastest Way to Build!

ZEGO® An environmentally friendly product!

Introducing ZEGO® Commercial Building Systems (ICFs)

- ✓ ZEGO® Commercial Fire Form™ only 6 interconnects per form
- ✓ Fire ratings to FRL's 240/240/240
- ✓ ZEGO® uses only 100% flame retardant EPS BRANZ Report Number: FAR 2469
- ✓ Cast reinforced concrete 70mm to 800mm + wide
- ✓ Form 300mm high 2.8 per m² (Metric)
- ✓ 50mm Interlock & Intersect
- ✓ Multiple cost savings due to speed with less labour
- ✓ Easier material handling
- ✓ Patented Dovetail grooves (for render & plasterboard support)
- ✓ Patented Wall Brace scaffold system
- ✓ Insulation ratings R1.5 to R10+
- ✓ Sound Transmission (STC) 55+
- ✓ Cyclone rated to Cat 4 or 70m per sec (252kmh)
- ✓ Termite, rodent & mildew resistant
- ✓ Australia Wide Technical and Practical Training Support

Watch a demonstration video on our website at www.zego.com.au

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ZEGO® ...It's ZEE GO!!!!

ZEGO® Fire Form ™

(Insulated Concrete Forms ICF's)

IN MAJOR BUILDINGS

The Use of ZEGO ICF's In Buildings of BCA Class 2 to 9

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PREFACE

This Manual describes the use of the ZEGO® FireForm System in multi residential and commercial buildings. These buildings are generally of Class 2, 3 and 5, and may also include Classes 6, 7, 8 or 9. As such, they will be designed and specified by a professional design team comprising at least an Architect or Building Designer, and a Structural Engineer. They will also require building – specific certification by the Structural Engineer.

The ZEGO® FireForm System is a formwork system, and as such does not affect compliance with AS 3600 *Concrete Structures*. **However, there are characteristics of the Systems componentry that can govern dimensions, configurations and the like, so that this Manual will assist designers in the application of AS 3600 to structures built with the ZEGO® FireForm System.**

There are two main types of ZEGO® FireForms – permanent expanded polystyrene Insulated Concrete Forms (ICF), and Reusable Forms – moulded hard plastic reusable panels. Both are held across walls by cross ties which are proprietary ZEGO hard copolymer plastic Interconnects.

The Manual is aimed primarily for the professional design team, particularly Structural Engineers. Owners and Developers, and Local Authorities, will also find it useful. It contains design aids, key dimensions of system componentry, and suggested general solutions. It is intended to make the Designer's job easier. It contains few specific details or standard solutions, as for the buildings addressed; these vary widely from project to project. It is also the Certifying Engineer's right and responsibility for preparation and control of the design.

Issues covered in the Manual are

- **Section 1 - An Introduction to ZEGO Pty Limited and to the System**
- **Section 2 - A description of those aspects of the System and its componentry, which are relevant to the professional design team**
- **Section 3 - Fire Hazard Properties and Fire Resistance Rating of structures incorporating ZEGO® FireForm Insulated Concrete Formwork (ICF) permanent formwork, and the ZEGO Interconnect cross – wall formwork ties**
- **Section 4 - Energy efficiency of the ZEGO® FireForm Insulated Concrete Formwork (ICF) permanent formwork**
- **Section 5 -The structural use of ZEGO® FireForm unreinforced walls**
- **Section 6 - The structural use of ZEGO® FireForm reinforced walls – general description**
- **Section 7 - Reinforced Walls design aids**
- **Section 8 – Attached Beams (downturned and upturned edge beams and lintel downturns of slabs) using ZEGO® FireForms.**

A separate Manual is in course of preparation to cover Construction, intended for use of those on site.

For costing advice and costing aids, refer directly to ZEGO

1. INTRODUCTION

1. 1 The ZEGO Story

ZEGO Pty Limited is a wholly Australian owned and operated building system company, which manufactures the MAGU Building System under a license agreement with MAGU Insulated Concrete Forms of Germany. MAGU have been operating in Germany for over 40 years. They are world leaders in alternate wall and floor systems. It has been conservatively estimated that in Germany alone there are between 2.5 and 3.0 billion square metres of building constructed using the system.

Scott A. Evans founded ZEGO in 2000, for the initial purpose of supplying a simple, cost effective, energy efficient product to quality residential homes requiring a solid type of construction to quality residential housing. Since then, hundreds of homes have been built, most in the upper price range $1m upwards and of 1000 square metres or more in floor area.

ZEGO has now expanded to supplying the Commercial and Multi Unit Residential sectors. This Manual has been published to support that market, to provide assistance to Architects, Engineers, Quantity Surveyors, Estimators, Builders and Developers.

1.2 Outline Product Description

The ZEGO Pty Limited Magu Wall System comprises Insulated Concrete Forms (ICF's) filled with concrete. After pouring, the ZEGO® "Magu" ICF remains as permanent formwork and as wall insulation. It allows plumbing and electrical services to be installed on the critical path without structurally damaging the walls.

The concrete fill plus any reinforcement comprises the complete wall structure, with no structural contribution required from the ZEGO® "Magu" ICF. A ZEGO® Magu wall is thus a pure concrete structure and is designed in accordance with conventional concrete design principles.

The ZEGO® "Magu" System when designed and constructed in accordance with ZEGO Specifications, complies with the relevant Australian Standards referenced in the Structural Provisions of the Building Code of Australia Volumes 1 and 2.

A notable advantage of the ZEGO® "Magu" System is its ease of adaptation on site, as the ZEGO® ICF's are easily cut and worked, as they are only made of EPS foam. There is no need to work to modular dimensions or coursing based on component size. Even curved or non-rectangular layouts are no problem for ZEGO. Unlike most non-traditional building systems, no complicated ordering and scheduling, shop drawing or off site fabrication is required. Estimation is easy. The concrete quantity is the net wall area times the core thickness, where the net wall area is the wall perimeter x floor-to-floor height less window and door openings.

As well as walls, ZEGO can be used to form columns, beams, lintels, swimming pools, retaining walls and any other concrete structure involving formwork on either side of a concrete core.

1.3 Use and Types of ZEGO Forms

ZEGO Forms come in three basic types: **Block type ICF units**, **Panel type ICF Fireform units** and **Reusable hard plastic Fireform panels**.

1.3.1 The Block Type ICF Units

look a little like hollow masonry blocks, but are non-structural. There is a large horizontal void space as well as a vertical space, so that on completion of pouring of concrete, a concrete grid within the ZEGO cores is formed. The block type unit is shown in Figure 1.1.

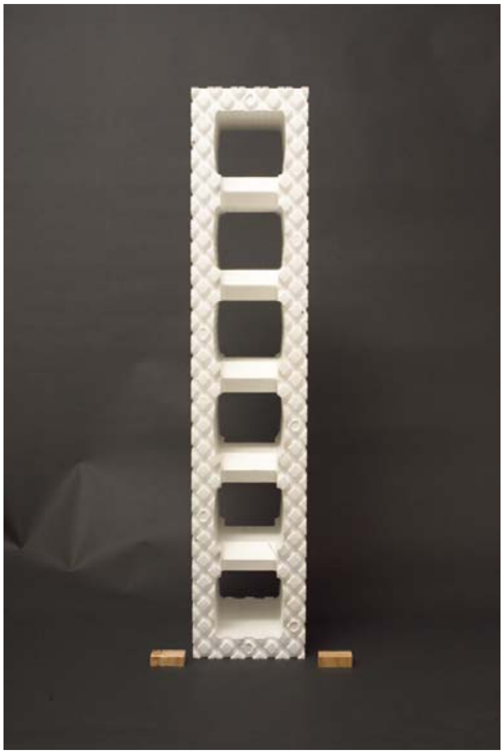


Figure 1.1 Block Type ICF Unit

The block type units are mainly used in domestic construction and come in nominal 200 mm widths. Fore more information on these, refer to the ZEGO Domestic Construction Manual.

1.3.2 The Panel type ICF Fireform Unit is the type for use in major construction. Construction comprises two separate ZEGO Styropor form panels, one on each side of the wall or other element to be poured. These are held in place on each side with special ZEGO plastic interconnects. The cross sectional area of these Interconnects penetrating the concrete core is small enough to ensure that the Fire Resistance Level of the core concrete as determined in accordance with AS 3600 *Concrete structures* is not affected. (Refer BRANZ Report FAR 2469, attached as Appendix A). They are thus suitable as firewalls for boundary and party walls, and other situations where the Building Code of Australia (BCA) requires fire isolated walls and partitions.

The Panel type units allow much more flexibility in use, compared with the block type units. When used in various combinations they can provide insulation thicknesses from 52 mm and 100 mm thick and concrete core thicknesses from 80 mm to 312 mm thick (as available at the time of writing). Total wall thicknesses depend on the core thickness chosen for structural reasons and insulation thicknesses chosen for thermal reasons. Typical configurations for load bearing walls in 6 to 10 storey commercial and multi unit residential construction in most parts of Australia might be 60 mm ZEGO panels, with 80 mm, 104 mm or 120 mm concrete core, total 200 mm, 224 mm or 240 mm respectively.

The arrangement is shown in Figure 1.2.

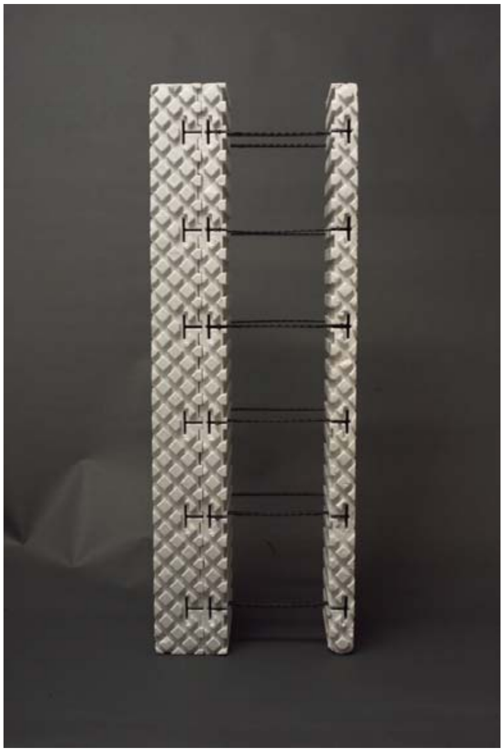


Figure 1.2 Panel Type ICF FireForm Unit, Panels Connected with Plastic Interconnects

Figure 1.3 Panel Type ICF FireForm Unit with Reusable Plastic FireForm Unit and Plastic Interconnects

1.3.3 Reusable Hard Plastic Fireform Panels have a nominal thickness 19 mm and are used where strippable formwork is required, where wall thickness must be limited, or where an exposed concrete finish is specified. Being of hard plastic and very robust construction, they can be reused a great number of times, and are available from ZEGO as hire as well as purchase. They are cross-connected with plastic Interconnects as for the Panel type ICF Units, and are therefore also suitable for fire resistant construction.   An assembly showing both Panel type ICF and Reusable Plastic panels is shown in Figure 1.3.

1.4 Availability and Service

World wide ZEGO Pty Limited manufacture is carried out in four locations. These are at Swan Hill, Victoria; Bowen, Queensland; Colombo, Sri Lanka and Hufingen, Germany.

For quotes, orders and technical information contact ZEGO at:
Local Call 1300 13 ZEGO (1300 13 9346)
Sydney Head Office: Phone 02 9651 2277 or Fax 02 9651 2477
International: Phone +61 2 9651 2277 or Fax +61 2 9651 2477

1.5 Scope of Application

The ZEGO® "Magu" System is applicable for any structure provided the wall or other element incorporating the System is proportioned, designed and constructed by properly qualified people in accordance with the Building Code of Australia (BCA) and the relevant Australian Standards as listed elsewhere in this Manual, to suit the conditions for which the application is intended.

1.6 Disclaimer

This Manual is written to assist Architects, Designers, Engineers, Owners, Builders and Building Inspectors to determine the correct reinforcement and other data for buildings and structures using ZEGO Pty Limited “Magu” Insulated Concrete Formwork Polystyrol “F” units. It also contains general information for initial guidance in commonly met and straightforward situations. Neither ZEGO Pty Limited nor its Consultants have any knowledge or control over the manner in which this information might be used, and cannot be aware of specific situations where it might be used. The Authors, Editors and Publishers of this Publication shall not be held liable or responsible in any way whatsoever and expressly disclaim any liability or responsibility for any loss or damage consequences incurred as a result of any kind of use of this Publication. Use of this Manual and the inclusion of a Certificate as to the compliance of its contents with various Codes do not absolve Engineers, Architects, Building Designers, Project managers and others directly connected with and having responsibility for specific projects from their statutory or common law responsibilities. Accordingly, it is strongly recommended that where a possibility exists that any erroneous use of ZEGO Pty Limited “Magu” ICF or of this Manual could result in significant losses, the advice of an appropriately qualified and responsible party should be sought.

1.7 References

1.7.1 Australian Standards

Below are listed Australian Standards and Codes used in the preparation of this Manual, and assumed complied with in the use of ZEGO Pty Limited “Magu” ICF.

AS 1170:2002 series *Structural design actions*

Part 0: General principles

Part 1: Permanent, imposed and other actions

Part 2: Wind actions

AS 3600: 2001 *Concrete Structures*

AS 3700: 2001 *Masonry Structures*

BCA 2005 Volume 1 *Building Code of Australia Class 2 to Class 9 Buildings*

Standards referenced in the Text are expressed as their number only eg AS 3600.

All construction referred to in this Manual must comply with these Codes.

1.7.2 Other References

SAA HB 71 – 2002 Cement and Concrete Association of Australia/Standards Australia *Concrete Design Handbook*

Smorgon ARC – *Reinforcement Handbook* 2nd edition 2001

Warner R F, B V Rangan and A S Hall *Reinforced Concrete* 3rd Edition Longman Cheshire Melbourne 1989

1.8 Use of this Manual

1.8.1 Valid Only for Genuine ZEGO® "Magu" ICF

THIS IS AN IMPORTANT NOTE FOR BUILDING INSPECTORS

This Manual is valid only when Genuine ZEGO® "Magu" ICF as shown is used as formwork to set the dimensions and configuration of the structural concrete. Other formwork products may have significant differences in dimensions and conformation to ZEGO® "Magu" ICF and it is thus essential that only ZEGO® "Magu" ICF be used. The Certification at the head of this Manual is not valid for other products.

ZEGO® "Magu" ICF is readily identified as to genuine source by the logo stamps on each ICF unit. These stamps comprise a circle 38 mm in diameter embossed at intervals along the top face of the ICF unit and inscribed with the words www.zego.com.au as shown below or by the Patented Diamond Interlock and dovetailed surface. If any one of the stamp, the diamond interlock or the dovetailed surface is not present, the construction should be rejected.

www.
zego.
com.au

1.8.2 Manual to be Read in its Entirety

This Manual if used as an aid to design and construction is intended to be read and understood in its entirety

1.8.3 Qualifications of User

This Manual is written for the use of professional engineers qualified and experienced to the level required for registration under the Australian National Professional Engineers Register Section 3 in the category of Civil/Structural and with recent and continuing Structural design experience in the types of structures referred to in this Manual. Throughout the Manual, reference is made to "The Designer", meaning the qualified professional engineer responsible for the design of the specific project in which the ZEGO® System is to be used.

1.8.4 Silence of the Manual

The apparent omission of reference to members, components, materials, workmanship and the like including items not shown but necessary for the construction, shall not be taken to mean they are not required. The Manual is written on the basis that users will have sufficient knowledge and experience to include all such items in their design documents and to ensure that they comply with the current Building Act, current Australian Standards and recognised correct practice.

2. ZEGO PANEL SYSTEM COMPONENTS AND ASSEMBLIES

2.1 Introduction

ZEGO is a full building system, comprising not only Insulated Concrete Form (ICF) Panels and Blocks), but a full range of ancillary components to make construction simpler, faster and more economical. The System also includes numerous items of construction aid hardware, and a full advisory and support service throughout the building delivery process – planning, design, estimating and construction support.

The range of ZEGO components and construction aids include Insulated Concrete Form (ICF) Panels and Blocks), Reusable Form Panels, Interconnects of various sizes to hold ICF and / or Reusable Panels in position, ICF End Closers for ends of ICF panel walls, etc. Construction aids include wall braces, cutting tools, wire working tools and the like. Many of these non-consumable Construction Aids are available for hire

The Cover of this Manual indicates the range of system componentry available.

This Manual is a Design Manual, for Commercial scale construction. The range of products listed here is restricted to those within the interest of the Design Team on Commercial Projects – that is, Developer, Architect, Structural Engineer, Quantity Surveyor or Estimator and Project Manager.

For ZEGO products suited to domestic housing, refer to the ZEGO “Magu” Domestic Construction Manual.

For details of ZEGO construction aids and equipment, refer to ZEGO Construction Support staff.

2.2 ZEGO Panel System Components

2.2.1 General

Panel ICF dimensions are nominal 1200 long (actually 1152), 300 nominal course height and thicknesses 52, 60 and 100. There is also a “piggyback” panel of 52 effective thickness, with large dovetail interlocks on each face, to enable buildup using more than one panel.

The upper and lower surfaces of panels are embossed with interlocks to ensure bond prior to pouring concrete and before concrete has hardened. Outside faces have dovetails to ensure keying of render, and witness lines to assist assembly. Inside faces have a large dovetail pattern, to enable “piggybacking” of multiple panels for increased insulation.

A ZEGO end closer is used at ends of walls, door jambs, window reveals and the like, to form the ends of the concrete elements.

Owing to ease of on site cutting, the cost of cutting is insignificant; therefore there is no point in designing to modular ICF lengths or coursing. The only design constraint, therefore, is thickness.

A typical assembly is shown on Figure 2.1.

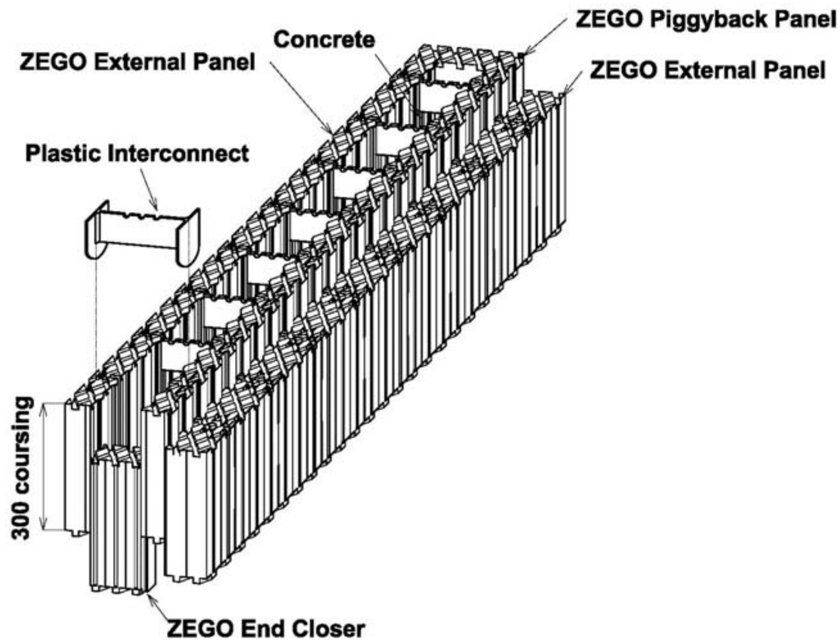


Figure 2.1
Isometric Drawing of Assembly

2.2.2 Panel Types and Accessories

Figure 2.2 shows the four currently available ICF panel types in plan. Figure 2.3 shows an elevation (all ICF panel types being the same in elevation) and Figure 2.4 shows a pair of typical ICFs in section. Coursing is 300, and the height of a panel is 312.5, the interlock being 12.5.

Figure 2.5 shows a ZEGO removable form, for use where total wall thickness must be minimised and there is no requirement for insulation, and Figure 2.6 shows the range of end closers.

Figure 2.7 shows a plastic Interconnect. The functions of the various features of the Interconnect are explained in the next Section. The Interconnects come in a range of sizes, to suit various thicknesses of concrete. The left and right ends are the same for all sizes, but the centre section varies in width. The thickness of concrete is the distance between the Index Marks shown at 42.5 mm in from the end “dumbbells”.

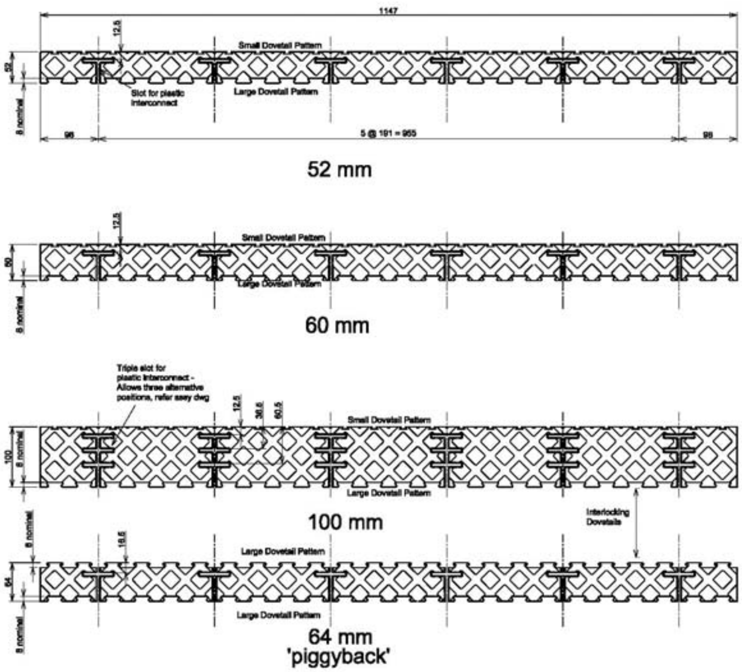


Figure 2.2
ZEGO ICF Panel Types

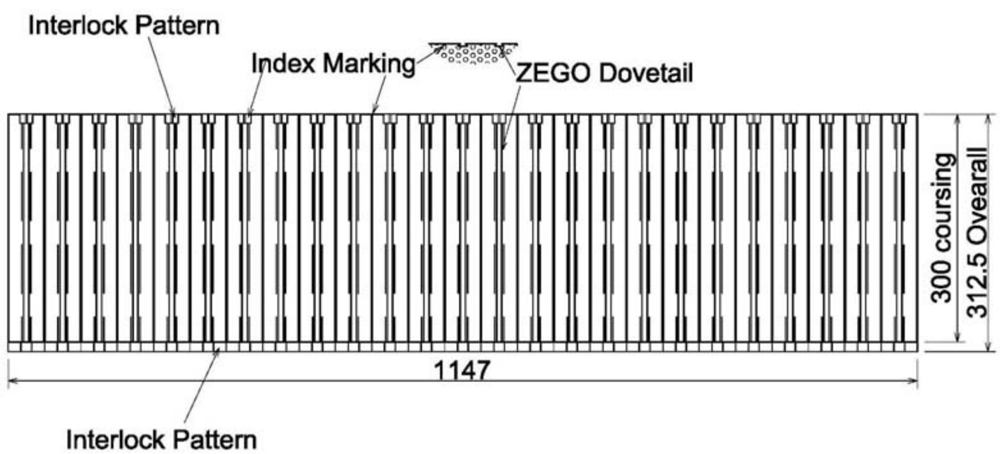


Figure 2.3
Typical ZEGO ICF Panel Elevation

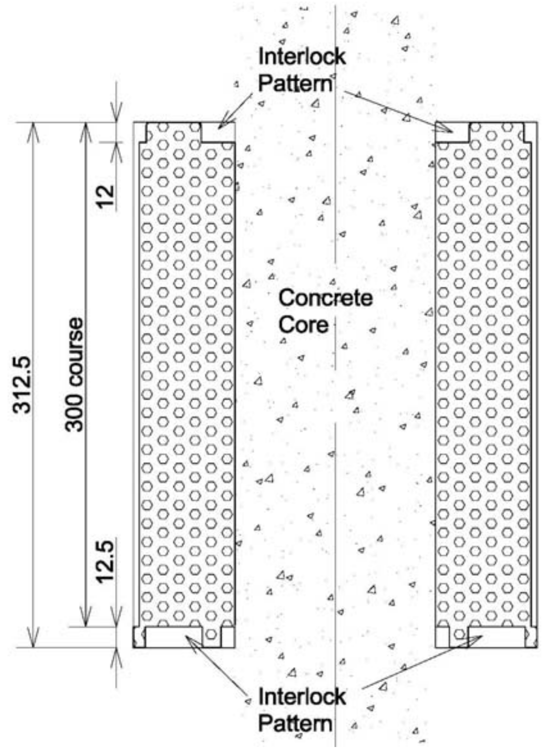
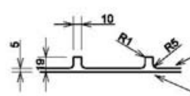
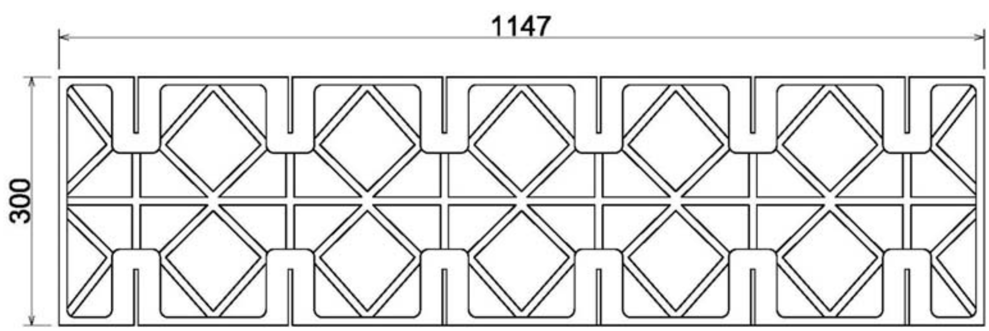


Figure 2.4
Typical ZEGO Panel Section
(Interlocks and Reinforcement Omitted)



Typical Ribs



Elevation on Back Face

Figure 2.5
ZEGO Removable Form

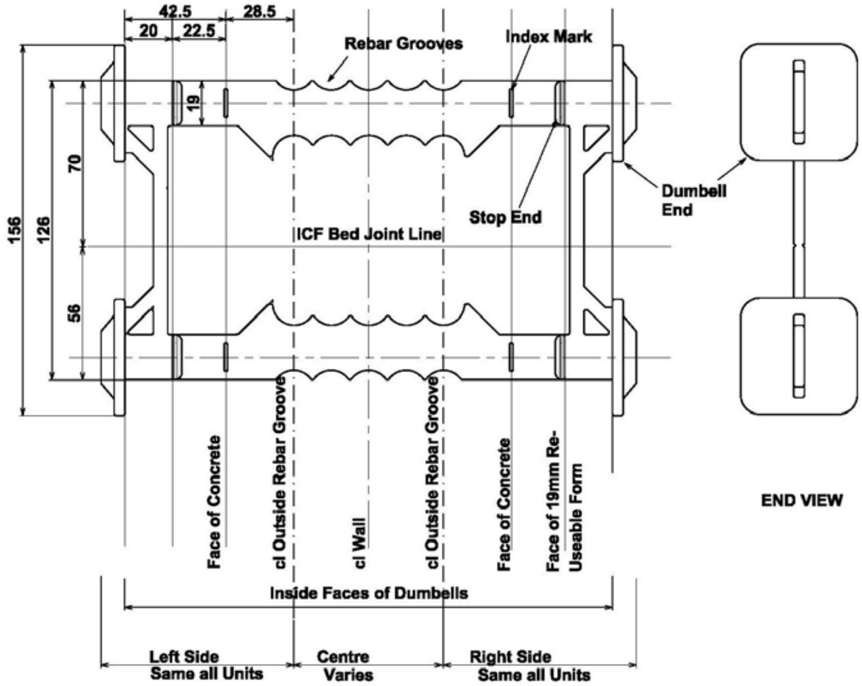


Figure 2.6
Plastic Interconnect

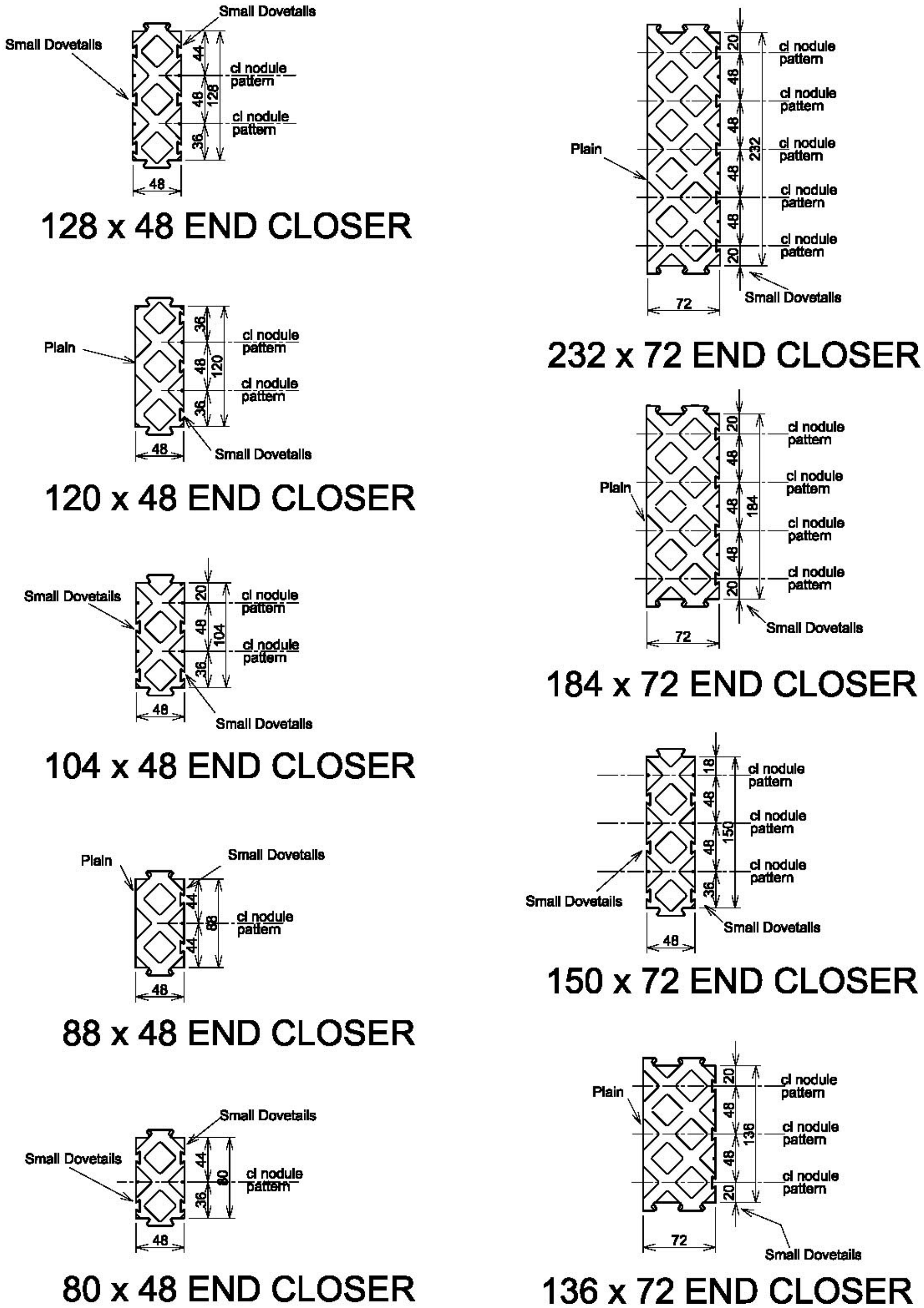


Figure 2.7
ZEGO ICF End Closers

2.3 Assembly

2.3.1 General

The previously mentioned Figure 2.1 shows a general view of an assembly, shown in plan on Figure 2.8. The assembly is shown in section without Interconnects and reinforcement, on Figure 2.4, and with both Interconnects and reinforcement on Figure 2.9.

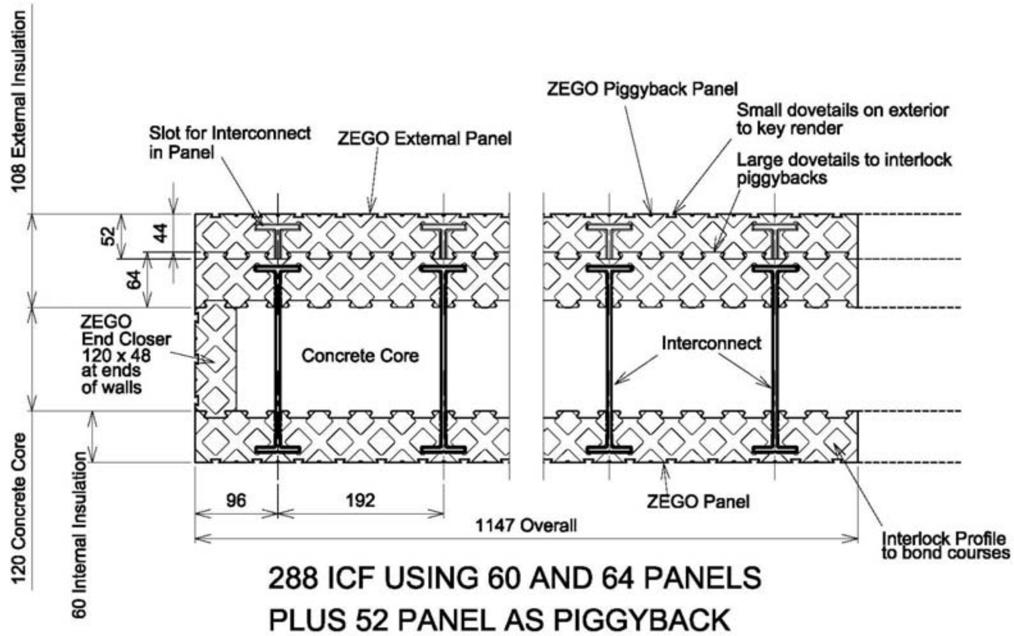


Figure 2.8
Assembly In Plan
Showing a "Piggyback" Installation

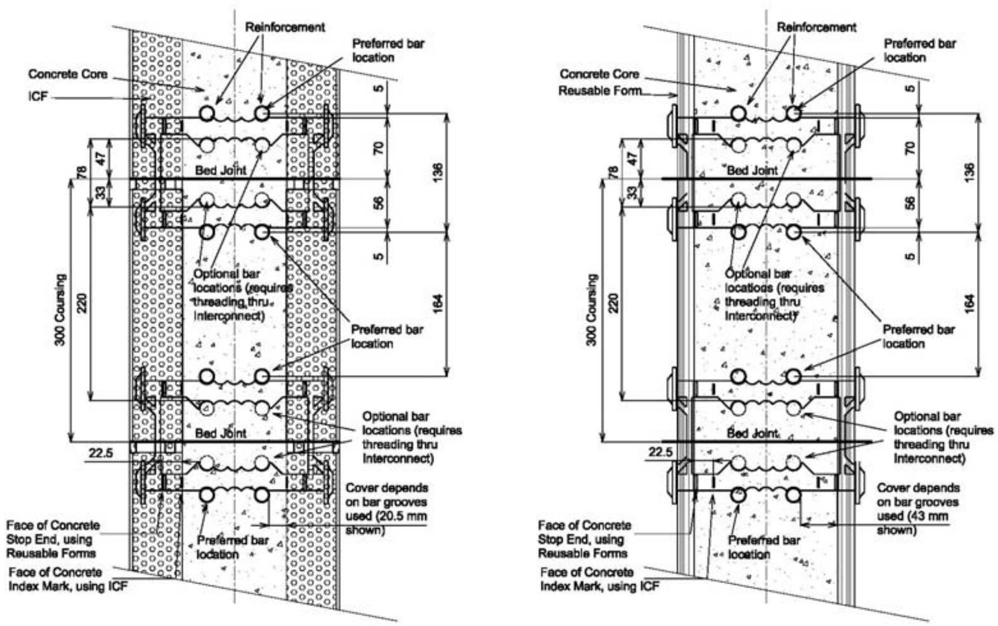
2.3.2 Interconnects

The use of the Interconnect is now described. Refer to Figures 2.7 and 2.9.

The Interconnect has a top and bottom section and “dumbbells” at each end. The “dumbbells slide into the T – shaped slots in the panels, see Figures 2.1, 2.2, and 2.8 (multiple slots are to provide wall width options).

The Interconnects come in a range of sizes, to suit various thicknesses of concrete. The left and right ends are the same for all sizes, but the centre section varies in width. The thickness of concrete is the distance between the Index Marks shown at 42.5 mm in from the end “dumbbells”. The size of Interconnects required is determined from the thickness of concrete required, which is the distance between the Index Marks (shown at 42.5 mm in from each end “dumbbell”).

The bottom section is slid into the T – slots from above, so the top section projects above the “bed joint line” between ICF courses, as shown in Figure 2.9. For the lowest course, the bottom section is broken off, and for a top course, the top section is broken off. The vertical bars have a formed nick on the course line for this purpose.



Using ICF **Using Reusable Forms**

Figure 2.9
Assembly – Section

Reinforcement is held in place by the grooves on the horizontal interconnect bars. Reinforcement can be placed either above or below interconnect bars, whichever is most convenient. Usually, the preference is on top of the upper bar and below the lower bar, to avoid having to thread bars through the centre gap. Reinforcement below the Interconnect bars can be lifted and held in place with tie wire.

Reinforcement retaining grooves are 9 mm radius, allowing for reinforcing bar sizes up to 16 mm diameter.

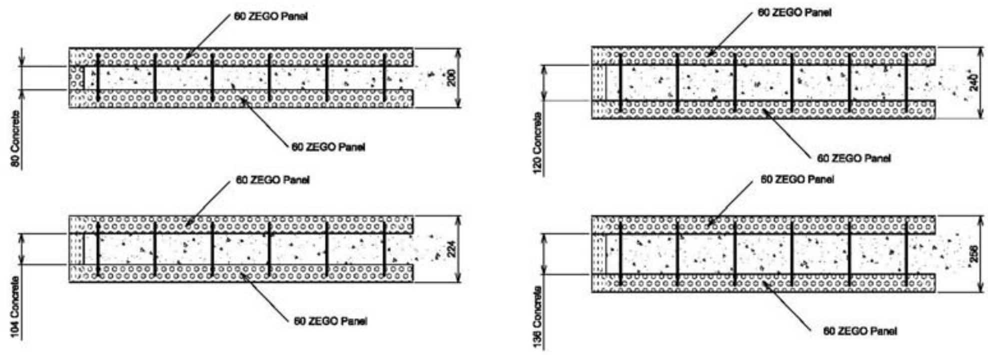
Positions of reinforcement retaining grooves allow for a range of covers, as may be required for a particular design by the durability and fire provisions of AS 3600.

When using the reusable form panel, the outer face of the 19 mm rib of the form is at the stop end shown on Figure 2.7 at 20 mm from the “dumbbell”. To strip the form, the “dumbbell” and projecting plastic is cut off. A reusable form can be used on one side of a wall and an ICF on the other.

2.4 Thickness and Reinforcement Options

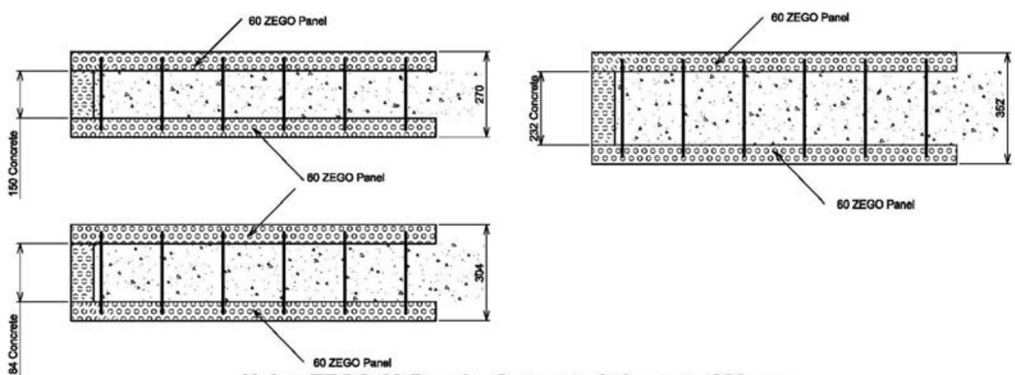
2.4.1 Examples of Assemblies

Figures 2.10 (a), (b), (c) and (d) show some options with various combinations of ICF and concrete thickness. In addition, assemblies can be made using reusable forms.



Using ZEGO 60 Panels, Concrete 80 mm to 136 mm

Figure 2.10 (a)



Using ZEGO 60 Panels, Concrete 150 mm to 232 mm

Figure 2.10 (b)

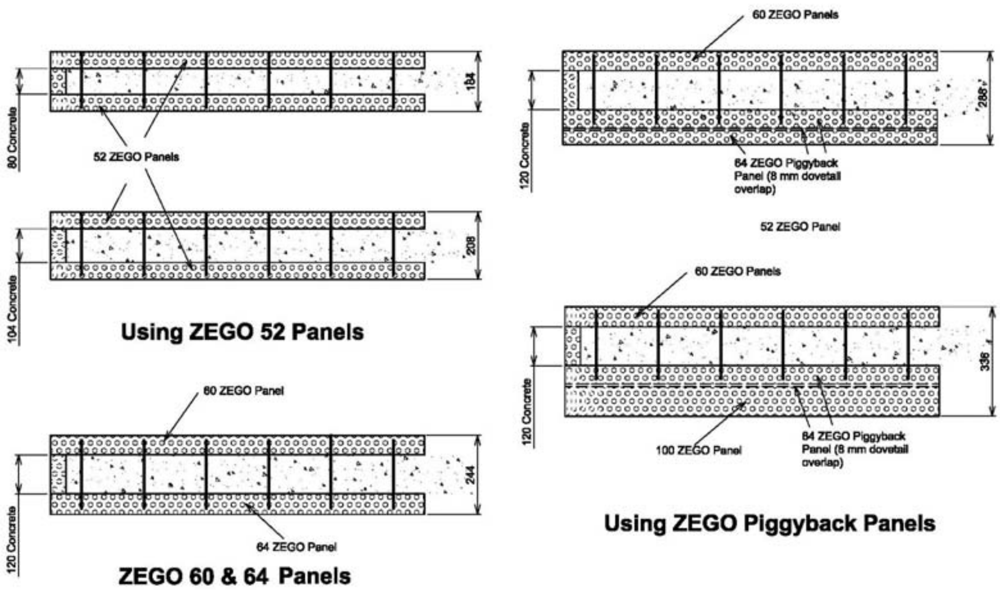


Figure 2.10(c)

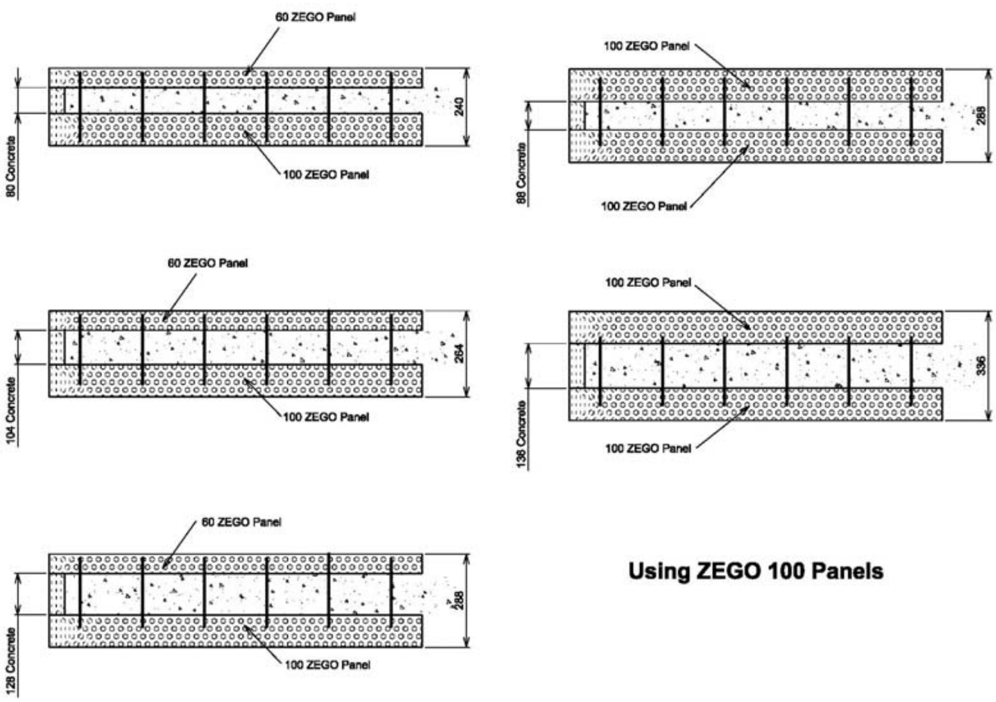


Figure 2.10 (d)

As can be seen from these Figures, a very large combination can be used. Those shown in Figures 2.10 (a) and (b) will have the greatest application in commercial and multi residential construction.

2.4.2 Selection of ICF Thickness

Total ICF thicknesses for either side of a wall can be

- 52 mm
- 60 mm (generally the preferred thickness)
- 64 mm (using the "piggyback" panel with large interlock dovetails on the outside face)
- 100 mm
- 108 mm (64 mm "piggyback" plus 52 mm – 8 mm dovetail overlap)
- 116 mm (64 mm "piggyback" plus 60 mm – 8 mm dovetail overlap)
- 156 mm (64 mm "piggyback" plus 100 mm – 8 mm dovetail overlap)

While 52 mm is thinnest, and leads to the thinnest overall wall section, the profile height of the inside dovetails is 8 mm, leaving a minimum net thickness of 44 mm. This is not adequate for a 50 mm chase depth, bearing in mind that one advantage of ZEGO is the ability to chase, without interrupting either structure or finishes.

The preferred ICF thickness is 60 mm. This panel can easily be chased to 50 mm, it is adequately robust, and a wall with 60 ICF on each side will comply with the energy efficiency provisions of the BCA, as discussed on Section 3.

Thicker ICF can be used to enhance air conditioning efficiency, or to build out a wall for architectural reasons. It can also be used to match thickness to existing work.

The main application of thick ICF is as a cladding over timber framing, to replace sheeting and at the same time to provide an outside skin of similar thickness to brickwork.

2.4.3 Selection of Concrete Thickness

Concrete thickness when formed by ICF both sides is governed by the sizes of ICF end closers as shown on Figure 2.6 and as listed below. When using reusable forms on one or both sides, the concrete thicknesses increase by 22.5 mm on each side where a reusable form is used.

Components for the current "preferred sizes" are in bold face and marked with an asterisk *, are held in stock and are readily available.

- **80***
- 88
- **104***
- **120***
- 128
- **136***
- **150***
- 184
- 232

Concrete thickness follows the same principles as for any conventional reinforced concrete structure, except, as discussed in Section 5, there is an option for unreinforced walls.

2.4.4 Concrete Mix

The following concrete mix options are recommended.

- Strength at 28 days can be any of f'_c = 20 MPa, 25 MPa, 32 MPa and 40 MPa, to suit structural and durability requirements. Strength 50 MPa may be used provided the Designer can ensure proper control of mix, placement and curing.
- Aggregates are generally 10 mm maximum size. Where both clear cover and gaps between horizontal bars exceed 50 mm, and thorough compaction can be assured, 20 mm aggregate may be used.
- The recommended slump is 80 mm, unless there are concerns about proper compactability due to restricted spaces, in which cases higher slumps should be considered.
- Admixtures may be used so long as they comply with relevant Australian Standards, result in a mix of predictable characteristics and do not induce corrosion, reduce concrete durability or introduce any other deleterious effects.

2.4.5 Concrete Cover

Bar grooves in Interconnects are designed to ensure a choice of side cover to 16 dia horizontal reinforcement of 20.5 mm, 36.5 mm, or 52.5 mm. These would be used to comply with (and in fact slightly exceed) fire provisions of AS 3600:2001 Table 5.7.4, which specifies 20 mm for FRL 60/-/-; 35 mm for 90/-/- and 50 mm for FRL 240/-/-.

Further information on FRL of the ZEGO system is given in Section 3.

3. FIRE

3.1 Fire Hazard Properties

The BCA at Specification C1.10 sets out requirements in relation to the fire hazard properties of materials and assemblies in buildings. The properties of concern for other than sarking type materials and for other than finishes, surfaces, linings or attachments are Spread of Flame Index and Smoke Developed Index.

Fire Hazard Property	Values for BASF Styropor F Expanded Polystyrene ICF	Values for Yuhwa HCPP Black Copolymer Polypro SB9430 Plastic Interconnects
Flammability Index	0	
Spread of Flame Index	0	
Smoke Developed Index	4	

(insert comment on actual BCA requirements if final figures are less than minimum requirements for all situations)

3.2 Fire Resistance Level

3.2.1 BCA

The BCA requires a specified Fire Resistance Level (FRL) for partition walls, floors and other elements for various parts of construction. The FRL is a measure of the time for which the wall, floor or other element will maintain fire separation between parts of a building or within the building. It is expressed as three figures showing structural adequacy / integrity/ insulation. For example FRL 120/60/30 means a structural adequacy of 120 minutes / integrity 60 minutes / insulation 30 minutes, all when tested in accordance with AS 1530.4.

The ZEGO® FireForm ™ ICF system is a wall system, so what follows applies to walls. It can also be applied to Spandrels (either downturned or upturned edge beams).

3.2.2 BRANZ Report FAR 2469

The ZEGO® FireForm ™ ICF system comprises formwork manufactured from either expanded polystyrene "Styropor" or reusable plastic panels, tied across the wall with hard copolymer injection moulded plastic interconnects, as described in section 2.

The "Styropor" forms, although permanent, play no part in fire resistance. The ZEGO® FireForm ™ wall is a reinforced concrete wall to AS 3600 – 2001 except for the plastic interconnect penetrations.

The ZEGO® FireForm ™ ICF system has been the subject of a BRANZ Report, number FAR 2469, dated 16 February 2005. The Report concludes that a concrete wall manufactured using the ZEGO® FireForm™ ICF system would provide at least the fire resistance in accordance with AS 1530.4-1997 as given in AS 3600 – 2001, subject to the structural design of the wall being in accordance with AS 3600-2001.

Therefore, the fire engineering design of a ZEGO® FireForm ™ wall is carried out in accordance with AS 3600 – 2001 Section 5, with neither permanent forms nor plastic interconnects considered as affecting Fire Resistance Level.

3.2.3 FRL of ZEGO® FireForm ™ Walls

3.2.3.1 Structural Adequacy

AS 3600 Clause 5.7.4 states that a laterally supported wall has the required fire resistance period for structural adequacy if the structural design is in accordance with Clause 11.2, the slenderness is within the limits of Clause 5.7.4 (c) and (d) (depending on the axial load); and if the effective thickness is not less than the effective thickness required by Table 5.7.2 for that period.

Clause 5.7.4 (d) (ii) specifies minimum cover to reinforcement for structural adequacy for walls where the design Strength Limit State vertical force $V^* > 0.03 f'_c A_g$. These are shown on Table 3.1. (Note that for lightly loaded walls where $V^* \leq 0.03 f'_c A_g$ the cover requirement does not apply)

3.2.3.2 Integrity

AS 3600 Clause 5.7.3 states that a wall has the stated fire resistance period for integrity if it meets the requirements for both insulation and structural adequacy for that period.

3.2.3.3 Insulation

AS 3600 Table 5.7.2 gives minimum effective thicknesses for insulation.

3.2.4 Summary

Table 3.1 consolidates effective thickness and cover requirements (where $V^* > 0.03 f'_c A_g$) from AS 3600 Tables 5.7.2 and 5.7.4, with standard ZEGO® FireForm ™ ICF system thicknesses and cover.

Table 3.1
Concrete Cover and Thickness for Various FRL

Fire Resistance Period (minutes)	Cover (mm) For Structural Adequacy where $N^* > 0.03f'_c A_g$		Thickness (mm) For Structural Adequacy and Insulation	
	AS 3600 Table 5.7.4	ZEGO® FireForm ™ standard cover (with N16 bars)	AS 3600 Table 5.7.2	ZEGO® FireForm ™ standard thickness
30	20	20.5 (1st bar groove)	60	80
60	20	20.5 (1st bar groove	80	80
90	35	36.5 (2nd bar groove)	100	104
120	40	52.5 (3rd bar groove)	120	120
180	45	52.5 (3rd bar groove)	150	150
240	50	52.5 (3rd bar groove)	170	184

Note also slenderness requirements of AS 3600 Clause 5.7.4

For example a wall of specified FRL 240/180/180 and with $N^* > 0.03 f'_c A_g$ requires minimum 50 cover and 150 concrete thickness for 180 minute structural adequacy – adopt 52.5 mm, at 3rd bar groove, 150 ZEGO® FireForm ™ standard thickness. It requires 180 minutes for Integrity, which is met provided structural adequacy and insulation are met. The example is shown in Figure 3.1 below.

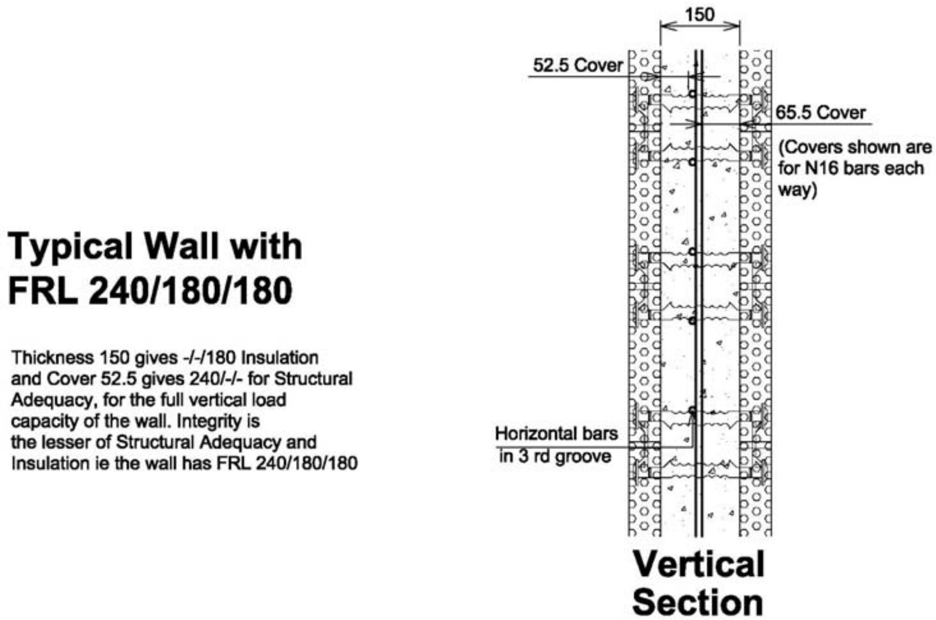


Figure 3.1
Example of Fire Rated wall

Note that service recesses and chases, provided they are less than 60 mm, are accommodated in the ICF without intruding into the concrete, and therefore do not diminish FRL.

3.2.4 FRL of ZEGO® FireForm ™ Attached Beams

AS 3600 Clause 5.4 and Figures 5.4.2 (A) and 5.4.2 (B) give FRL for Structural Adequacy for beams. Clause 5.4.1 states that FRL requirements for Insulation and Integrity are met when FRL for Structural Adequacy is met.

For Beams, FRL for Structural Adequacy depends on

- The beam support condition (Figure 5.4.2 (A) is for Simply Supported beams and 5.4.2 (B) is for Continuous Beams)
- The beam width
- The beam cover.

As there are three variables, each beam shape must be considered separately. This is done in Section 8, Attached Beams

4. ENERGY EFFICIENCY

4.1 ICF R - Values

BASF Styropor foam has a maximum thermal conductivity of 0.040 W/mK. The minimum effective thermal thickness of a panel is the nominal thickness less 4 mm for the indentations of the internal dovetails against the concrete. (The dovetails are 8 mm deep and take up 50% of the cross section). The R-value (thickness divided by thermal conductivity) for single panels is therefore as shown in Table 2.3.1

Table 4.1

Panel Nominal Thickness	Thermal Thickness	Single Panel R-Value
52 mm	48 mm	**1.20**
60 mm	56 mm	**1.40**

4.2 ZEGO Walls R - Values

When calculated in accordance with Specification J1.5 of the BCA, R-Values of ZEGO walls with no render, 80 mm concrete and plasterboard directly fixed to the ZEGO panel face, without an air gap, are as shown in Table 4.2

Table 4.2

External wall construction description	R-Value	
	With 52 mm ZEGO Panels each side	With 60 mm ZEGO Panels each side
Outside air film	0.03	0.03
ZEGO Panel	1.20	1.40
80 mm core concrete	0.06	0.06
ZEGO Panel	1.20	1.40
10 mm Plasterboard	0.06	0.06
Indoor air film	0.12	0.12
TOTAL R-VALUE	**2.67**	**3.07**

4.3 BCA Requirements for R – Values

Table J1.5 of the BCA specifies required R-Values for various climatic zones of Australia. These are reproduced in Table 4.3 below.

Table 4.3

Climate Zone	1, 2, 3 & 5	4 & 6	7	8
Minimum Total R - Value	**1.4**	**1.7**	**1.9**	**2.8**

Comparing with Table 4.2, the only zone where a minimal ZEGO wall (52 mm panels plus 80 mm concrete for which R = 2.67) does not meet the BCA is Zone 8, requiring R = 2.8. Requirements of all zones are complied with if 60 mm panels (R = 3.07) are used.

Figure A1.1 and Table A1.1 of the BCA show locations of these climatic zones. Zone 8 is restricted to high alpine areas of NSW, Victoria and Tasmania, the only significant population centre being Thredbo.

Figure A1.1 of the BCA is reproduced below as Figure 4.1.

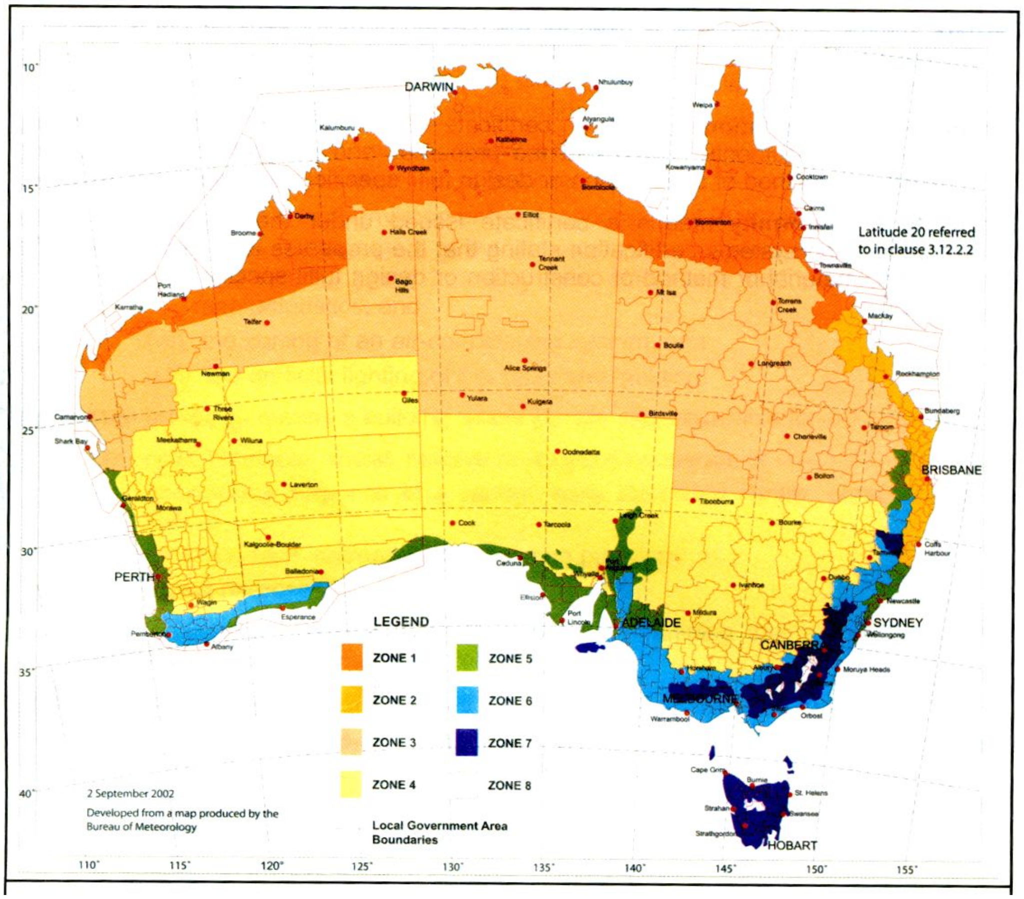


Figure 4.1
Climatic Zones of Australia
(BCA Figure A1.1)

Walls using the recommended ZEGO 60 mm panels will satisfy Energy Efficiency requirements of the BCA for all areas of Australia. Walls using ZEGO 52 mm panels will satisfy Energy Efficiency requirements of the BCA for all areas of Australia except alpine areas.

4.4 ZEGO Panels and Air Conditioning

For commercial buildings, and for residential buildings with air conditioning installed as part of the construction, increased thickness of ZEGO may well result in substantial savings in air conditioning costs. The additional panel thicknesses will come at a relatively low cost, whereas air conditioning is a very high proportion of both capital and running costs of a fully air conditioned building.

Such an investigation would need to be done on a project-by-project basis, taking into account such matters as areas and orientation of windows, aspect of the building, shading and other sun control measures, climatic conditions, electricity tariffs, Developer's cost of capital and so on.

4.5 Recommended ZEGO Panels

For commercial and multi unit residential buildings where there are no requirements for extra thick panels resulting from air conditioning design or the need to match to other wall thicknesses, the recommended panel is the 60 mm panel. A ZEGO wall using 60 mm panels will meet energy efficiency requirements for all climatic zones in Australia. It also provides sufficient thickness for chasing up to 50 mm.

A 52 mm panel is also available, but after deducting for dovetails at the concrete/panel interface, the net thickness is only 44 mm, restricting chasing. Insulation is also reduced, although still BCA compliant for all except high alpine areas.

5. STRUCTURE – UNREINFORCED WALLS

5.1 Important Note

This Section contains design guides that rely for their correct interpretation on the Reader having engineering knowledge at University Graduate level. The Guides are also based on principles that are not directly covered by Australian Standards. We believe those Principles are conservative, are soundly based on the accepted principles of structural mechanics, and are correctly implied from Australian Standards for similar construction. However, Readers must assess the validity of the material for themselves.

In view of the above,

- The use of this Section for final design should be restricted to qualified and experienced Structural Engineers
- We do not certify this Section as complying with Australian Standards.

5.2 Unreinforced Walls and AS 3600 *Concrete Structures*

AS 3600 Section 11 *Design of Walls* specifies, at Section 11.6, a minimum amount of reinforcement. Section 15 *Plain Concrete Members* does not include walls.

Concrete Design Handbook SAA HB 71 – 1995 C & CAA Clause 7.1 states in part "AS 3600 Section 11 gives design rules for only a limited range of walls. Where walls are outside this range, the designer can adopt any appropriate rational design method under Clause 1.3. In these cases the design will still have to comply with the general design requirements as set out in Sections 1, 2 and 3".

Our approach is to design in accordance with Sections 1, 2 and 3 of AS 3600, which are performance requirements. Compliance with these performance requirements is established by comparison with and reference to AS 3700 *Masonry Structures* as explained in the next Section.

AS 3600 Clause 1.3.1 states "Provided that the requirements of Section 2 are met, this Standard shall not be interpreted so as to prevent the use of materials or methods of design or construction not specifically referred to herein".

5.3 Unreinforced Walls and AS 3700 *Masonry Structures*

In using AS 3700: 2001 *Masonry Structures*, an unreinforced concrete wall is simulated as an unreinforced masonry wall with solid concrete masonry units of the same strength and thickness as the concrete wall, with mortar of at least equal strength to a selected mortar specified in AS 3700.

This simulation is regarded as conservative for the following reasons.

- The concrete wall is monolithic with no material interfaces between "units" and "mortar"
- The simulated "Mortar" is untooled so concrete wall thickness and simulated masonry "bed joint" thickness will be the same
- Concrete characteristic strength f'_c is determined from tests on cylinders whereas masonry unit characteristic strength f'_{uc} is determined from tests on masonry units. Masonry units are squatter than cylinders, so test machine end platens will impose a more confining restraint. Concrete characteristic strength f'_c is therefore an underestimate of the simulated "masonry unit" characteristic strength f'_{uc}.
- The simulated "mortar", actually concrete 20 MPa or stronger with controlled water addition, is conservatively regarded as being of Classification M3 in AS 3700 Table 10.1.

5.4 Design Properties of Simulated Masonry

5.4.1 Compressive Strength

Design properties are from AS 3700 Section 3.

The characteristic compressive strength of the simulated masonry wall is

$$f'_m = k_h f'_{mb}$$

where

k_h = 1.4 (AS 3700 Table 3.1 for full bedded concrete masonry units using M3 mortar)

k_m = 1.30 ((AS 3700 Table 3.2 for unit height greater than or equal to 19.0, in this case effectively infinite)

$f'_{mb} = k_m\sqrt{(f'_{uc})}$

$f'_{uc} = f'_c$ for the concrete (conservatively, see preceding paragraph)

f'_c can be 20 MPa, 25 MPa, 30 MPa or 40 MPa

Values of simulated masonry f'_m based on concrete f'_c are shown on Table 4.1.

Table 5.1
Concrete and Equivalent Simulated Masonry Characteristic Strengths

Concrete f'_c, MPa	20	25	30	40
Simulated Masonry f'_m, MPa	8.19	9.10	10.00	11.44

5.4.2 Flexural Tensile Strength

AS 3700 Clause 3.3.3 specifies a maximum value for flexural tensile strength

$$f'_{mt} = 0.20 \text{ MPa.}$$

(This is very conservative compared with that for concrete to AS 3600, $f'_{cf} = 0.6\sqrt{(f'_{uc})}$ which for 20 MPa concrete is 2.68 MPa).

5.4.3 Capacity Reduction Factors

As 3700 Table 4.1 gives Capacity Reduction factors f for masonry.

Unreinforced masonry in compression $\phi = 0.45$

Unreinforced masonry in other actions $\phi = 0.60$

These are adopted for Simulated Masonry.

5.5 Robustness, AS 3700 Clause 4.6.2

5.5.1 Wall Configurations

The walls covered by the design aids in this Section are as described here, selected from those shown in AS 3700 Section 4.6

- Walls are supported laterally at both top and bottom; i.e. they will span vertically against any horizontal pressure.
- No allowance is made for piers
- No allowance is made for lateral support of vertical edges
- Walls can be supporting either a concrete slab, or "other than a concrete slab".
- Lateral loads are short term transient wind and / or differential air pressure loads
- The walls are not subject to significant shelf loads that cause eccentricity and are long term.

Walls outside these restrictions can be checked for robustness using relevant provisions of AS 3700 Section 4.6

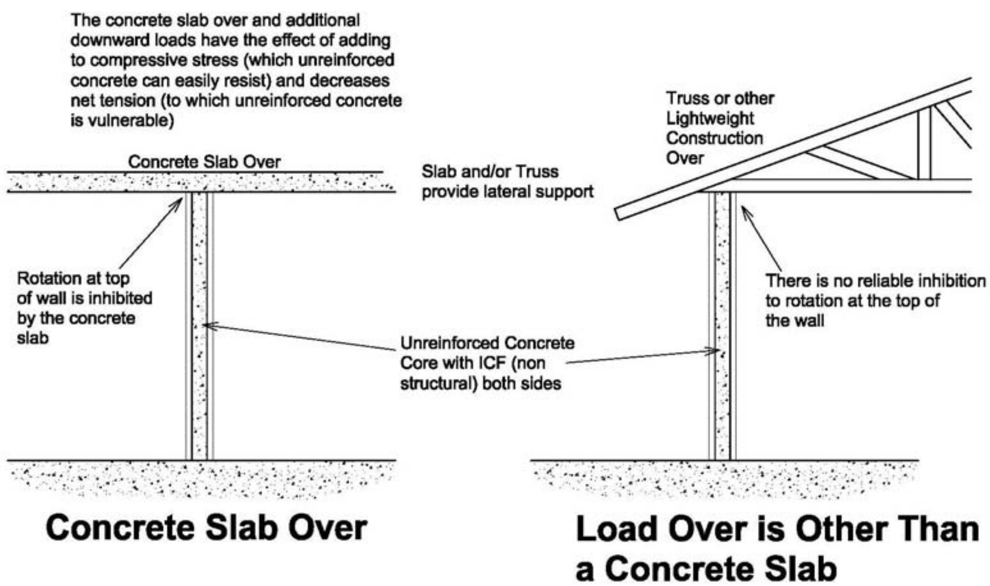


Figure 5.1
Top Support Condition and Supported Work

5.5.2 Vertical Edges

No allowance is made for support from vertical edges.

- Poured and hardened concrete is hidden by the ICF, so cracking, which may interrupt horizontal spanning capability, would go unnoticed.
- If horizontal spanning is to be relied upon, care would have to be exercised in designing, specifying, and constructing movement joints, in regard to their positions, to ensure horizontal spanning were not compromised.
- Special provisions would need to be made for door and window penetrations.

Designers can allow for horizontal spanning on particular projects, provided adequate attention is given to joint location and treatment at door and window openings.

5.5.3 Supported Work

A wall supporting a concrete slab is considerably more robust than one supporting lightweight work (termed "other than a concrete slab"). The weight of the slab and the flatness of the soffit bearing down on the top of the wall prevent rotation and consequently stiffen the wall up considerably. Extra vertical load, while adding to compression (which an unreinforced wall can easily resist) reduces net tension, against which an unreinforced wall is vulnerable. It therefore has an effect similar to prestress.

It is therefore essential when designing a wall to distinguish between the two conditions.

5.5.4 Wall Heights

In what follows, wall heights H are taken as 2.7 m and 3.0 m.

5.5.5 Determination of Robustness Limits

Reference is made to AS 3700 Clause 4.6.2. Walls examined are restricted to those spanning vertically, and without piers. Therefore k_t = 1.0 and the limiting slenderness ratio, the wall height over the wall thickness

$$\frac{H}{t_r} \leq C_v$$

where

$C_v = 36$ when the supported work is a concrete slab

$C_v = 27$ when the supported work is other than a concrete slab

When the supported work is a concrete slab, the maximum height for a wall 80 thick is 2.88 m and for 104 thick is 3.74 m.

When the supported work is other than a concrete slab, the maximum height for a wall 80 thick is only 2.16 m and for 104 thick is 2.81 m.

These results are shown on Table 5.2. It should be noted that thinner concrete could be used if horizontal spanning was designed and detailed, and / or if piers were used.

Table 5.2
Robustness Limitations for Unreinforced Walls Spanning Vertically

	Maximum Wall height (m) for Concrete Thickness (mm)				
Concrete Thickness	**80**	**104**	**120**	**136**	**150**
Supporting a Concrete Slab	2.88	3.74	4.32	4.90	5.40
Supporting Other than a Concrete Slab	2.16	2.81	3.24	3.67	4.05

Note that walls also have to be checked for compression and bending loads

5.6 Design for Compression

The following describes application of AS 3700 Clause 7.3.3 Design by simple rules,

The basic compressive capacity F_o is

$$Fo = \phi f'_m A_b$$

Where

$\phi = 0.45$ (see para 4.4.3)

f'_m is a function of concrete f'c, as shown on Table 4.1

A_b is the area of cross section, which is (concrete thickness) x 1 metre, per metre length of wall.

The design compressive force capacity F_d is

$$F_d \leq kF_o$$

where k is a reduction factor for slenderness and eccentricity, not greater than 0.67.

For a wall supporting a concrete slab

$$k = 0.67 - 0.02(S_{rs} - 14)$$

For a wall supporting Other than a concrete slab

$$k = 0.67 - 0.02(S_{rs} - 10)$$

and for a wall without lateral support along one or both of its edges, without engaged piers and with lateral support along the top edge

$$S_{rs} = \frac{H}{t}$$

Design Ultimate Limit State Compression capacity is shown for wall heights 2700 and 3000 in Table 5.3.

5.7 Design for Lateral Pressures

The following describes application of AS 3700 Clause 7.4.2 Design for vertical bending.

The bending capacity of a wall is increased by the presence of an accompanying vertical force, which has the effect of prestress, see Figure 5.1 and section 5.5.3..

The design vertical bending moment capacity M_{dv} resulting from out of plane transient forces acting on the member in vertical spanning action is

$$M_{dv} \leq M_{cv}$$

where M_{cv} is the lesser of

$$M_{cv(A)} = \phi k_{mt} f'_{mt} Z_d + f_d Z_d$$

and

$$M_{cv(B)} = 3.0 \phi k_{mt} f'_{mt} Z_d$$

$\phi = 0.60$ (para 5.4.3)
$k_{mt} = 1.0$
$f'_{mt} = 0.20\ MPa$ (para 5.4.2) (applicable for concrete f'_c = 20 MPa upwards)
Z_d = the section modulus of the concrete section
f_d = the minimum design compressive stress on the wall.

Table 5.4 shows capacities in terms of wall pressures, calculated from moment capacities M_{dv} and wall heights H, for various simultaneously applied vertical loads, from which vertical compressive stresses are calculated for the range of wall thicknesses.

Note that the vertical wall loads in Table 5.4 are not the same as the limit state compression capacities given in Table 5.3. Those in Table 5.4 are ***minima***, typically Dead Load times a load factor of 0.9, compared with Table 5.3 which are ***maxima***, typically 1.2 x Dead Load + 1.5 x Live Load.

TABLE 5.3
UNREINFORCED WALLS
ULTIMATE STRENGTH LIMIT STATE COMPRESSION CAPACITY kN/m

Do not use this Table unless you have read, understood and accepted Section 5.1

FOR WALL HEIGHT 2700

	Core Concrete f'c, MPa	LIMIT STATE COMPRESSION CAPACITY kN/m FOR CONCRETE THICKNESS, mm				
		80	**104**	**120**	**136**	**150**
WALLS SUPPORTING A CONCRETE SLAB	**20**	80.6	164	220	275	324
	25	90.1	184	246	308	362
	30	98.7	201	269	337	397
	40	114	232	311	390	458
WALLS SUPPORTING OTHER THAN A CONCRETE SLAB	**20**		134	185	236	280
	25		149	206	263	313
	30		164	226	289	343
	40		189	261	333	396

FOR WALL HEIGHT 3000

	Core Concrete f'c, MPa	LIMIT STATE COMPRESSION CAPACITY kN/m FOR CONCRETE THICKNESS, mm				
		80	**104**	**120**	**136**	**150**
WALLS SUPPORTING A CONCRETE SLAB	**20**		142	198	254	302
	25		159	221	283	338
	30		174	242	310	370
	40		201	280	358	427
WALLS SUPPORTING OTHER THAN A CONCRETE SLAB	**20**			163	214	258
	25			182	239	289
	30			199	262	316
	40			230	302	365

Areas shaded in grey are considered insufficiently robust without reinforcement

TABLE 5.4

UNREINFORCED WALLS

ULTIMATE STRENGTH LIMIT STATE LATERAL PRESSURE CAPACITIES ϕp_u AND WORKING PRESSURES p_w

Do not use this Table unless you have read Section 5.1

FOR WALL HEIGHT 2700

FOR LOWEST VERTICAL LOAD, kN/m		DESIGN PRESSURES, kPa, FOR CONCRETE THICKNESS, mm				
		80	104	120	136	150
2.0	ϕp_u				0.46	0.55
	p_w				0.30	0.37
10.0	ϕp_u		0.43	0.54	0.65	0.77
	p_w		0.29	0.36	0.44	0.51
20.0	ϕp_u	0.42	0.62	0.76	0.90	1.04
	p_w	0.28	0.41	0.50	0.60	0.70
30.0	ϕp_u	0.42	0.71	0.95	1.15	1.32
	p_w	0.28	0.47	0.63	0.77	0.88

FOR WALL HEIGHT 3000

FOR LOWEST VERTICAL LOAD, kN/m		DESIGN PRESSURES, kPa, FOR CONCRETE THICKNESS, mm				
		80	104	120	136	150
2.0	ϕp_u				0.37	0.44
	p_w				0.25	0.30
10.0	ϕp_u			0.43	0.53	0.62
	p_w			0.29	0.35	0.41
20.0	ϕp_u		0.50	0.61	0.73	0.84
	p_w		0.33	0.41	0.49	0.56
30.0	ϕp_u		0.58	0.77	0.93	1.07
	p_w		0.38	0.51	0.62	0.71

Shaded areas have working capacity less than 0.25 kPa, or are considered insufficiently robust without reinforcement.

The Table is suitable for concrete f'_c 20 MPa upwards.

6. STRUCTURE – REINFORCED WALLS

6.1 Reinforced Walls and AS 3600 *Concrete Structures*

Reinforced concrete ZEGO® walls are designed and constructed to AS 3600. The Styropor permanent ICF or the reusable forms are of no structural significance and the Interconnect penetrations are too small to affect the structure. This Section shows design information for wall thicknesses and reinforcement layouts that provide the best economies using the System.

6.2 Concrete Durability

6.2.1 Using Permanent Styropor ICF

Concrete in the ZEGO® system using permanent Styropor ICF have both surfaces protected by the ICF and for exterior surfaces, by render. The recommended renders are Granosite or Supacoat products, comprising a smear base coat, a high build 8 mm coat incorporating fibre reinforcing mesh, topped with a surface coat. The outside face of the ICF has vertical dovetail grooves at 48 mm centres, which make a very effective key for holding the render onto the ICF.

Referring to AS 3600 Table 4.3, exposure classification will always be A1. The minimum concrete characteristic compressive cylinder strength at 28 days f'_c is 20 MPa, and cover using ZEGO® plastic Interconnects and N16 bars is a minimum of 20.5 mm.

6.2.2 Using Reusable Forms

When reusable forms are removed, concrete is exposed to the environment. The Designer needs to assess this exposure in accordance with AS 3600 Table 4.3, and select cover and concrete strength accordingly. Note that a wall with a ZEGO® reusable form held in place with a ZEGO® plastic interconnect will have cover of 22.5 mm additional to that for a ZEGO® ICF, i.e. a total minimum cover of 20.5 mm + 22.5 mm = 43 mm.

6.3 Typical Concrete and Reinforcement Specification

6.3.1 Concrete

Concrete shall be to AS 3600.

Minimum concrete characteristic compressive cylinder strength at 28 days *f'c* can be any AS 3600 standard strength grade, 20 MPa, 25 MPa, 32 MPa, 40 MPa. The grades 50 MPa and 65 MPa could also be used, but are not considered here as the Designer needs to pay special attention to placement and other design and construction issues.

The recommended maximum aggregate size is generally 10 mm. Where both clear cover between horizontal bars and form faces, and the gap between horizontal bars in walls reinforced on both faces, exceed 50 mm, and thorough vibration can be assured, 20 mm aggregate can be used.

The recommended slump is 80 mm, unless there are concerns about proper compactability due to restricted spaces, in which cases higher slumps should be considered.

On no account should water be added after test cylinder samples have been taken.

Admixtures to improve workability, and/or to reduce water and cement content, may be used so long as they comply with relevant Australian Standards, result in a mix design of predicable characteristics in accordance with the Specification, and do not reduce durability, corrode or otherwise affect reinforcement, or cause any other deleterious effect.

6.3.2 Reinforcement

Reinforcement shall be to AS 3600 and AS 1302 or AS/NZS 4671. The design information in this Section is based on the use of Normal Ductility D500N bars to AS/NZS 4671, of sizes N10, N12 and N16.

6.4 Concrete Thickness

Standard ZEGO® concrete thicknesses using ZEGO® ICF both sides are **80***, 88, **104***, **120***, 128, **136***, **150***, 168, 184, **200*** and 232. (Thicknesses in bold and marked * are preferred, as their components are held in stock and are readily available). When ZEGO® removable forms are used with ZEGO® plastic Interconnects, thicknesses increase by 23.5 mm for a removable form on one side and 47 mm if removable forms are on both sides.

6.5 Standard Reinforcing Details

6.5.1 Bar Diameter

Bar grooves in Interconnects are 9 mm diameter, to take **N16 diameter** horizontal bars plus deformations. N10 and N12 mm bars may also of course be used.

6.5.2 Cover and Placement Sequence

The bar grooves in the Interconnects are positioned to allow cover to 16 mm horizontal bars of 20.5 mm for a bar in the first groove, 36.5 mm for the second groove and 52.5 mm for the third groove. Placement in the first groove for 20.5 mm cover will be sufficient for durability, however for walls with a required FRL exceeding 60/-/- and where $N^* > 0.03f'_cA_g$, more cover is needed, refer to Section 3.

If structural considerations dictate that vertical bars are outside, horizontal bars can be placed in inner bar grooves. The Designer needs to check that both concrete and vibrators can be placed easily between the inner horizontal bars

6.5.3 Reinforcement Spacing

6.5.3.1 Vertical Reinforcement

Interconnects are at **192 centres**, which is a convenient positioning for vertical bars. They can be tied to and held in position by the Interconnects, and 192 spacing complies with the bar spacing provisions of AS 3600 Clause 11.6.3.

6.5.3.2 Horizontal Reinforcement

Placement of bars in Interconnect bar grooves as shown in Figures 6.1, 6.2 and 6.3 results in bars at vertical centres of either 300, or alternating between 170 and 130. (If there is only one bar layer required per course, bars are at 300 vertical centres). The two layer per course configuration complies with the bar spacing provisions of AS 3600 Clause 11.6.3 for all ZEGO® wall thicknesses, and the one layer per course complies with ZEGO® wall thicknesses 120 and above.

6.5.3.3 Number of Bar Grids

Thinner walls will usually have one bar grid, centrally placed at the approximate centre of the wall. Two grids may be used where the pour gap between horizontal bars exceeds 50 mm, allowing adequate vibration and compaction.

Concrete thickness greater than 200 requires two grids, one on each face (AS 3600 Clause 11.6.3)

6.5.4 Laps

Laps are conventional, to AS 3600.

6.5.5 Reinforcement Percentages

6.5.5.1 Horizontal Reinforcement for Crack Control

When using ICF, the concrete is permanently hidden from view, is in exposure classification A1 and performs no weatherproofing or waterproofing function. However, there will normally be intersecting walls restraining shrinkage or thermal movement. Therefore the provision of AS 3600 Clause 11.6.2 (a) (i), where a minor degree of control over cracking is required, specifies a minimum reinforcement ratio p_w **≥ 0.0025**. Where removable forms are used and cracking on striped concrete would be visible, or where exposure classification is B1, B2 or C, the Designer may be required to use a higher reinforcement ratio.

6.5.5.2 Vertical Reinforcement

AS 3600 Clause 11.6.1 (a) specifies a minimum p_w **≥ 0.0015**

6.6 Typical Details

Typical wall details are shown on Figures 6.1 (ZEGO® ICFs each side), Figure 6.2 (ZEGO® ICF one side, ZEGO® Removable Form 1 side, and Figure 6.3 (ZEGO® Removable Forms each side).

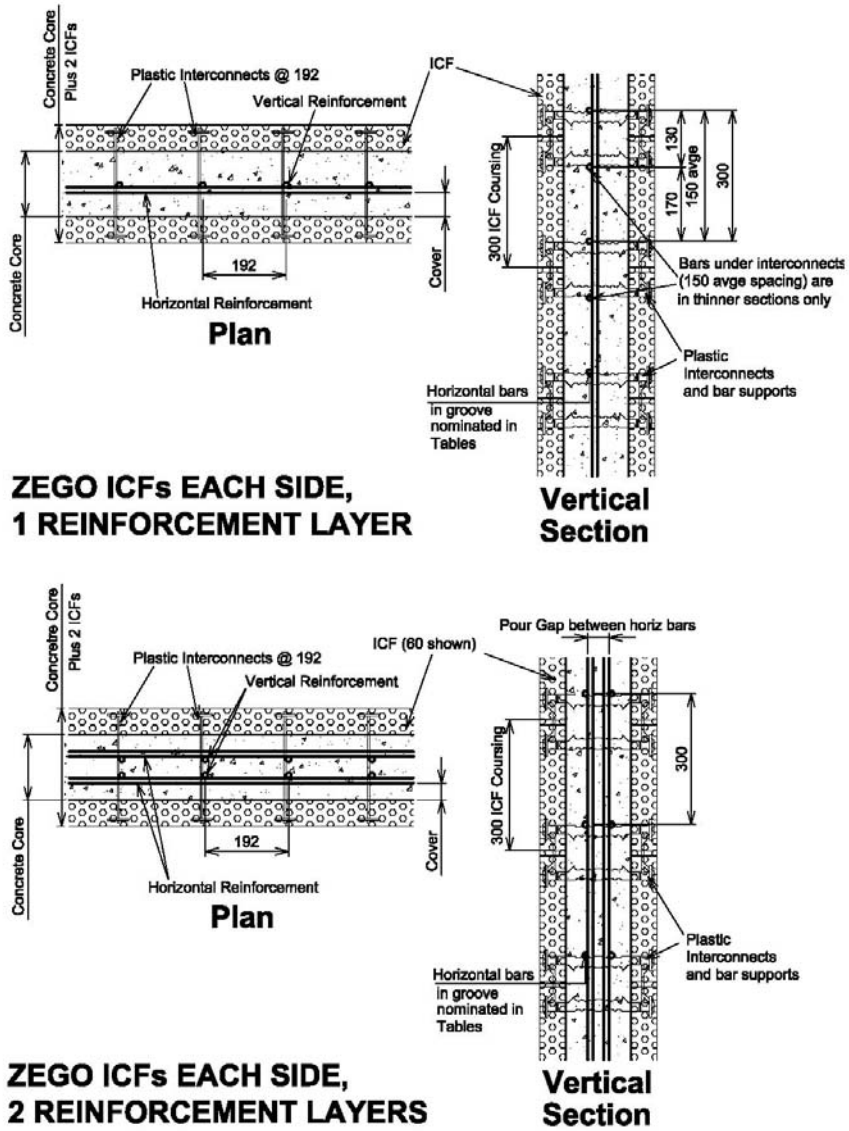


Figure 6.1
Walls - ZEGO ICFs Both Sides

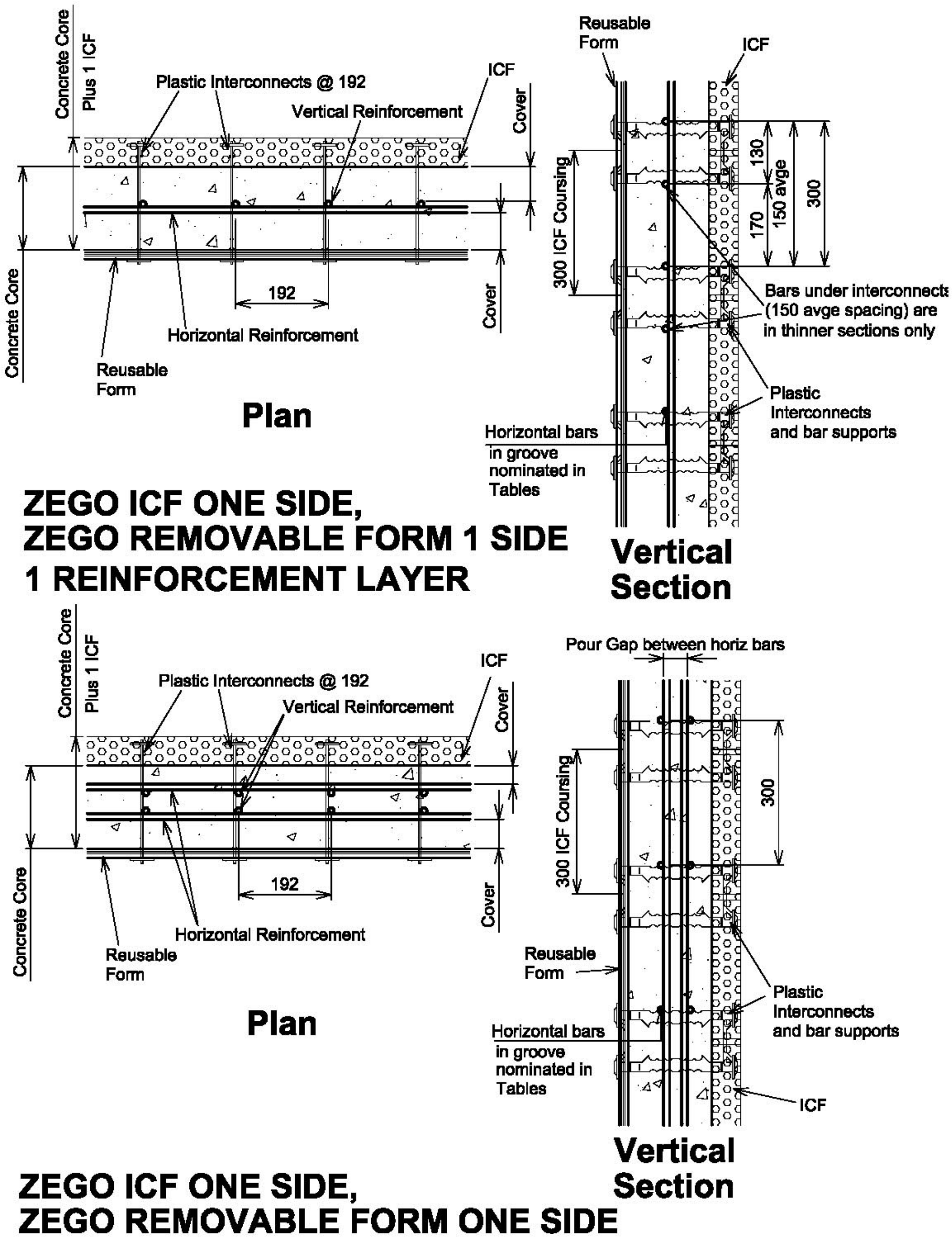


Figure 6.2
Walls – ZEGO ICF One Side, ZEGO Reusable One Side

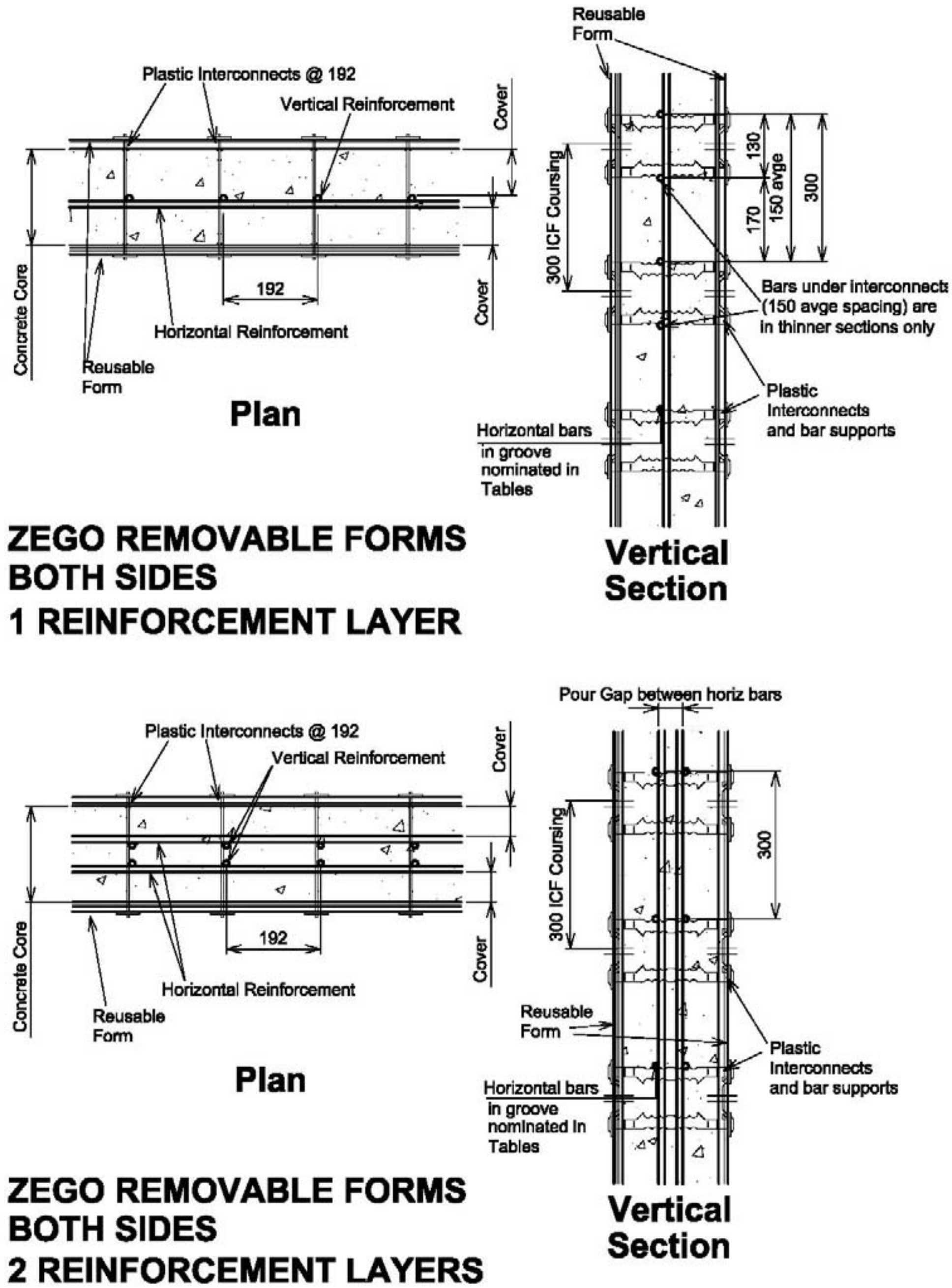


Figure 6.3
Walls – ZEGO Reusable Form Both Sides

7. STRUCTURE – REINFORCED WALL DESIGNS

7.1 Standard Walls

Standard walls as scheduled in the following Tables are selected as being both the most common likely to be encountered, and utilising preferred and currently available (mid 2005) componentry.

The key setting out component is the ZEGO® Plastic Interconnect, as described in Section 2. The concrete/ICF interface is at the small Index Mark 42.5 mm from the inside face of the Interconnect end dumbbell. The concrete/ reusable form interface is at the Stop End 20 mm from the inside face of the Interconnect end dumbbell and 22.5 mm from the small Index Mark. Use of removable form therefore adds 22.5 mm of concrete compared with use of ICF.

7.2 Tables

7.2.1 Intent of the Tables

The Tables are provided to assist with preliminary design for walls using preferred and available (mid 2005) componentry. Final designs should be engineered by the Designer in accordance with AS 3600 and recognised engineering practice.

7.2 Wall Configurations

Table 7.1 shows Standard and Preferred concrete core thicknesses for forms comprising ZEGO® ICFs on each side, ZEGO® ICF on one side and ZEGO® Removable Form on the other side, and ZEGO® Removable Form on each side. The Table also shows total thicknesses (excluding finishes) for walls using 60 mm ICF and/or 19 mm Removable Forms.

7.3 Standard Designs and Tables Layout

Tables 7.2.1 to 7.2.7 show standard designs with useful information, for selected configurations based on preferred componentry and most likely design requirements.

To use the Tables, it is recommended to proceed as follows.

It will presumably be a Management or Architectural decision whether to use either ICFs on both sides, ICF one side and Removable Form on the other, or Removable Forms on both sides. Referring to Table 7.1, pick initially either the smallest concrete core thickness in a preferred size for the form configuration required, or the core size corresponding to the total wall thickness anticipated by the Architect. For example, if it is required to have ICF one side and Removable Form the other, start with either a concrete core thickness of 103 mm, or if a total wall thickness of 200 was anticipated, a core thickness of 143 (giving a total finished wall thickness of 203 mm).

Reference can then be made to Tables 7.2.1 to 7.2.7 as appropriate. Comments on the entries in each of these Tables follow.

Column a - Concrete Core Thickness for the initial selection of wall from Table 7.1.

Column b - Fire Resistance Level (FRL). The FRL is based on total concrete core thickness (Column a) and minimum cover to reinforcement (determined from the bar groove number shown in Column k). The FRL is derived directly from AS 3600 Tables 5.7.2 and 5.7.4.

Two points are worth noting.

- For residential buildings (BCA Class 1, 2 or 3) the required FRL does not exceed 90/90/90 (BCA Vol 1 Part C Tables 3, 4 and 5)
- For concrete thicknesses exceeding 100 mm, a 920/90/90 FRL is easily achieved using the ZEGO® Fireform system

Column c - 28 day Concrete Strength f'_c. Four choices are listed, 20 MPa, 25 MPa, 32 MPa and 40 MPa. Increasing concrete strength has a big effect on axial load capacity, but a minimal effect on flexural strength. If flexural strength is the main design issue, increasing f'c above 20 MPa will only be worthwhile if the small increase in strength will bring the design into compliance. For some thinner walls, minimum reinforcement to AS 3600 may result in over reinforced walls (k_u > 0.4) unless 32 MPa concrete is used.

Column d - number of bar grids. A single grid at the approximate centre (actual position is determined by bar groove locations in the plastic interconnects) will be more economical than 2 grids in most cases. 2 grids will be used when high flexural strength is required, and when concrete thicknesses exceed 200 mm (AS 3600 Clause 11.6.3). In most cases, walls 200 thick or less will use a single grid.

Column e – Vertical Reinforcement. Bars are located at Interconnect positions, at 192 centres. (Doubling the spacing would have bars at 384 centres, which exceeds the maximum 350 mm permitted by AS 3600 Clause 11.6.3). Options given are generally centrally placed N10@192 (minimum normal ductility bars N10) and N12@192; and for wider wall sections bars placed near each face N12@192 and N16@192 (for situations where substantial bending capacity is required). In most cases the minimum single grid will probably be adequate.

Referring to Figures 6.21, 6.2 and 6.3, vertical reinforcement position is set by horizontal reinforcement position, set in tern by the specified bar groove in the plastic Interconnect.

Column f – Horizontal reinforcement. Bars are located at each course module in the plastic Interconnects, except for thinner concrete sections where the AS 3600 Clause 11.6.3 requirement that bars be at maximum centres $2.5t_w$ dictates bars closer than 300. In such cases the bars are at top and bottom of Interconnects, spacing 170 and 130, average 150 (see Figures 6.1, 6.2 and 6.3). Again, N10, N12 and N16 bar sizes are given, chosen generally for compliance with minimum reinforcement requirements.

Columns g and h – Maximum Wall Height. Maximum wall heights are from AS 3600 Clauses 5.7.4(c) (fire walls), 11.4.2 and 11.4.3, applicable to walls where the axial load does not exceed $0.03f'_cA_g$ and based on walls spanning in the vertical direction only. The requirement is that for an effective wall height H_{we}, the slenderness ratio H_{we}/t_w shall not exceed 50. The value of $0.03f'_cA_g$, the maximum limit state axial load permitted for "simplified" design, is given in Column q.

The effective height H_{we} is 0.75 H_{wu}, the actual height, where the top of the wall is restrained against rotation by a concrete floor slab and is 1.0 H_{wu} where it isn't.

As the minimum allowed height (with lightweight construction offering no rotational resistance at the top) is 4000 mm for a 80 mm concrete wall, maximum wall height will rarely be an issue, but should be ch4ecked anyway.

Column i – Interconnect Type. Sets down the Interconnect Component required for the particular configuration under consideration (also given in Table 7.21).

Column j – Central Pour Gap. Referring to Figures 6.21, 6.2 and 6.3, in assessing buildability", it is necessary to know, for 2 grid designs, the gap between horizontal bars at the centre of the wall. The minimum acceptable for pouring and for access by vibrator or effective rodding is taken to be 50 mm.

Column k – Placement in Groove Number. The groove number locates a horizontal bar in the groove that for a single grid is closest to the wall centre. For two grids, the groove number is that which gives the required cover for the FRL listed in Column b.

Column l – Gross Reinforcement Ratio for Vertical Steel. Listed, for comparison with the minimum given in AS 3600 Clause 11.6.1 (which is 0.0015).

Column m – Gross Reinforcement Ratio for Horizontal Steel. This is listed for comparison with the minima given in AS 3600 Clauses 11.6.1 and 11.6.2. Clause 11.6.2 lists several values depending on degree of crack control required and exposure classification. For ICF both sides, exposure classification of concrete (which is completely protected) is A1, and any cracking that may occur is within the permanent forms and therefore of no cosmetic significance. The figure of 0.0025 therefore applies. When removable forms are used, however, the concrete may be exposed to any classification, and cracking may be cosmetically objectionable. Therefore, *when removable forms are used on one or both sides, the Designer must check the reinforcement ratio listed in Column m and ensure it complies with the particular situation listed in AS 3600 Clause 11.6.2.*

Column n – Reinforcement Mass per Square Metre – given as an aid to cost estimating.

Column o – Concrete volume per square metre - given as an aid to cost estimating. The figure includes an allowance for 8 mm deep dovetails covering 50% of the concrete / ICF interface for ICF.

Column p – Cost Number. This is a notional cost number for comparing the cost of supply and place concrete and reinforcement in various wall configurations. Therefore, when more than one wall configuration complies with the design requirement, the configuration that is likely to be the most economical can be selected. The Cost Number is the reinforcement mass per square metre times a notional supply and place cost of reinforcement plus the concrete volume per cubic metre times a notional supply and place cost for concrete. (The notional costs were estimated from Rawlinsons Australian Construction Handbook Edition 23 for 2005. Those used are $2205 per tonne for supply and place reinforcement; $244.00 per cu m for supply and place 20 MPa concrete in walls, add extra $3.00 per cu m for 25 MPa concrete, $10.75 for 32 MPa and $21.80 for 40 MPa). *It is emphasised these cost numbers should not be used for estimating. They are provided as a guide to assist a Designer in wall selection. The Designer should review wall selection if a more informed opinion can be provided by a qualified and committed Quantity Surveyor or Estimator.*

Column q – Maximum Axial Load for Simple Design. When the Strength Limit State vertical axial load N^* exceeds $0.03f'_cA_g$, several design complications arise, requiring specific consideration by the Designer. Accordingly, *the value of $0.03f'_cA_g$ is listed, and is the limit up to which the design information in the Tables is valid.*

The complications arising when $N^* > 0.03f'_cA_g$ include the following.

- For combined horizontal forces perpendicular to the wall and vertical forces, the wall would have to be designed as a column (AS 3600 Clauses 11.2.4 and 11.2.5)
- The maximum slenderness ratio is reduced (AS 3600 Clause 11.4.2)
- For firewalls, the maximum slenderness ratio is further reduced (AS 3600 Clause 5.7.4)

The restriction to figures $N^* \leq 0.03f'_cA_g$ should cause few problems in application of the Tables for buildings not exceeding 3 or 4 stories. (A concrete floor 200 thick supported at 4 metre centres and carrying a Live Load of 3 kPa applies a Limit State axial load N^* of 41 kN/m. For 3 stories this amounts to 123 kN/m, within the figure $0.03f'_cA_g$ for most of the walls tabulated).

Column r – Bending Capacity ϕM_u Vertically. Calculated in accordance with AS 3600 and Warner Rangan and Hall *Reinforced Concrete* 3rd edition. In some cases of 20 MPa and 25

MPa concrete, using minimum reinforcement to AS 3600 and consistent with the ZEGO® Fireform layout, over-reinforcement with $K_u>0.4$ can arise. That is why for narrow walls some 20 MPa and 25 MPa entries have been omitted.

The lowest capacity listed is 5.68 kN/m/m (Table 7.2.1, 80 mm concrete, 32 MPa, N12@192 vertically). For a 2.7 m high wall this corresponds to a pressure onto the wall face of 6.2 kPa, only met as a wind load under extreme cyclonic loading, or as a retaining wall or part of a liquid holding structure.

Column s – Bending Capacity ϕM_u Horizontally. Calculated in accordance with AS 3600 and Warner Rangan and Hall *Reinforced Concrete* 3rd edition.

7.4 Situations Not Covered by the Tables

There is a limit to the variety of situations that Tables such as those provided can realistically cover. Situations not covered include walls with Limit State axial loads > $0.03f'_cA_g$ and Shear Walls.

Such walls can be readily handled by the Designer, alternatively designs can be provided by ZEGO on request.

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TABLE 7.1
ZEGO WALLS
STANDARD AND PREFERRED WALL CONFIGURATIONS

INTERCONNECT No	CONCRETE CORE THICKNESS			TOTAL WALL THICKNESS Using 60 mm ZEGO ICF and 19 mm ZEGO Removeable Form (Excluding finishes, plasterboard etc)			PREFERRED SIZE?
	WITH ICF's EACH SIDE	WITH ICF ONE SIDE AND REMOVEABLE FORM ONE SIDE	WITH REMOVABLE FORMS EACH SIDE	WITH ICF's EACH SIDE	WITH ICF ONE SIDE AND REMOVEABLE FORM ONE SIDE	WITH REMOVABLE FORMS EACH SIDE	
71/15/71	72	95	117	192	155	117	NO
71/23/71	**80**	**103**	**125**	**200**	**163**	**125**	**YES**
71/47/71	**104**	**127**	**149**	**224**	**187**	**149**	**YES**
71/63/71	**120**	**143**	**165**	**240**	**203**	**165**	**YES**
71/93/71	**150**	**173**	**195**	**270**	**233**	**195**	**YES**
71/111/71	168	191	213	288	251	213	NO
71/143/71	**200**	**223**	**245**	**320**	**283**	**245**	**YES**
71/`159/71	216	239	261	336	299	261	NO
71/193/71	250	273	295	370	333	295	NO
71/207/71	264	287	309	384	347	309	NO
71/255/71	312	335	357	432	395	357	NO

TABLE 7.2.1
ZEGO WALLS

FORMS: ZEGO ICF FIREFORMS EACH SIDE. CONCRETE THICKNESS 80 TO 120

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPACITY φMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT YPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ-ONTAL
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.m/m
80	60/60/60	32	1	N10@192	N10@150	5333	4000	71/23/71	N/A	1	0.0051	0.0065	7.27	0.088	38	76.8	5.68	4.96
80	60/60/60	40	1	N10@192	N10@150	5333	4000	71/23/71	N/A	1	0.0051	0.0065	7.27	0.088	39	96.0	5.81	5.16
104	90/90/90	20	1	N10@192	N10@150	6933	5200	71/47/71	N/A	2	0.0039	0.0050	7.27	0.112	43	62.4	7.12	7.71
104	90/90/90	25	1	N10@192	N10@150	6933	5200	71/47/71	N/A	2	0.0039	0.0050	7.27	0.112	44	78.0	7.31	8.03
104	90/90/90	32	1	N10@192	N10@150	6933	5200	71/47/71	N/A	2	0.0039	0.0050	7.27	0.112	45	99.8	7.48	8.31
104	90/90/90	40	1	N10@192	N10@150	6933	5200	71/47/71	N/A	2	0.0039	0.0050	7.27	0.112	46	124.8	7.61	8.51
104	90/90/90	32	1	N12@192	N12@150	6933	5200	71/47/71	N/A	2	0.0057	0.0072	10.48	0.112	52	99.8	9.92	11.33
104	90/90/90	40	1	N12@192	N12@150	6933	5200	71/47/71	N/A	2	0.0057	0.0072	10.48	0.112	53	124.8	10.17	11.75
120	90/90/90	20	1	N10@192	N12@300	8000	6000	71/63/71	N/A	2	0.0034	0.0031	6.13	0.128	45	72.0	8.10	5.87
120	90/90/90	25	1	N10@192	N12@300	8000	6000	71/63/71	N/A	2	0.0034	0.0031	6.13	0.128	45	90.0	8.29	6.04
120	90/90/90	32	1	N10@192	N12@300	8000	6000	71/63/71	N/A	2	0.0034	0.0031	6.13	0.128	46	115.2	8.47	6.19
120	90/90/90	40	1	N10@192	N12@300	8000	6000	71/63/71	N/A	2	0.0034	0.0031	6.13	0.128	48	144.0	8.59	6.29
120	60/60/60	20	2	N12@192	N12@300	8000	6000	71/63/72	51	1	0.0098	0.0063	15.07	0.128	64	72.0	16.69	12.96
120	60/60/60	25	2	N12@192	N12@300	8000	6000	71/63/73	51	1	0.0098	0.0063	15.07	0.128	65	90.0	17.10	13.13
120	60/60/60	32	2	N12@192	N12@300	8000	6000	71/63/74	51	1	0.0098	0.0063	15.07	0.128	66	115.2	17.46	13.28
120	60/60/60	40	2	N12@192	N12@300	8000	6000	71/63/75	51	1	0.0098	0.0063	15.07	0.128	67	144.0	17.71	13.38

TABLE 7.2.2
ZEGO WALLS

FORMS: ZEGO ICF FIREFORMS EACH SIDE: CONCRETE THICKNESS 150

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPACITY φMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT TYPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ-ONTAL
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.m/m
150	180/180/180	20	1	N10@192	N12@300	10000	7500	71/93/71	N/A	3	0.0027	0.0025	6.13	0.158	52	90.0	10.71	8.29
150	180/180/180	25	1	N10@192	N12@300	10000	7500	71/93/71	N/A	3	0.0027	0.0025	6.13	0.158	53	112.5	10.91	8.45
150	180/180/180	32	1	N10@192	N12@300	10000	7500	71/93/71	N/A	3	0.0027	0.0025	6.13	0.158	54	144.0	11.08	8.60
150	180/180/180	40	1	N10@192	N12@300	10000	7500	71/93/71	N/A	3	0.0027	0.0025	6.13	0.158	56	180.0	11.21	8.71
150	180/180/180	20	1	N12@192	N12@300	10000	7500	71/93/71	N/A	3	0.0039	0.0025	7.54	0.158	55	90.0	15.04	5.30
150	180/180/180	25	1	N12@192	N12@300	10000	7500	71/93/71	N/A	3	0.0039	0.0025	7.54	0.158	56	112.5	15.45	5.44
150	180/180/180	32	1	N12@192	N12@300	10000	7500	71/93/71	N/A	3	0.0039	0.0025	7.54	0.158	57	144.0	15.81	5.15
150	180/180/180	40	1	N12@192	N12@300	10000	7500	71/93/71	N/A	3	0.0039	0.0025	7.54	0.158	59	180.0	16.06	5.63
150	60/60/60	20	2	N12@192	N12@300	10000	7500	71/93/71	81	1	0.0079	0.0050	15.07	0.158	72	90.0	23.76	17.49
150	60/60/60	25	2	N12@192	N12@300	10000	7500	71/93/71	81	1	0.0079	0.0050	15.07	0.158	72	112.5	24.17	17.65
150	60/60/60	32	2	N12@192	N12@300	10000	7500	71/93/71	81	1	0.0079	0.0050	15.07	0.158	73	144.0	24.52	17.80
150	60/60/60	40	2	N12@192	N12@300	10000	7500	71/93/71	81	1	0.0079	0.0050	15.07	0.158	75	180.0	24.78	17.90
150	90/90/90	20	2	N12@192	N12@300	10000	7500	71/93/71	49	2	0.0079	0.0050	15.07	0.158	72	90.0	19.99	15.07
150	90/90/90	25	2	N12@192	N12@300	10000	7500	71/93/71	49	2	0.0079	0.0050	15.07	0.158	72	112.5	20.40	15.24
150	90/90/90	32	2	N12@192	N12@300	10000	7500	71/93/71	49	2	0.0079	0.0050	15.07	0.158	73	144.0	20.75	15.39
150	90/90/90	40	2	N12@192	N12@300	10000	7500	71/93/71	49	2	0.0079	0.0050	15.07	0.158	75	180.0	21.01	15.49

TABLE 7.2.3
ZEGO WALLS

FORMS: ZEGO ICF FIREFORMS EACH SIDE: CONCRETE THICKNESS 200

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPACITY φMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT YPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ-ONTAL
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.m/m
200	240/240/240	20	1	N10@192	N16@300	13333	10000	71/143/71	N/A	5	0.0020	0.0034	8.42	0.208	69	120.0	14.48	22.16
200	240/240/240	25	1	N10@192	N16@300	13333	10000	71/143/71	N/A	5	0.0020	0.0034	8.42	0.208	70	150.0	14.68	22.68
200	240/240/240	32	1	N10@192	N16@300	13333	10000	71/143/71	N/A	5	0.0020	0.0034	8.42	0.208	72	192.0	14.85	23.15
200	240/240/240	40	1	N10@192	N16@300	13333	10000	71/143/71	N/A	5	0.0020	0.0034	8.42	0.208	74	240.0	14.97	23.48
200	240/240/240	20	1	N12@192	N16@300	13333	10000	71/143/71	N/A	5	0.0029	0.0034	9.82	0.208	72	120.0	19.99	22.16
200	240/240/240	25	1	N12@192	N16@300	13333	10000	71/143/71	N/A	5	0.0029	0.0034	9.82	0.208	73	150.0	20.40	22.68
200	240/240/240	32	1	N12@192	N16@300	13333	10000	71/143/71	N/A	5	0.0029	0.0034	9.82	0.208	75	192.0	20.75	23.15
200	240/240/240	40	1	N12@192	N16@300	13333	10000	71/143/71	N/A	5	0.0029	0.0034	9.82	0.208	77	240.0	21.01	23.48
200	60/60/60	20	2	N12@192	N12@300	13333	10000	71/143/71	131	1	0.0059	0.0038	15.07	0.208	84	120.0	35.54	25.03
200	60/60/60	25	2	N12@192	N12@300	13333	10000	71/143/71	131	1	0.0059	0.0038	15.07	0.208	85	150.0	35.95	25.19
200	60/60/60	32	2	N12@192	N12@300	13333	10000	71/143/71	131	1	0.0059	0.0038	15.07	0.208	86	192.0	36.31	25.34
200	60/60/60	40	2	N12@192	N12@300	13333	10000	71/143/71	131	1	0.0059	0.0038	15.07	0.208	89	240.0	36.56	25.44
200	90/90/90	20	2	N12@192	N12@300	13333	10000	71/143/71	99	2	0.0059	0.0038	15.07	0.208	84	120.0	31.77	22.61
200	90/90/90	25	2	N12@192	N12@300	13333	10000	71/143/71	99	2	0.0059	0.0038	15.07	0.208	85	150.0	32.18	22.78
200	90/90/90	32	2	N12@192	N12@300	13333	10000	71/143/71	99	2	0.0059	0.0038	15.07	0.208	86	192.0	32.54	22.93
200	90/90/90	40	2	N12@192	N12@300	13333	10000	71/143/71	99	2	0.0059	0.0038	15.07	0.208	89	240.0	32.79	23.03
200	240/240/240	20	2	N12@192	N12@300	13333	10000	71/143/71	67	3	0.0059	0.0038	15.07	0.208	84	120.0	28.00	20.20
200	240/240/240	25	2	N12@192	N12@300	13333	10000	71/143/71	67	3	0.0059	0.0038	15.07	0.208	85	150.0	28.41	20.37
200	240/240/240	32	2	N12@192	N12@300	13333	10000	71/143/71	67	3	0.0059	0.0038	15.07	0.208	86	192.0	28.77	20.51
200	240/240/240	40	2	N12@192	N12@300	13333	10000	71/143/71	67	3	0.0059	0.0038	15.07	0.208	89	240.0	29.02	20.62
200	240/240/240	20	2	N16@192	N16@300	13333	10000	71/143/71	67	3	0.0105	0.0067	26.79	0.208	110	120.0	45.28	34.76
200	240/240/240	25	2	N16@192	N16@300	13333	10000	71/143/71	67	3	0.0105	0.0067	26.79	0.208	110	150.0	46.57	35.28
200	240/240/240	32	2	N16@192	N16@300	13333	10000	71/143/71	67	3	0.0105	0.0067	26.79	0.208	112	192.0	47.70	35.75
200	240/240/240	40	2	N16@192	N16@300	13333	10000	71/143/71	67	3	0.0105	0.0067	26.79	0.208	114	240.0	48.51	36.08

TABLE 7.2.4
ZEGO WALLS
FORMS: ZEGO ICF FIREFORM ONE SIDE, ZEGO 19 mm REMOVABLE FORM ON THE OTHER SIDE. CONCRETE THICKNESS 103 TO 143

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPA φMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT YPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO (Numbered from Removable Form side)	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ ONTAL
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.
103	90/90/90	20	1	N10@192	N10@150	6867	5150	71/23/71	N/A	1	0.0040	0.0051	7.27	0.107	42	61.8	5.89	9.
103	90/90/90	25	1	N10@192	N10@150	6867	5150	71/23/71	N/A	1	0.0040	0.0051	7.27	0.107	42	77.3	6.08	9.
103	90/90/90	32	1	N10@192	N10@150	6867	5150	71/23/71	N/A	1	0.0040	0.0051	7.27	0.107	43	98.9	6.26	9.
103	90/90/90	40	1	N10@192	N10@150	6867	5150	71/23/71	N/A	1	0.0040	0.0051	7.27	0.107	44	123.6	6.38	9.
127	120/120/120	20	1	N10@192	N12@300	8467	6350	71/47/71	N/A	2	0.0032	0.0030	6.13	0.131	45	76.2	7.03	8.
127	120/120/120	25	1	N10@192	N12@300	8467	6350	71/47/71	N/A	2	0.0032	0.0030	6.13	0.131	46	95.3	7.23	8.
127	120/120/120	32	1	N10@192	N12@300	8467	6350	71/47/71	N/A	2	0.0032	0.0030	6.13	0.131	47	121.9	7.40	8.
127	120/120/120	40	1	N10@192	N12@300	8467	6350	71/47/71	N/A	2	0.0032	0.0030	6.13	0.131	48	152.4	7.53	8.
127	120/120/120	20	1	N12@192	N12@300	8467	6350	71/47/71	N/A	2	0.0046	0.0030	7.54	0.131	49	76.2	9.27	8.
127	120/120/120	25	1	N12@192	N12@300	8467	6350	71/47/71	N/A	2	0.0046	0.0030	7.54	0.131	49	95.3	9.68	8.
127	120/120/120	32	1	N12@192	N12@300	8467	6350	71/47/71	N/A	2	0.0046	0.0030	7.54	0.131	50	121.9	10.03	8.
127	120/120/120	40	1	N12@192	N12@300	8467	6350	71/47/71	N/A	2	0.0046	0.0030	7.54	0.131	51	152.4	10.29	8.
143	120/120/120	20	1	N10@192	N12@300	9533	7150	71/63/71	N/A	2	0.0029	0.0026	6.13	0.147	49	85.8	9.65	9.
143	120/120/120	25	1	N10@192	N12@300	9533	7150	71/63/71	N/A	2	0.0029	0.0026	6.13	0.147	50	107.3	9.85	9.
143	120/120/120	32	1	N10@192	N12@300	9533	7150	71/63/71	N/A	2	0.0290	0.0026	6.13	0.147	51	137.3	10.02	9.
143	120/120/120	40	1	N10@192	N12@300	9533	7150	71/63/71	N/A	2	0.0029	0.0026	6.13	0.147	53	171.6	10.14	9.
143	120/120/120	20	1	N12@192	N12@300	9533	7150	71/63/71	N/A	2	0.0041	0.0026	7.54	0.147	52	85.8	13.04	9.
143	120/120/120	25	1	N12@192	N12@300	9533	7150	71/63/71	N/A	2	0.0041	0.0026	7.54	0.147	53	107.3	13.45	9.
143	120/120/120	32	1	N12@192	N12@300	9533	7150	71/63/71	N/A	2	0.0041	0.0026	7.54	0.147	54	137.3	13.80	9.
143	120/120/120	40	1	N12@192	N12@300	9533	7150	71/63/71	N/A	2	0.0041	0.0026	7.54	0.147	56	171.6	14.06	9.

TABLE 7.2.5

ZEGO WALLS

FORMS: ZEGO ICF FIREFORM ONE SIDE, ZEGO 19 mm REMOVABLE FORM ON THE OTHER SIDE. CONCRETE THICKNESS 173 & 223

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STAT CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL			CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO (Numbered from Removable Form side)	GROSS REO RATIOS						BENDING CAPA ϕMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCRETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT TYPE			VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	[illegible]
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN
173	240/240/240	20	1	N10@192	N16@300	11533	8650	71/93/71	N/A	3	0.0024	0.0039	8.42	0.177	62	103.8	11.61	19
173	240/240/240	25	1	N10@192	N16@300	11533	8650	71/93/71	N/A	3	0.0024	0.0039	8.42	0.177	62	129.8	11.81	20
173	240/240/240	32	1	N10@192	N16@300	11533	8650	71/93/71	N/A	3	0.0024	0.0039	8.42	0.177	64	166.1	11.98	20
173	240/240/240	40	1	N10@192	N16@300	11533	8650	71/93/71	N/A	3	0.0024	0.0039	8.42	0.177	66	207.6	12.11	20
173	240/240/240	20	1	N12@192	N16@300	11533	8650	71/93/71	N/A	3	0.0034	0.0039	9.82	0.177	65	103.8	15.87	19
173	240/240/240	25	1	N12@192	N16@300	11533	8650	71/93/71	N/A	3	0.0034	0.0039	9.82	0.177	65	129.8	16.27	20
173	240/240/240	32	1	N12@192	N16@300	11533	8650	71/93/71	N/A	3	0.0034	0.0039	9.82	0.177	67	166.1	16.63	20
173	240/240/240	40	1	N12@192	N16@300	11533	8650	71/93/71	N/A	3	0.0034	0.0039	9.82	0.177	69	207.6	16.89	20
173	180/180/180	20	2	N12@192	N12@300	11533	8650	71/93/71	49	1	0.0068	0.0044	15.07	0.177	76	103.8	23.88	17
173	180/180/180	25	2	N12@192	N12@300	11533	8650	71/93/71	49	1	0.0068	0.0044	15.07	0.177	77	129.8	24.29	17
173	180/180/180	32	2	N12@192	N12@300	11533	8650	71/93/71	49	1	0.0068	0.0044	15.07	0.177	78	166.1	24.64	17
173	180/180/180	40	2	N12@192	N12@300	11533	8650	71/93/71	49	1	0.0068	0.0044	15.07	0.177	80	207.6	24.90	17
223	180/180/180	20	2	N10@192	N12@300	14867	11150	71/143/71	100	1	0.0037	0.0034	12.26	0.227	82	133.8	25.36	25
223	180/180/180	25	2	N10@192	N12@300	14867	11150	71/143/71	100	1	0.0037	0.0034	12.26	0.227	83	167.3	25.56	25
223	180/180/180	32	2	N10@192	N12@300	14867	11150	71/143/71	100	1	0.0037	0.0034	12.26	0.227	85	214.1	25.73	25
223	180/180/180	40	2	N10@192	N12@300	14867	11150	71/143/71	100	1	0.0037	0.0034	12.26	0.227	87	267.6	25.85	25
223	240/240/240	20	2	N10@192	N12@300	14867	11150	71/143/71	84	2	0.0037	0.0034	12.26	0.227	82	133.8	22.74	22
223	240/240/240	25	2	N10@192	N12@300	14867	11150	71/143/71	84	2	0.0037	0.0034	12.26	0.227	83	167.3	22.94	22
223	240/240/240	32	2	N10@192	N12@300	14867	11150	71/143/71	84	2	0.0037	0.0034	12.26	0.227	85	214.1	23.11	23
223	240/240/240	40	2	N10@192	N12@300	14867	11150	71/143/71	84	2	0.0037	0.0034	12.26	0.227	87	267.6	23.23	23
223	180/180/180	20	2	N12@192	N12@300	14867	11150	71/143/71	100	1	0.0053	0.0034	15.07	0.227	89	133.8	35.66	25
223	180/180/180	25	2	N12@192	N12@300	14867	11150	71/143/71	100	1	0.0053	0.0034	15.07	0.227	89	167.3	36.07	25
223	180/180/180	32	2	N12@192	N12@300	14867	11150	71/143/71	100	1	0.0053	0.0034	15.07	0.227	91	214.1	36.42	25
223	180/180/180	40	2	N12@192	N12@300	14867	11150	71/143/71	100	1	0.0053	0.0034	15.07	0.227	94	267.6	36.68	25
223	240/240/240	20	2	N16@192	N16@300	14867	11150	71/143/71	80	2	0.0094	0.0060	26.79	0.227	114	133.8	52.19	39
223	240/240/240	25	2	N16@192	N16@300	14867	11150	71/143/71	80	2	0.0094	0.0060	26.79	0.227	115	167.3	53.48	39
223	240/240/240	32	2	N16@192	N16@300	14867	11150	71/143/71	80	2	0.0094	0.0060	26.79	0.227	117	214.1	54.61	40
223	240/240/240	40	2	N16@192	N16@300	14867	11150	71/143/71	80	2	0.0094	0.0060	26.79	0.227	119	267.6	55.42	40

TABLE 7.2.6
ZEGO WALLS

FORMS: ZEGO 19 mm REMOVABLE FORMS EACH SIDE: CONCRETE THICKNESSES 125, 149, 165

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPAC φMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT TYPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ-
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.r
125	120/120/120	20	1	N10@192	N12@300	8333	6250	71/23/71	N/A	1	0.0033	0.0030	6.13	0.125	44	75.0	9.16	6.
125	120/120/120	25	1	N10@192	N12@300	8333	6250	71/23/71	N/A	1	0.0033	0.0030	6.13	0.125	44	93.8	9.36	7.
125	120/120/120	32	1	N10@192	N12@300	8333	6250	71/23/71	N/A	1	0.0033	0.0030	6.13	0.125	45	120.0	9.53	7.
125	120/120/120	40	1	N10@192	N12@300	8333	6250	71/23/71	N/A	1	0.0033	0.0030	6.13	0.125	47	150.0	9.65	7.
125	120/120/120	20	1	N12@192	N12@300	8333	6250	71/23/71	N/A	1	0.0047	0.0030	7.54	0.125	47	75.0	12.57	6.
125	120/120/120	25	1	N12@192	N12@300	8333	6250	71/23/71	N/A	1	0.0047	0.0030	7.54	0.125	47	93.8	12.98	7.
125	120/120/120	32	1	N12@192	N12@300	8333	6250	71/23/71	N/A	1	0.0047	0.0030	7.54	0.125	48	120.0	13.33	7.
125	120/120/120	40	1	N12@192	N12@300	8333	6250	71/23/71	N/A	1	0.0047	0.0030	7.54	0.125	50	150.0	13.59	7.
149	120/120/120	20	1	N10@192	N12@300	9933	7450	71/47/71	N/A	2	0.0027	0.0025	6.13	0.149	50	89.4	10.63	9.
149	120/120/120	25	1	N10@192	N12@300	9933	7450	71/47/71	N/A	2	0.0027	0.0025	6.13	0.149	50	111.8	10.83	9.
149	120/120/120	32	1	N10@192	N12@300	9933	7450	71/47/71	N/A	2	0.0027	0.0025	6.13	0.149	51	143.0	11.00	9.
149	120/120/120	40	1	N10@192	N12@300	9933	7450	71/47/71	N/A	2	0.0027	0.0025	6.13	0.149	53	178.8	11.13	9.
149	120/120/120	20	1	N12@192	N12@300	9933	7450	71/47/71	N/A	2	0.0040	0.0025	7.54	0.149	53	89.4	14.45	9.
149	120/120/120	25	1	N12@192	N12@300	9933	7450	71/47/71	N/A	2	0.0040	0.0025	7.54	0.149	53	111.8	14.86	9.
149	120/120/120	32	1	N12@192	N12@300	9933	7450	71/47/71	N/A	2	0.0040	0.0025	7.54	0.149	55	143.0	15.22	9.
149	120/120/120	40	1	N12@192	N12@300	9933	7450	71/47/71	N/A	2	0.0040	0.0025	7.54	0.149	56	178.8	15.47	9.
165	180/180/180	20	1	N10@192	N16@300	11000	8250	71/63/71	N/A	2	0.0025	0.0041	8.42	0.165	59	99.0	12.11	15.
165	180/180/180	25	1	N10@192	N16@300	11000	8250	71/63/71	N/A	2	0.0025	0.0041	8.42	0.165	59	123.8	12.30	15.
165	180/180/180	32	1	N10@192	N16@300	11000	8250	71/63/71	N/A	2	0.0025	0.0041	8.42	0.165	61	158.4	12.47	16.
165	180/180/180	40	1	N10@192	N16@300	11000	8250	71/63/71	N/A	2	0.0025	0.0041	8.42	0.165	62	198.0	12.60	16.
165	180/180/180	20	2	N12@192	N12@300	11000	8250	71/63/71	51	1	0.0071	0.0046	15.07	0.165	73	99.0	21.99	16.
165	180/180/180	25	2	N12@192	N12@300	11000	8250	71/63/71	51	1	0.0071	0.0046	15.07	0.165	74	123.8	22.40	16.
165	180/180/180	32	2	N12@192	N12@300	11000	8250	71/63/71	51	1	0.0071	0.0046	15.07	0.165	75	158.4	22.76	16.
165	180/180/180	40	2	N12@192	N12@300	11000	8250	71/63/71	51	1	0.0071	0.0046	15.07	0.165	77	198.0	23.01	16.

TABLE 7.2.7
ZEGO WALLS
FORMS: ZEGO 19 mm REMOVABLE FORMS EACH SIDE: CONCRETE THICKNESSES 195, 245

a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s
			REINFORCEMENT			MAXIMUM WALL HEIGHT for axial load less than column g			REINFORCEMENT				QUANTITIES/COST NOs			ENGINEERING LIMIT STATE CAPACITIES		
						SUPPORTED WORK ON TOP OF WALL					GROSS REO RATIOS						BENDING CAPAC ϕMu	
CONCRETE THICKNESS	FIRE FRL	CONCRETE STRENGTH	No OF GRIDS	VERTICAL	HORIZONTAL (average)	CONCR-ETE SLAB	LIGHT-WEIGHT	USE INTERCONNECT YPE	CENTRAL POUR GAP BETWEEN HORIZ BARS	PLACE HORIZ BARS IN BAR GROOVE NO	VERTICAL (AS 3600 Minimum 0.0015)	HORIZONTAL (AS 3600 Minimum 0.0025)	REINF MASS/sq m	CONCRETE VOLUME/sq m	COST No	MAX AXIAL LOAD 0.03f'cAg FOR AS 3600 SIMPLE DESIGN	VERTICAL	HORIZ-
mm	-/-/-	MPa				mm	mm		mm				kg/sq m	cu m/sq m		kN/m	kN.m/m	kN.r
195	240/240/240	20	1	N10@192	N16@300	13000	9750	71/93/71	N/A	3	0.0021	0.0034	8.42	0.195	66	117.0	14.72	19.
195	240/240/240	25	1	N10@192	N16@300	13000	9750	71/93/71	N/A	3	0.0021	0.0034	8.42	0.195	67	146.3	14.92	20.
195	240/240/240	32	1	N10@192	N16@300	13000	9750	71/93/71	N/A	3	0.0021	0.0034	8.42	0.195	68	187.2	15.09	20.
195	240/240/240	40	1	N10@192	N16@300	13000	9750	71/93/71	N/A	3	0.0021	0.0034	8.42	0.195	70	234.0	15.22	20.
195	240/240/240	20	1	N12@192	N16@300	13000	9750	71/93/71	N/A	3	0.0030	0.0034	9.82	0.195	69	117.0	20.81	19.
195	240/240/240	25	1	N12@192	N16@300	13000	9750	71/93/71	N/A	3	0.0030	0.0034	9.82	0.195	70	146.3	21.22	20.
195	240/240/240	32	1	N12@192	N16@300	13000	9750	71/93/71	N/A	3	0.0030	0.0034	9.82	0.195	71	187.2	21.58	20.
195	240/240/240	40	1	N12@192	N16@300	13000	9750	71/93/71	N/A	3	0.0030	0.0034	9.82	0.195	73	234.0	21.83	20.
195	180/180/180	20	2	N12@192	N12@300	13000	9750	71/93/71	81	1	0.0060	0.0039	15.07	0.195	81	117.0	29.06	20.
195	180/180/180	25	2	N12@192	N12@300	13000	9750	71/93/71	81	1	0.0060	0.0039	15.07	0.195	81	146.3	29.47	21.
195	180/180/180	32	2	N12@192	N12@300	13000	9750	71/93/71	81	1	0.0060	0.0039	15.07	0.195	83	187.2	29.83	21.
195	180/180/180	40	2	N12@192	N12@300	13000	9750	71/93/71	81	1	0.0060	0.0039	15.07	0.195	85	234.0	30.08	21.
245	180/180/180	20	2	N10@192	N12@300	16333	12250	71/143/71	131	1	0.0033	0.0031	12.26	0.245	87	147.0	28.96	28.
245	180/180/180	25	2	N10@192	N12@300	16333	12250	71/143/71	131	1	0.0033	0.0031	12.26	0.245	88	183.8	29.16	28.
245	180/180/180	32	2	N10@192	N12@300	16333	12250	71/143/71	131	1	0.0033	0.0031	12.26	0.245	89	235.2	29.33	28.
245	180/180/180	40	2	N10@192	N12@300	16333	12250	71/143/71	131	1	0.0033	0.0031	12.26	0.245	92	294.0	29.45	28.
245	180/180/180	20	2	N12@192	N12@300	16333	12250	71/143/71	131	1	0.0048	0.0031	15.07	0.245	93	147.0	40.84	28.
245	180/180/180	25	2	N12@192	N12@300	16333	12250	71/143/71	131	1	0.0048	0.0031	15.07	0.245	94	183.8	41.25	28.
245	180/180/180	32	2	N12@192	N12@300	16333	12250	71/143/71	131	1	0.0048	0.0031	15.07	0.245	96	235.2	41.61	28.
245	180/180/180	40	2	N12@192	N12@300	16333	12250	71/143/71	131	1	0.0048	0.0031	15.07	0.245	98	294.0	41.86	28.
245	240/240/240	20	2	N10@192	N12@300	16333	12250	71/143/71	99	2	0.0033	0.0031	12.26	0.245	87	147.0	26.34	26.
245	240/240/240	25	2	N10@192	N12@300	16333	12250	71/143/71	99	2	0.0033	0.0031	12.26	0.245	88	183.8	26.54	26.
245	240/240/240	32	2	N10@192	N12@300	16333	12250	71/143/71	99	2	0.0033	0.0031	12.26	0.245	89	235.2	26.71	26.
245	240/240/240	40	2	N10@192	N12@300	16333	12250	71/143/71	99	2	0.0033	0.0031	12.26	0.245	92	294.0	26.83	26.
245	240/240/240	20	2	N16@192	N16@300	16333	12250	71/143/71	95	2	0.0085	0.0055	26.79	0.245	119	147.0	61.41	45.
245	240/240/240	25	2	N16@192	N16@300	16333	12250	71/143/71	95	2	0.0085	0.0055	26.79	0.245	120	183.8	62.70	45.
245	240/240/240	32	2	N16@192	N16@300	16333	12250	71/143/71	95	2	0.0085	0.0055	26.79	0.245	121	235.2	63.83	46.
245	240/240/240	40	2	N16@192	N16@300	16333	12250	71/143/71	95	2	0.0085	0.0055	26.79	0.245	124	294.0	64.63	46.

8. STRUCTURE – ATTACHED BEAMS

8.1 Attached Beams and AS 3600 *Concrete Structures*

Attached beams include downturned edge beams, upturned edge beams and lintels engaged into slabs. ZEGO® ICF and Reusable Forms are used as side forms. Reinforced concrete ZEGO® beams are designed and constructed to AS 3600. The Styropor permanent ICF or the reusable forms are of no structural significance and the Interconnect penetrations are too small to affect the structure. This Section shows design information for beam sizes and reinforcement layouts that provide the best economies using the System.

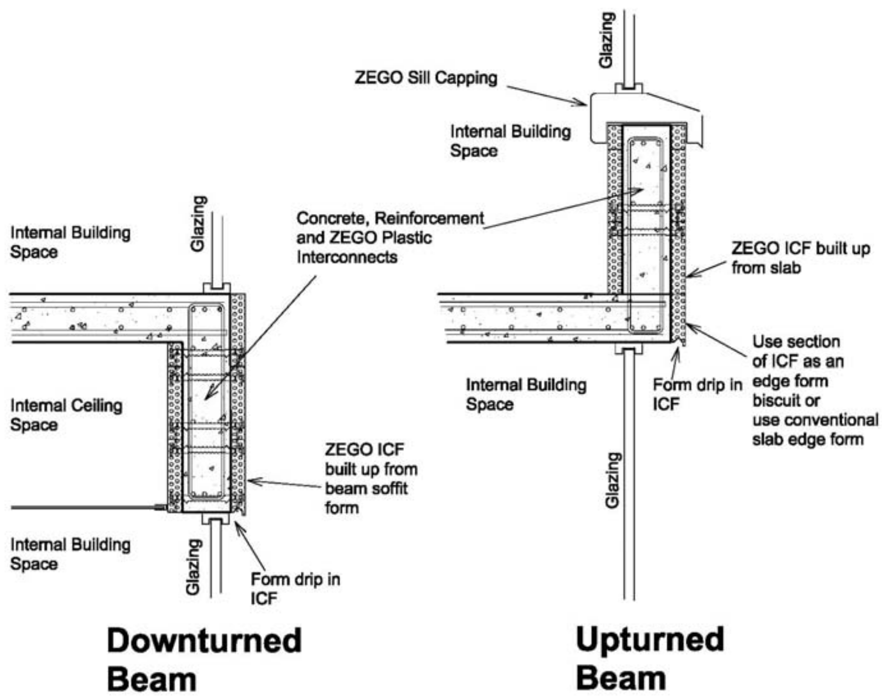


Figure 8.1
Typical ZEGO ® Attached Beams

8.2 Concrete Durability

8.2.1 Using Permanent Styropor ICF

Concrete in the ZEGO® system using permanent Styropor ICF have both surfaces protected by the ICF and for exterior surfaces, by render. The recommended renders are Granosite or Supacoat products, comprising a smear base coat, a high build 8 mm coat incorporating fibre reinforcing mesh, topped with a surface coat. The outside face of the ICF has vertical dovetail grooves at 48 mm centres, which make a very effective key for holding the render onto the ICF.

For upturned beams, protection of the top surface can be by use of a ZEGO® proprietary sill capping, or a precast, masonry or other sill treatment.

Referring to AS 3600 Table 4.3, the faces of the beam will usually be Exposure Classification A1 (the exterior being protected by the render and the interior being internal). Soffits and, for upturned beams, sills, will depend on actual design conditions. The minimum concrete characteristic compressive cylinder strength at 28 days f'_c is 20 MPa, although the Tables in this section use 25 MPa, generally the most common strength for structural concrete. Cover using ZEGO® ICF and Plastic Interconnects with N16 bars is a minimum of 26.5 mm, but varies depending on which bar grooves in the Interconnects are used to position the bars. Cover is discussed in more detail under the appropriate section, and is as shown in the Tables and Details.

8.2.2 Using Reusable Forms

When reusable forms are removed, concrete is exposed to the environment. The Designer needs to assess this exposure in accordance with AS 3600 Table 4.3, and select cover and concrete strength accordingly. Note that a wall with a ZEGO® reusable form held in place with a ZEGO® Plastic Interconnect will have cover as discussed in the appropriate Section.

8.3 Typical Concrete and Reinforcement Specification

8.3.1 Concrete

Concrete shall be to AS 3600.

Minimum concrete characteristic compressive cylinder strength at 28 days *f'c* can be any AS 3600 standard strength grade, 20 MPa, 25 MPa, 32 MPa, 40 MPa. The grades 50 MPa and 65 MPa could also be used, but are not considered here as the Designer needs to pay special attention to placement and other design and construction issues. The Tables assume 25 MPa.

The recommended maximum aggregate size is 10 mm for narrow upturned beams poured separately to slabs. Otherwise 20 mm may be used, for consistency with the attached slab, provided clear cover between horizontal bars and form faces, and the gap between horizontal bars in walls reinforced on both faces, exceed 50 mm, and thorough vibration can be assured.

The recommended slump is 80 mm, unless there are concerns about proper compactability due to restricted spaces, in which cases higher slumps should be considered.

On no account should water be added after test cylinder samples have been taken.

Admixtures to improve workability, and/or to reduce water and cement content, may be used so long as they comply with relevant Australian Standards, result in a mix design of predicable characteristics in accordance with the Specification, and do not reduce durability, corrode or otherwise affect reinforcement, or cause any other deleterious effect.

8.3.2 Reinforcement

Reinforcement shall be to AS 3600 and AS 1302 or AS/NZS 4671. The design information in this Section is based on the use of Normal Ductility D500N bars to AS/NZS 4671, of sizes N10 ligatures and N12 and N16 main bars.

8.4 Concrete Thickness

Standard ZEGO® concrete thicknesses for beams using ZEGO® ICF both sides are **104***, **150***, 168, **200*,** 250, 264 and 312 and 232. (Thicknesses in bold and marked * are preferred as at the time of writing, as their components are held in stock and are readily available). When ZEGO® reusable forms are used with ZEGO® plastic Interconnects, standard thicknesses are 117, **149***, **195***, 213, **245***, 295, 309 and 357.

8.5 Standard Reinforcing Details

8.5.1 Bar Diameter

Bar grooves in Interconnects are 9 mm diameter, to take **N16 diameter** horizontal bars plus deformations. N10 and N12 mm bars may also of course be used.

8.5.2 Bar Positioning

Bars are positioned using ZEGO® Plastic Interconnects, the major relevant dimensions for which are shown in Figure 8.2. For upturned beams, beam bottom and sidebars are positioned with the Interconnects, but ligatures position top bars conventionally. These are shown on Figures 8.3 to 8.12.

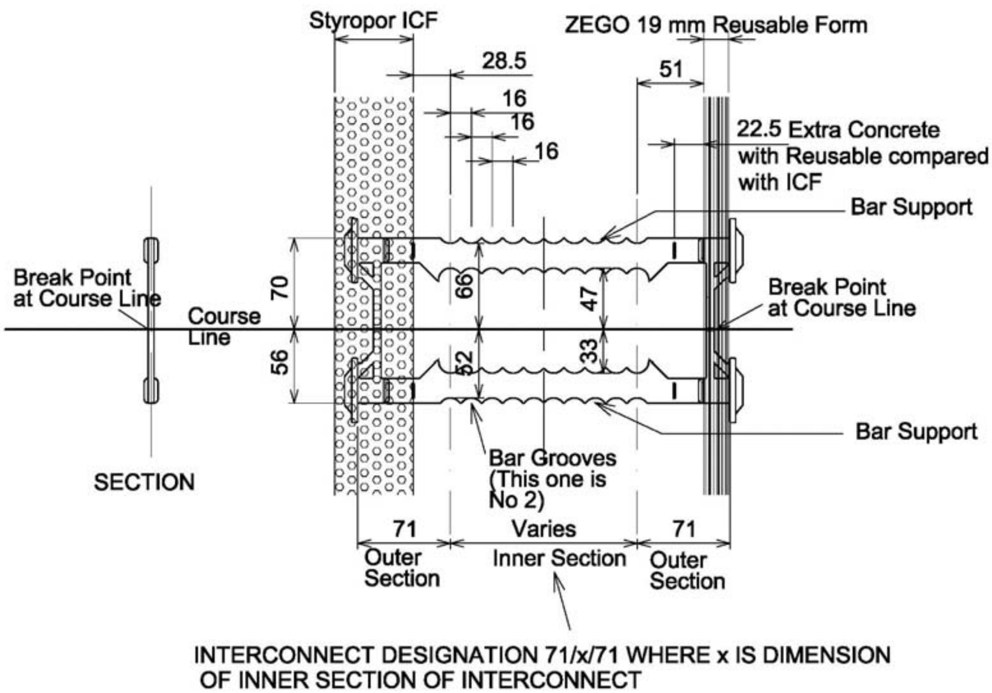


Figure 8.2
Interconnect Terminology and Dimensions

8.5.3 Cover – Side Cover

8.5.3.1 Using ICF

For a beam, ligatures must be placed outside longitudinal bars. For N16 longitudinal bars positioned in the **second** bar groove in the Interconnect, cover is 26.5 mm (This is 44.5 mm being the distance from the side face of concrete to the centre of the second bar groove, *less* 8 mm longitudinal bar radius *less* 10 mm ligature diameter), which is **26.5 mm**. (Placing the longitudinal bar in the first bar groove only gives 10.5 mm cover, which is less than any cover allowed in Table 4.10.3.2 of AS 3600). These dimensions are illustrated in Figure 8.3. For N16 bars in the third bar groove, cover is 26.5 mm + 16 mm = 42.5 mm.

Tables in this Section provide required bar grooves if side covers of and exceeding 26.5 mm are required.

8.5.3.2 Using Reusable Forms

An extra 22.5 cover is available using reusable forms compared with ICF. This means that longitudinal bars can usually be placed in the **first** bar groove, in which cover is 51 mm being the distance from the side face of concrete to the centre of the first bar groove, *less* 8 mm longitudinal bar radius *less* 10 mm ligature diameter, which is **33 mm**. These dimensions are illustrated in Figure 8.9.

Tables in this Section show required bar grooves if side covers of and exceeding 33 mm are required.

8.5.4 Cover– Soffit and Sill Cover

For downturned beams, Interconnects are used to position longitudinal bars. Referring to Figures 8.2 and 8.3, and allowing for a ligature bend radius 15 mm (resulting from a 3 x bar diameter pin and a 10 mm bar) bottom cover is 50 mm.

For sills on upturned beams, longitudinal bars are held in position by ligatures, and cover is set as required for durability of fire resistance.

8.5.5 Laps and Anchorage

Laps and anchorages are conventional, to AS 3600. Bar positioning and anchorages are suggested in general terms in the beam elevations of Figure 8.13. Actual anchorages and cutoff locations depend on actual bending moment and shear distributions along the beam, and widths of support columns. As such, they must be determined by the Designer in accordance with AS 3600 Section 8.1.8.

8.6 Typical Designs and Details

8.6.1 Design Configurations, Capacities and Details

Tables 8.1 and 8.2 show the range of standard Design Configurations for downturned and upturned edge beams, for ZEGO® ICF both sides (Table 8.1) and ZEGO® Reusable Forms both sides (Table 8.2).

Tables 8.3 to 8.12 show Moment and Shear Capacities for the Design Configurations listed in Tables 8.1 and 8.2.

The Interconnect is shown on Figure 8.2, with dimensions relevant to beams. Figures 8.3 to 8.8 show sections of beams with ICF and Figures 8.9 to 8.12 show sections of beams with Reusable Forms. Figure 13 shows beam elevations.

8.6.2 Using the Tables

Firstly, architectural or functional considerations will determine Exposure Classification and FRL.. These, in turn, determine concrete cover. Other configuration issues determine whether the beam is downturned or upturned, and whether forms are to be ICF or Reusable. A range of beam configurations can then be selected from Table 8.1 (ICF) or 8.2 (Reusable Forms). These Tables, in the last two columns, show the Table Numbers to refer to for design capacities, and the Figure Numbers to refer to for beam cross sections.

Next, determine Limit State loads $+M^*$, $-M^*$ and V^*.

Once these loads are known, refer to the relevant Design Capacity Table listed for a particular configuration in Table 8.1 or 8.2, and select a suitable beam.

As an example, consider a beam that is to be downturned, 900 deep, not more than 350 total width including ICF formwork, is continuous, and is to have a FRL of 90/90/90.

- Because it is ICF, Table 8.1 applies, and because it is downturned, the top section of the Table applies.
- The total width shall not exceed 350, so deducting 60 + 60 for the ICF both sides, the maximum permitted concrete width is 230.
- Looking at the FRL column for continuous beams, suitable beam alternatives are
  - 25 nominal cover/3 N16 bars/200 width
  - 40 nominal cover/2 N16 bars/168 width
  - 50 nominal cover/2 N16 bars/200 width
- Of these, the first, 25 nominal cover/3 N16/200 width will have the greatest capacity (3 N16 instead of 2). Hence this configuration is selected. The second last column of Table 8.1 refers us to Table 8.3 for Capacities.
- Referring to table 8.3, for a beam depth 900, concrete width 200, 3 N16 longitudinal bars top and bottom and N10 ligatures @ 500,
  - Positive Moment Capacity ϕMu = 195.2 kN.m
  - Negative Moment Capacity ϕMu = - 190.0 kN.m
  - Shear Capacity ϕVu = 23.5 kN.
- The cross section, as indicated in table 8.1 last column, is shown on Figure 8.3.

8.6.3 Other Required Checks

8.6.3.1 Lateral Restraint

It is important to check that the distance between lateral restraints (for negative bending moments for downturned beams and for positive bending moments for upturned beams) does not exceed the maximum given in the third column of the Design capacity Tables, based on AS 3600 Clause 8.9.2. This requirement will nearly always govern over the Deep beam requirement of AS 3600 Clause 12.1.1.1.

8.6.3.2 Serviceability

Owing to the wide range of possible loadings, load durations and functional and client requirements and expectations, it must be the Designer's responsibility alone to check Serviceability.

8.6.4 Basis of Design Capacity Tables

- Material properties are taken as f'_c = 25 MPa and fs_y = 500 MPa.
- Covers are taken as shown in Figures 8.3 to 8.12.
- For attached beams where the attached slab is at the compression face, the effective width has been taken as (web width + 0.1 x 4000), relevant for spans 4 metres or more (AS 3600 Clause 8.8.2)
- Tensile reinforcement only is taken into account. This enables considerable freedom of lap and termination treatment for longitudinal reinforcement at the compression face, while making little difference to capacity.
- In none of the designs provided does k_u exceed 0.4.
- For the narrowest beam in each range, the ligature is assumed to have a single leg. For all others, two leg ligatures are assumed. The number of ligature legs is given in the 6th column of each of the Capacity Tables.

8.6.5 Under-dimensioning and Tolerances

For some reusable formwork configurations, some under-dimensioning is shown. For the nominal 50 mm cover, the side cover is actually 49 mm; and for the nominal 150 concrete width, the actual concrete width is 149 mm.

These under-dimensions are justified because AS 3600 tolerance for these dimensions as specified in Clause19.5.2.3 and 19.5.3 is up to – 5 mm. For the use of ZEGO® Fire Forms, formwork and reinforcement are held in place in a much more controlled manner than is the case for conventional construction on which AS 3600 is based. Using the ZEGO® FireForm system, out of position tolerance is unlikely to exceed 1 or 2 mm, so an under-dimension of up to 3 mm will still result in final construction complying with AS 3600 tolerances.

.

Table 8.1
ZEGO® Attached Beams with ZEGO® ICF Both Sides

Formwork: ICF

Downturned Edge Beam

Note: Minimum dist between bars 2_{db} = 2 bar grooves

MINIMUM NOMINAL SPECIFIED COVER	SIDE COVER		ACTUAL SOFFIT COVER (Positioned with Interconnect)	WIDTH			FRL		EXPOSURE CLASSIFICATION (AS 3600 Table 4.10.3.2). (Subject to compliance with Table 4.10.3.2 Strength f'c Reqmnts)	REFER TO	
	OUTSIDE BAR IN INTERCONNECT GROOVE No	ACTUAL SIDE COVER		No OF N 16 LONGITUDINAL BARS	INTERCONNECT DESIGNATION	CONCRETE WIDTH b	SIMPLY SUPPORTED BEAM (AS 3600 Figure 5.4.2 (A)	CONTINUOUS BEAM (AS 3600 Figure 5.4.2(B)		BENDING AND SHEAR CAPACITIES, REFER TABLES NoS	DRAWINGS, REFER FIGURES NoS
25	2	26.5	50	1	71/47/71	104	30/-/-	30/-/-			
				2	71/93/71	150	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 32 MPa); B1 (f'c = 50 MPa)	Table 8.3	Figure 8.3
				3	71/143/71	200	60/-/-	90/-/-			
				4	71/193/71	250	60/-/-	120/-/-			
				5	71/255/71	312	60/-/-	120/-/-			
40	3	42.5	50	1	71/93/71	150	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c = 50 MPa)	Table 8.4	Figure 8.4
				2	71/111/71	168	90/-/-	90/-/-			
				3	71/193/71	250	90/-/-	180/-/-			
				4	71/207/71	264	90/-/-	180/-/-			
50	4	58.5	50	1	71/111/71	168	90/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c min = 40 MPa); C (f'c min = 50 MPa)	Table 8.5	Figure 8.5
				2	71/143/71	200	120/-/-	120/-/-			
				3	71/207/71	264	120/-/-	180/-/-			
				4	71/255/71	312	120/-/-	240/-/-			

Upturned Edge Beam

Note: Minimum dist between bars 2_{db} = 2 bar grooves

MINIMUM NOMINAL SPECIFIED COVER	SIDE COVER		ACTUAL SILL COVER (Positioned with correctly fabricated ligatures)	WIDTH			FRL		EXPOSURE CLASSIFICATION (AS 3600 Table 4.10.3.2). (Subject to compliance with Table 4.10.3.2 Strength f'c Reqmnts)	REFER TO	
	OUTSIDE BAR IN INTERCONNECT GROOVE No	ACTUAL SIDE COVER		No OF N 16 LONGITUDINAL BARS	INTERCONNECT DESIGNATION	CONCRETE WIDTH b	SIMPLY SUPPORTED BEAM (AS 3600 Figure 5.4.2 (A)	CONTINUOUS BEAM (AS 3600 Figure 5.4.2(B)		BENDING AND SHEAR CAPACITIES, REFER TABLES NoS	DRAWINGS, REFER FIGURES NoS
25	2	26.5	25	1	71/47/71	104	30/-/-	30/-/-			
				2	71/93/71	150	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 32 MPa); B1 (f'c = 50 MPa)	Table 8.6	Figure 8.6
				3	71/143/71	200	60/-/-	90/-/-			
				4	71/193/71	250	60/-/-	120/-/-			
				5	71/255/71	312	60/-/-	120/-/-			
40	3	42.5	40	1	71/93/71	150	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c = 50 MPa)	Table 8.7	Figure 8.7
				2	71/111/71	168	90/-/-	90/-/-			
				3	71/193/71	250	90/-/-	180/-/-			
				4	71/207/71	264	90/-/-	180/-/-			
50	4	58.5	50	1	71/111/71	168	90/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c min = 40 MPa); C (f'c min = 50 MPa)	Table 8.8	Figure 8.8
				2	71/143/71	200	120/-/-	120/-/-			
				3	71/207/71	264	120/-/-	180/-/-			
				4	71/255/71	312	120/-/-	240/-/-			

Table 8.2
ZEGO® Attached Beams with ZEGO® Reusable Forms Both Sides

Formwork: Reusable

Downturned Edge Beam

Note: Minimum dist between bars 2_{db} = 2 bar grooves

MINIMUM NOMINAL SPECIFIED COVER	SIDE COVER		ACTUAL SOFFIT COVER (Positioned with Interconnect)	WIDTH			FRL		EXPOSURE CLASSIFICATION (AS 3600 Table 4.10.3.2). (Subject to compliance with Table 4.10.3.2 Strength f'c Reqmnts)	REFER TO	
	OUTSIDE BAR IN INTERCONNECT GROOVE No	ACTUAL SIDE COVER		No OF N 16 LONGITUDINAL BARS	INTERCONNECT DESIGNATION	CONCRETE WIDTH b	SIMPLY SUPPORTED BEAM (AS 3600 Figure 5.4.2 (A)	CONTINUOUS BEAM (AS 3600 Figure 5.4.2 (B)		BENDING AND SHEAR CAPACITIES, REFER TABLES NoS	DRAWINGS, REFER FIGURES NoS
30	1	33.0	50	1	71/15/71	117	30/-/-	30/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 32 MPa); B1 (f'c = 40 MPa)	Table 8.9	Figure 8.9
				2	71/47/71	149	60/-/-	90/-/-			
				3	71/111/71	213	60/-/-	90/-/-			
				4	71/143/71	245	60/-/-	120/-/-			
				5	71/207/71	309	90/-/-	180/-/-			
				6	71/255/71	357	90/-/-	180/-/-			
50	2	49.0	50	1	71/47/71	149	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c = 40 MPa); C (f'c = 50 MPa)	Table 8.10	Figure 8.10
				2	71/93/71	195	90/-/-	90/-/-			
				3	71/143/71	245	120/-/-	180/-/-			
				4	71/193/71	295	120/-/-	240/-/-			
				5	71/255/71	357	120/-/-	240/-/-			

Upturned Edge Beam

Note: Minimum dist between bars 2_{db} = 2 bar grooves

MINIMUM NOMINAL SPECIFIED COVER	SIDE COVER		ACTUAL SILL COVER (Positioned with correctly fabricated ligatures)	WIDTH			FRL		EXPOSURE CLASSIFICATION (AS 3600 Table 4.10.3.2). (Subject to compliance with Table 4.10.3.2 Strength f'c Reqmnts)	REFER TO	
	OUTSIDE BAR IN INTERCONNECT GROOVE No	ACTUAL SIDE COVER		No OF N 16 LONGITUDINAL BARS	INTERCONNECT DESIGNATION	CONCRETE WIDTH b	SIMPLY SUPPORTED BEAM (AS 3600 Figure 5.4.2 (A)	CONTINUOUS BEAM (AS 3600 Figure 5.4.2 (B)		BENDING AND SHEAR CAPACITIES, REFER TABLES NoS	DRAWINGS, REFER FIGURES NoS
30	1	33.0	30	1	71/15/71	117	30/-/-	30/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 32 MPa); B1 (f'c = 40 MPa)	Table 8.11	Figure 8.11
				2	71/47/71	149	60/-/-	90/-/-			
				3	71/111/71	213	60/-/-	90/-/-			
				4	71/143/71	245	60/-/-	120/-/-			
				5	71/207/71	309	90/-/-	180/-/-			
				6	71/255/71	357	90/-/-	180/-/-			
50	2	49.0	50	1	71/47/71	149	60/-/-	90/-/-	A1 (f'c min = 20 MPa); A2 (f'c min = 25 MPa); B1 (f'c min = 32 MPa); B2 (f'c = 40 MPa); C (f'c = 50 MPa)	Table 8.12	Figure 8.12
				2	71/93/71	195	90/-/-	90/-/-			
				3	71/143/71	245	120/-/-	180/-/-			
				4	71/193/71	295	120/-/-	240/-/-			
				5	71/255/71	357	120/-/-	240/-/-			

NOTE 1: Side cover 49 is 1 mm less than specified. This is justified from AS 3600 Clause 19.5.3 (a) (i) where cover tolerance is -5 mm. Using the ZEGO Fire Form system with Interconnects the bars are held in place in a much more controlled manner than is normally applicable for concrete construction, such that the out of position tolerance is unlikely to exceed 1 mm, rather than the allowed of up to 5 mm.

NOTE 2: Wall thickness 149 mm is 1 mm less than nominated 150 mm specified in AS 3600 Figures 5.4.2 (A) & (B) for FRL. This is justified from AS 3600 Clause 19.5.2.3 where crosss ectional dimensional tolerance is 5 mm. Using the ZEGO Fire Form system with Interconnects the forms are held in place in a much more controlled manner than is normally applicable for concrete construction, such that the out of position tolerance is unlikely to exceed 1 mm, rather than the allowed of up to 5 mm.

Table 8.3
Design Capacities

Formwork: ICF
Downturned Edge Beam

MINIMUM NOMINAL COVER 25 mm

(Actual Side Cover 26.5 mm, Slab Top Cover 45 mm, Soffit Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	104	4.33	1	330	1	29.6	28.4	11.0
	150	9.00	2	330	2	58.6	55.3	17.1
	200	12.00	3	330	2	87.2	82.0	23.5
	250	15.00	4	330	2	115.4	108.6	29.8
	312	18.72	5	330	2	143.4	135.7	37.2
600	104	3.24	1	450	1	41.6	40.4	11.0
	150	6.75	2	450	2	82.6	79.3	17.1
	200	12.00	3	450	2	123.2	118.0	23.5
	250	15.00	4	450	2	163.4	156.6	29.8
	312	18.72	5	450	2	203.4	195.7	37.2
900	104	2.16	1	500	1	65.6	64.4	11.0
	150	4.50	2	500	2	130.6	127.3	17.1
	200	8.00	3	500	2	195.2	190.0	23.5
	250	12.50	4	500	2	259.4	252.6	29.8
	312	18.72	5	500	2	323.4	315.7	37.2
1200	104	1.62	1	500	1	89.6	88.4	11.0
	150	3.38	2	500	2	178.6	175.3	17.1
	200	6.00	3	500	2	267.2	262.0	23.5
	250	9.38	4	500	2	355.4	348.6	29.8
	312	14.60	5	500	2	443.4	435.7	37.2

Table 8.4
Design Capacities

Formwork: ICF
Downturned Edge Beam

MINIMUM NOMINAL COVER 40 mm

(Actual Side Cover 42.5 mm, Slab Top Cover 45 mm, Soffit Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	150	9.00	1	330	1	29.7	28.9	14.5
	168	10.08	2	330	2	58.7	55.8	18.6
	250	15.00	3	330	2	87.4	83.7	27.8
	264	15.84	4	330	2	115.5	109.2	31.0
600	150	6.75	1	450	1	41.7	40.9	14.5
	168	8.47	2	450	2	82.7	79.8	18.6
	250	15.00	3	450	2	123.4	119.7	27.8
	264	15.84	4	450	2	163.5	157.2	31.0
900	150	4.50	1	500	1	65.7	64.9	14.5
	168	5.64	2	500	2	130.7	127.8	18.6
	250	12.50	3	500	2	195.4	191.7	27.8
	264	13.94	4	500	2	259.5	253.2	31.0
1200	150	3.38	1	500	1	89.7	88.9	14.5
	168	4.23	2	500	2	178.7	175.8	18.6
	250	9.38	3	500	2	267.4	263.7	27.8
	264	10.45	4	500	2	355.5	349.2	31.0

Table 8.5
Design Capacities

Formwork: ICF

Downturned Edge Beam

MINIMUM NOMINAL COVER 50 mm

(Actual Side Cover 58.5 mm, Slab Top Cover 50 mm, Soffit Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	168	10.08	1	330	1	29.7	28.6	16.6
	200	12.00	2	330	2	58.7	55.8	22.3
	264	15.84	3	330	2	87.4	82.9	30.4
	312	18.72	4	330	2	115.8	109.4	36.9
600	168	8.47	1	450	1	41.7	40.6	16.6
	200	12.00	2	450	2	82.7	79.8	22.3
	264	15.84	3	450	2	123.4	118.9	30.4
	312	18.72	4	450	2	163.8	157.4	36.9
900	168	5.64	1	500	1	65.7	64.6	16.6
	200	8.00	2	500	2	130.7	127.8	22.3
	264	13.94	3	500	2	195.4	190.9	30.4
	312	18.72	4	500	2	259.8	253.4	36.9
1200	168	4.23	1	500	1	89.7	88.6	16.6
	200	6.00	2	500	2	178.7	175.8	22.3
	264	10.45	3	500	2	267.4	262.9	30.4
	312	14.60	4	500	2	355.8	349.4	36.9

Table 8.6
Design Capacities

Formwork: ICF

Upturned Edge Beam

MINIMUM NOMINAL COVER 25 mm

(Actual Side Cover 26.5 mm, Slab Soffit Cover 45 mm, Sill Cover 25 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	104	4.33	1	330	1	29.8	30.2	8.3
	150	9.00	2	330	2	59.0	59.0	13.0
	200	12.00	3	330	2	87.7	87.5	17.9
	250	15.00	4	330	2	116.0	116.0	22.7
	312	18.72	5	330	2	144.2	144.9	28.3
600	104	3.24	1	450	1	41.8	42.2	8.3
	150	6.75	2	450	2	83.0	83.0	13.0
	200	12.00	3	450	2	123.7	123.5	17.9
	250	15.00	4	450	2	164.0	164.0	22.7
	312	18.72	5	450	2	204.2	204.9	28.3
900	104	2.16	1	500	1	65.8	66.2	8.3
	150	4.50	2	500	2	131.0	131.0	13.0
	200	8.00	3	500	2	195.7	195.5	17.9
	250	12.50	4	500	2	260.0	260.0	22.7
	312	18.72	5	500	2	324.2	324.9	28.3
1200	104	1.62	1	500	1	89.8	90.2	8.3
	150	3.38	2	500	2	179.0	179.0	13.0
	200	6.00	3	500	2	267.7	267.5	17.9
	250	9.38	4	500	2	356.0	356.0	22.7
	312	14.60	5	500	2	444.2	444.9	28.3

Table 8.7
Design Capacities

Formwork: ICF

Upturned Edge Beam

MINIMUM NOMINAL COVER 40 mm

(Actual Side Cover 42.5 mm, Slab Soffit Cover 45 mm, Sill Cover 40 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	150	9.00	1	330	1	29.8	29.5	13.3
	168	10.08	2	330	2	59.0	57.1	17.1
	250	15.00	3	330	2	87.9	85.6	25.5
	264	15.84	4	330	2	116.1	111.8	28.6
600	150	6.75	1	450	1	41.8	41.5	13.3
	168	8.47	2	450	2	83.0	81.1	17.1
	250	15.00	3	450	2	123.9	121.6	25.5
	264	15.84	4	450	2	164.1	159.8	28.6
900	150	4.50	1	500	1	65.8	65.5	13.3
	168	5.64	2	500	2	131.0	129.1	17.1
	250	12.50	3	500	2	195.9	193.6	25.5
	264	13.94	4	500	2	260.1	255.8	28.6
1200	150	3.38	1	500	1	89.8	89.5	13.3
	168	4.23	2	500	2	179.0	177.1	17.1
	250	9.38	3	500	2	267.9	265.6	25.5
	264	10.45	4	500	2	356.1	351.8	28.6

Table 8.8
Design Capacities

Formwork: ICF
Upturned Edge Beam

MINIMUM NOMINAL COVER 50 mm

(Actual Side Cover 58.5 mm, Slab Soffit Cover 50 mm, Sill Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	168	10.08	1	330	1	29.4	28.9	16.2
	200	12.00	2	330	2	58.3	56.2	21.7
	264	15.84	3	330	2	86.7	83.6	29.5
	312	18.72	4	330	2	114.8	110.3	35.9
600	168	8.47	1	450	1	41.4	40.9	16.2
	200	12.00	2	450	2	82.3	80.2	21.7
	264	15.84	3	450	2	122.7	119.6	29.5
	312	18.72	4	450	2	162.8	158.3	35.9
900	168	5.64	1	500	1	65.4	64.9	16.2
	200	8.00	2	500	2	130.3	128.2	21.7
	264	13.94	3	500	2	194.7	191.6	29.5
	312	18.72	4	500	2	258.8	254.3	35.9
1200	168	4.23	1	500	1	89.4	88.9	16.2
	200	6.00	2	500	2	178.3	176.2	21.7
	264	10.45	3	500	2	266.7	263.6	29.5
	312	14.60	4	500	2	354.8	350.3	35.9

Table 8.9
Design Capacities

Formwork: Reusable
Downturned Edge Beam

MINIMUM NOMINAL COVER 30 mm

(Actual Side Cover 33 mm, Slab Top Cover 45 mm, Soffit Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	117	5.48	1	330	1	29.6	28.6	12.0
	149	8.88	2	330	2	58.6	55.3	17.0
	213	12.78	3	330	2	87.2	82.5	24.6
	245	14.70	4	330	2	115.3	108.3	29.3
	309	18.54	5	330	2	143.4	135.6	36.9
	357	21.42	6	330	2	171.0	162.0	43.1
600	117	4.11	1	450	1	41.6	40.6	12.0
	149	6.66	2	450	2	82.6	79.3	17.0
	213	12.78	3	450	2	123.2	118.5	24.6
	245	14.70	4	450	2	163.3	156.3	29.3
	309	18.54	5	450	2	203.4	195.6	36.9
	357	21.42	6	450	2	243.0	234.0	43.1
900	117	2.74	1	500	1	65.6	64.6	12.0
	149	4.44	2	500	2	130.6	127.3	17.0
	213	9.07	3	500	2	195.2	190.5	24.6
	245	12.01	4	500	2	259.3	252.3	29.3
	309	18.54	5	500	2	323.4	315.6	36.9
	357	21.42	6	500	2	387.0	378.0	43.1
1200	117	2.05	1	500	1	89.6	88.6	12.0
	149	3.33	2	500	2	178.6	175.3	17.0
	213	6.81	3	500	2	267.2	262.5	24.6
	245	9.00	4	500	2	355.3	348.3	29.3
	309	14.32	5	500	2	443.4	435.6	36.9
	357	19.12	6	500	2	531.0	522.0	43.1

Table 8.10
Design Capacities

Formwork: Reusable

Downturned Edge Beam

MINIMUM NOMINAL COVER 50 mm

(Actual Side Cover 49.0 mm, Slab Top Cover 50 mm, Soffit Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	149	8.88	1	330	1	29.7	28.5	15.2
	195	11.70	2	330	2	58.7	55.7	21.9
	245	14.70	3	330	2	87.4	82.4	28.7
	295	17.70	4	330	2	115.7	108.8	35.4
	357	21.42	5	330	2	143.8	135.6	43.2
600	149	6.66	1	450	1	41.7	40.5	15.2
	195	11.41	2	450	2	82.7	79.7	21.9
	245	14.70	3	450	2	123.4	118.4	28.7
	295	17.70	4	450	2	163.7	156.8	35.4
	357	21.42	5	450	2	203.8	195.6	43.2
900	149	4.44	1	500	1	65.7	64.5	15.2
	195	7.61	2	500	2	130.7	127.7	21.9
	245	12.01	3	500	2	195.4	190.4	28.7
	295	17.41	4	500	2	259.7	252.8	35.4
	357	21.42	5	500	2	323.8	315.6	43.2
1200	149	3.33	1	500	1	89.7	88.5	15.2
	195	5.70	2	500	2	178.7	175.7	21.9
	245	9.00	3	500	2	267.4	262.4	28.7
	295	13.05	4	500	2	355.7	348.8	35.4
	357	19.12	5	500	2	443.8	435.6	43.2

Table 8.11
Design Capacities

Formwork: Reusable
Upturned Edge Beam

MINIMUM NOMINAL COVER 30 mm

(Actual Side Cover 33.0 mm, Slab Soffit Cover 45 mm, Sill Cover 30 mm)

CONCRETE $f'c$ = 25 MPa

BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	117	5.48	1	330	1	29.8	30.0	9.7
	149	8.88	2	330	2	58.9	58.1	13.9
	213	12.78	3	330	2	87.7	86.8	20.1
	245	14.70	4	330	2	116.0	114.1	23.9
	309	18.54	5	330	2	144.2	142.8	30.1
	357	21.42	6	330	2	144.2	142.8	30.1
600	117	4.11	1	450	1	41.8	42.0	9.7
	149	6.66	2	450	2	82.9	82.1	13.9
	213	12.78	3	450	2	123.7	122.8	20.1
	245	14.70	4	450	2	164.0	162.1	23.9
	309	18.54	5	450	2	204.2	202.8	30.1
	357	21.42	6	450	2	204.2	202.8	30.1
900	117	2.74	1	500	1	65.8	66.0	9.7
	149	4.44	2	500	2	130.9	130.1	13.9
	213	9.07	3	500	2	195.7	194.8	20.1
	245	12.01	4	500	2	260.0	258.1	23.9
	309	18.54	5	500	2	324.2	322.8	30.1
	357	21.42	6	500	2	324.2	322.8	30.1
1200	117	2.05	1	500	1	89.8	90.0	9.7
	149	3.33	2	500	2	178.9	178.1	13.9
	213	6.81	3	500	2	267.7	266.8	20.1
	245	9.00	4	500	2	356.0	354.1	23.9
	309	14.32	4	500	2	356.4	356.7	28.5
	357	19.12	6	500	2	356.4	356.7	28.5

Table 8.12
Design Capacities

Formwork: Reusable
Upturned Edge Beam

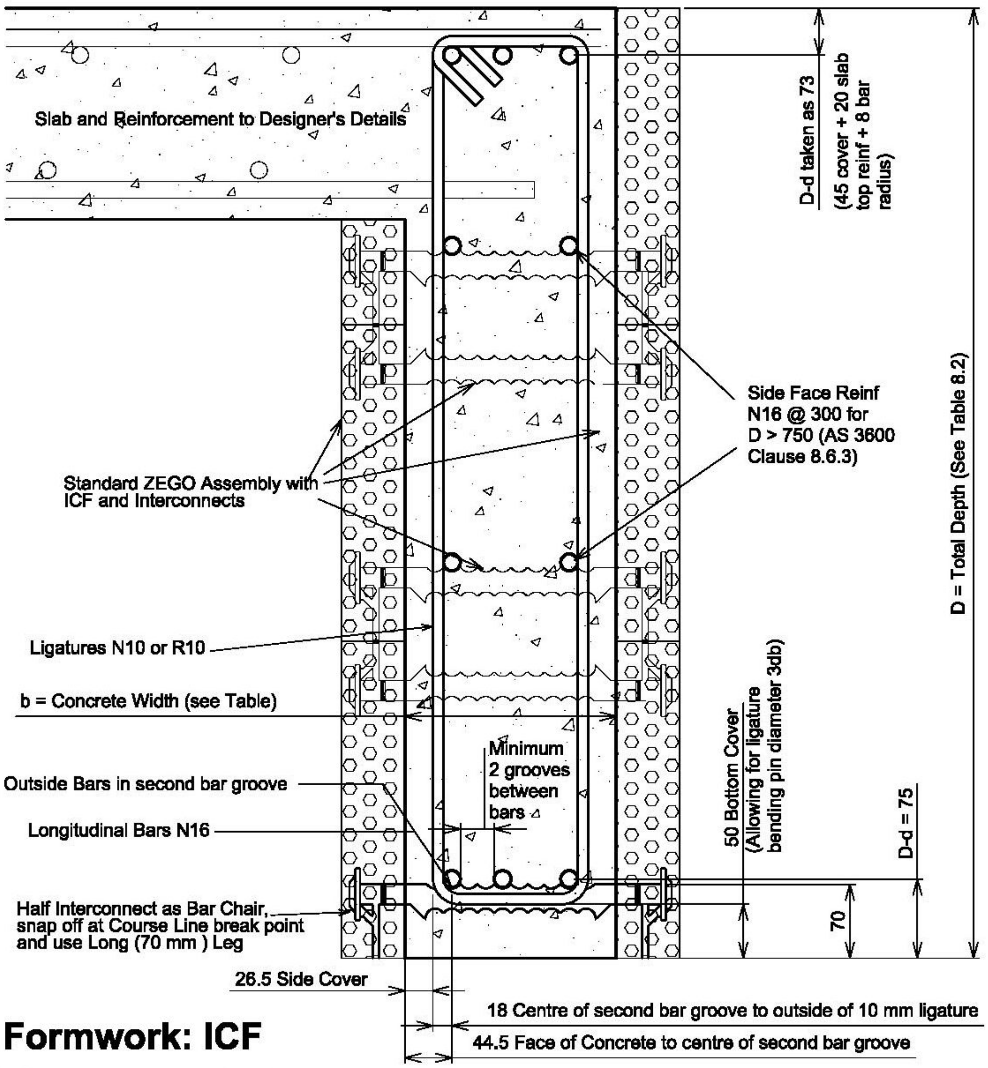
MINIMUM NOMINAL COVER 50 mm

(Actual Side Cover 49.0 mm, Slab Soffit Cover 50 mm, Sill Cover 50 mm)

CONCRETE $f'c$ = 25 MPa

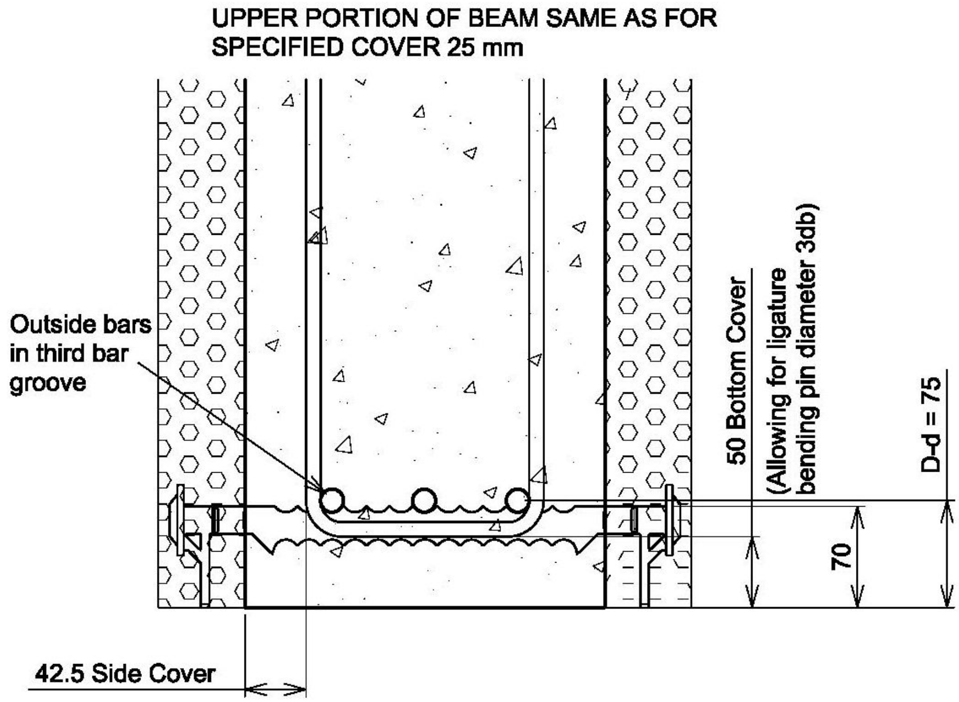
BEAM DIMENSIONS			REINFORCEMENT			CAPACITIES		
TOTAL BEAM DEPTH D	CONCRETE WIDTH b	MAX DIST BETWEEN LATERAL RESTRAINTS FOR NEGATIVE BM	No OF N16 LONGITUDINAL BARS (Each of Top & Bottom)	SPACING OF N10 LIGATURES	No of Ligature Legs	BENDING, POSITIVE, $+\phi Mu$	BENDING, NEGATIVE, $-\phi Mu$	SHEAR, ϕVu
mm	mm	m		mm		kN.m	kN.m	kN
450	149	8.88	1	330	1	29.4	28.7	14.7
	195	11.70	2	330	2	58.3	56.1	21.3
	245	14.70	3	330	2	86.7	83.1	27.9
	295	17.70	4	330	2	114.7	109.8	34.4
	357	21.42	5	330	2	142.6	136.8	42.0
600	149	6.66	1	450	1	41.4	40.7	14.7
	195	11.41	2	450	2	82.3	80.1	21.3
	245	14.70	3	450	2	122.7	119.1	27.9
	295	17.70	4	450	2	162.7	157.8	34.4
	357	21.42	5	450	2	202.6	196.8	42.0
900	149	4.44	1	500	1	65.4	64.7	14.7
	195	7.61	2	500	2	130.3	128.1	21.3
	245	12.01	3	500	2	194.7	191.1	27.9
	295	17.41	4	500	2	258.7	253.8	34.4
	357	21.42	5	500	2	322.6	316.8	42.0
1200	149	3.33	1	500	1	89.4	88.7	14.7
	195	5.70	2	500	2	178.3	176.1	21.3
	245	9.00	3	500	2	266.7	263.1	27.9
	295	13.05	4	500	2	354.7	349.8	34.4
	357	19.12	4	500	2	355.1	351.6	39.8

Figure 8.3
Beam Sections



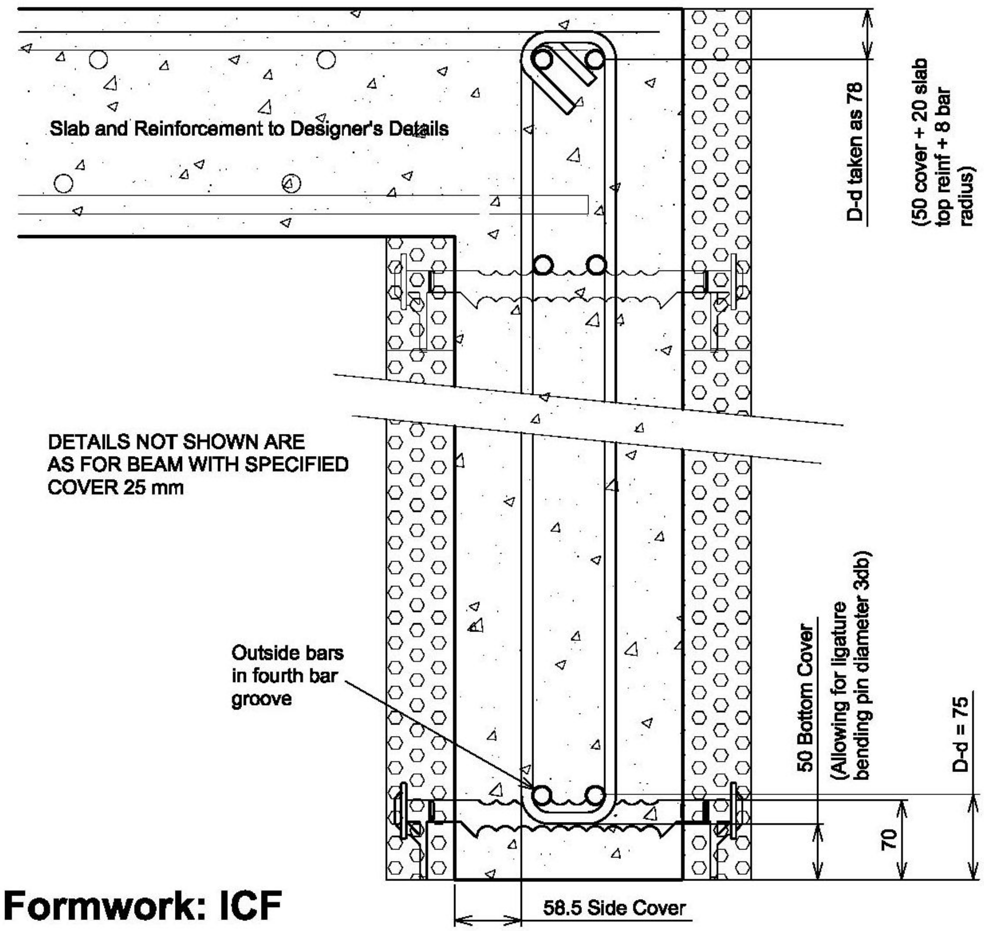
Formwork: ICF
Downturned Edge Beam
Minimum Specified Cover 25 mm

Figure 8.4
Beam Sections



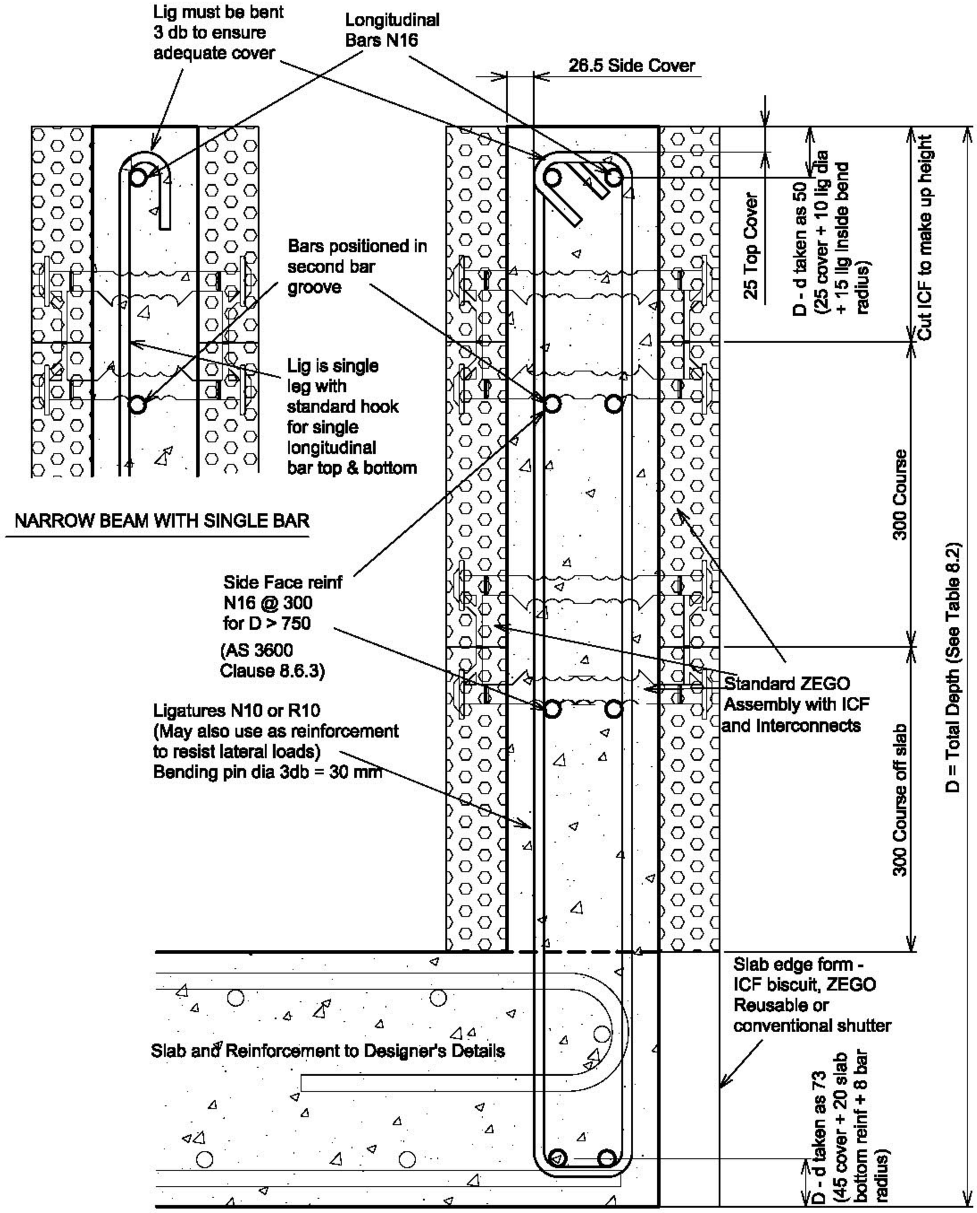
Formwork: ICF
Downturned Edge Beam
Minimum Specified Cover 40 mm

Figure 8.5
Beam Sections



Formwork: ICF
Downturned Edge Beam
Minimum Specified Cover 50 mm

Figure 8.6
Beam Sections

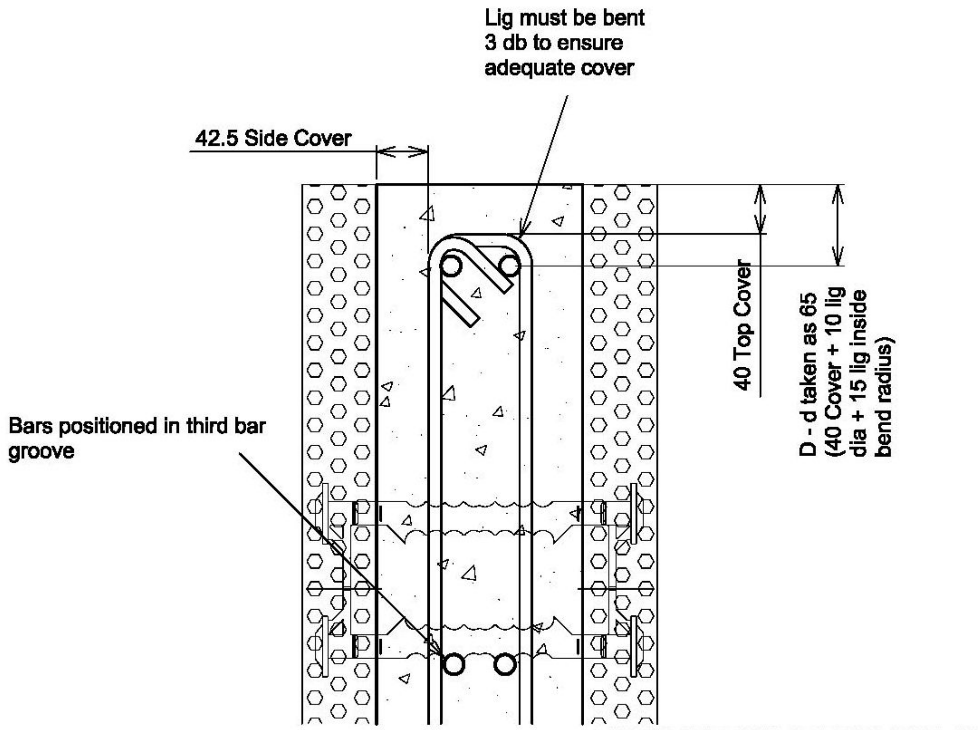


Formwork: ICF

Upturned Edge Beam

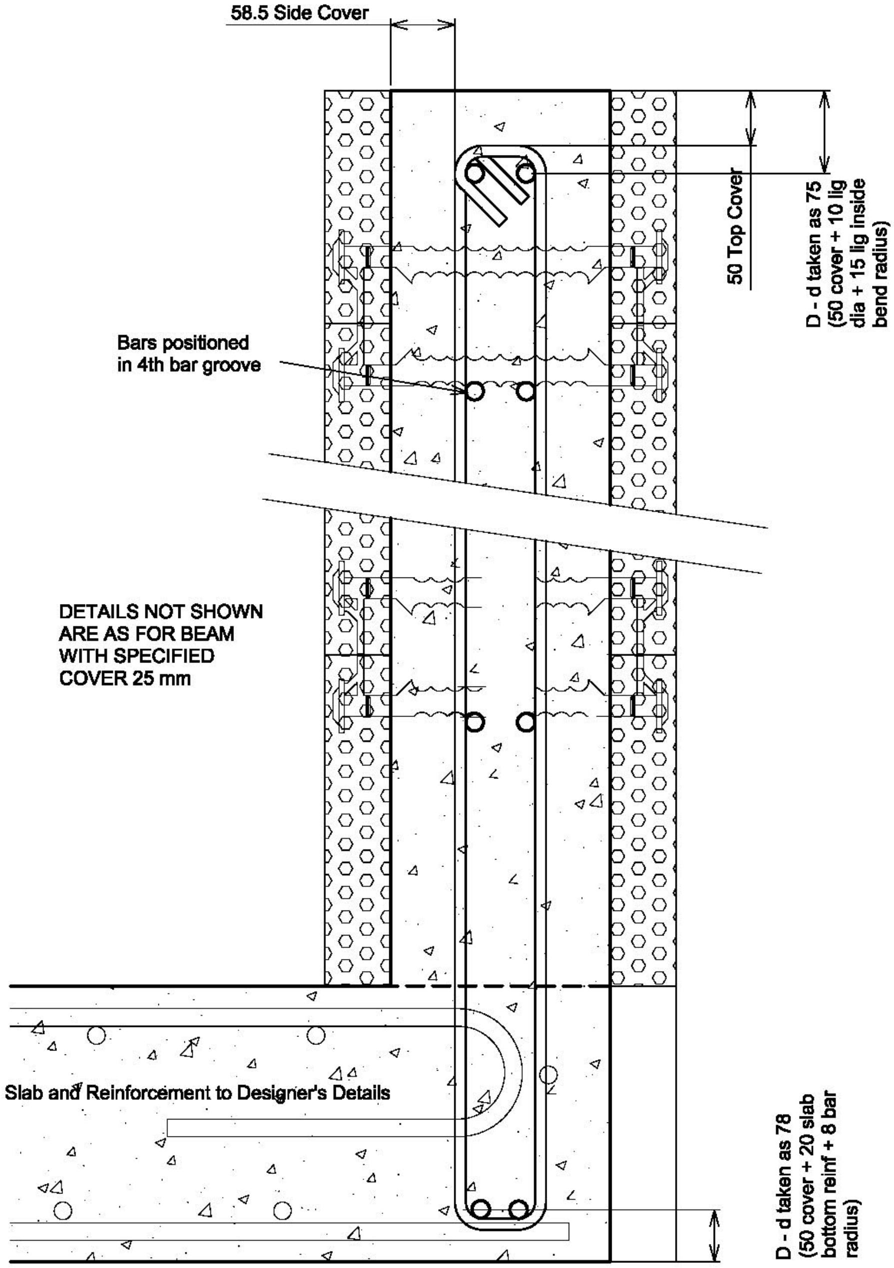
Minimum Specified Cover 25 mm

Figure 8.7
Beam Sections



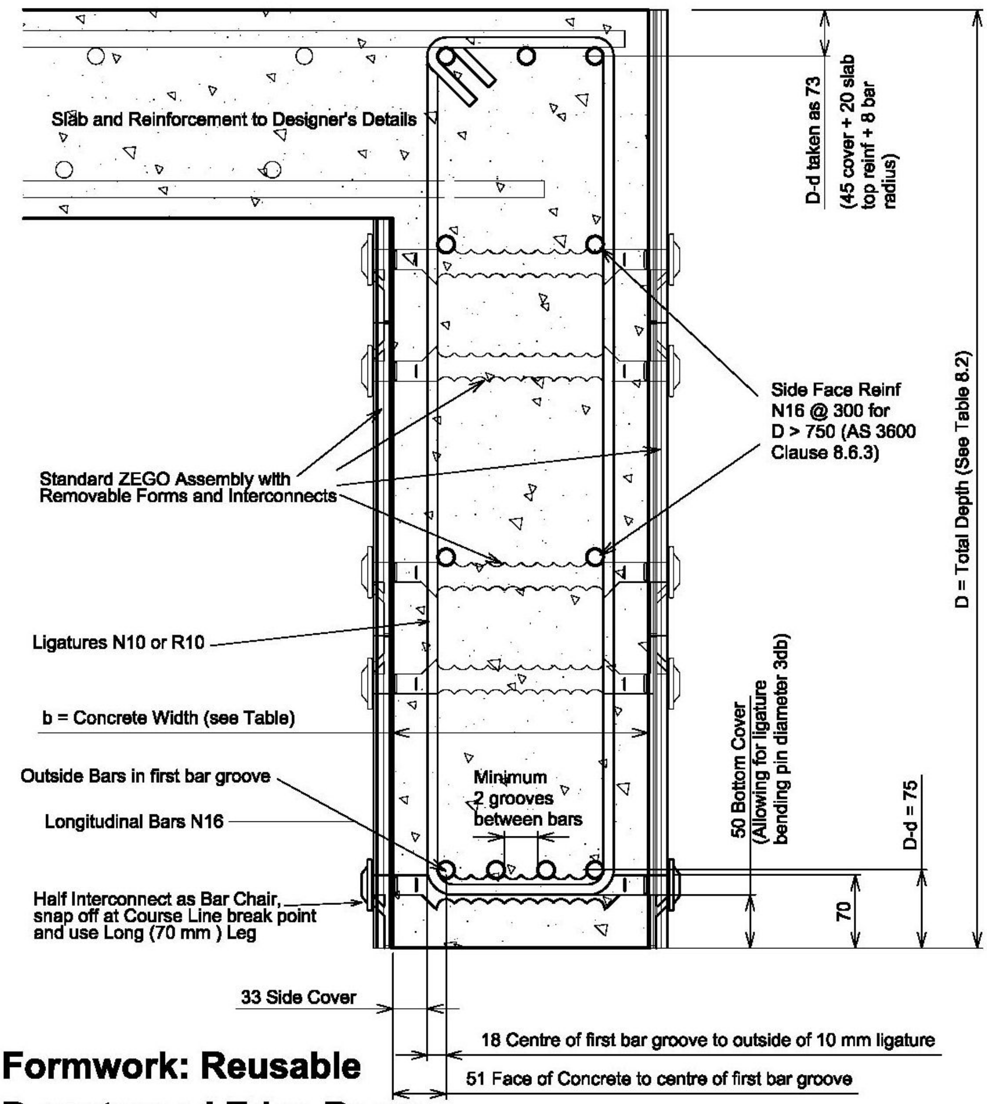
Formwork: ICF
Upturned Edge Beam
Minimum Specified Cover 40 mm

Figure 8.8
Beam Setions



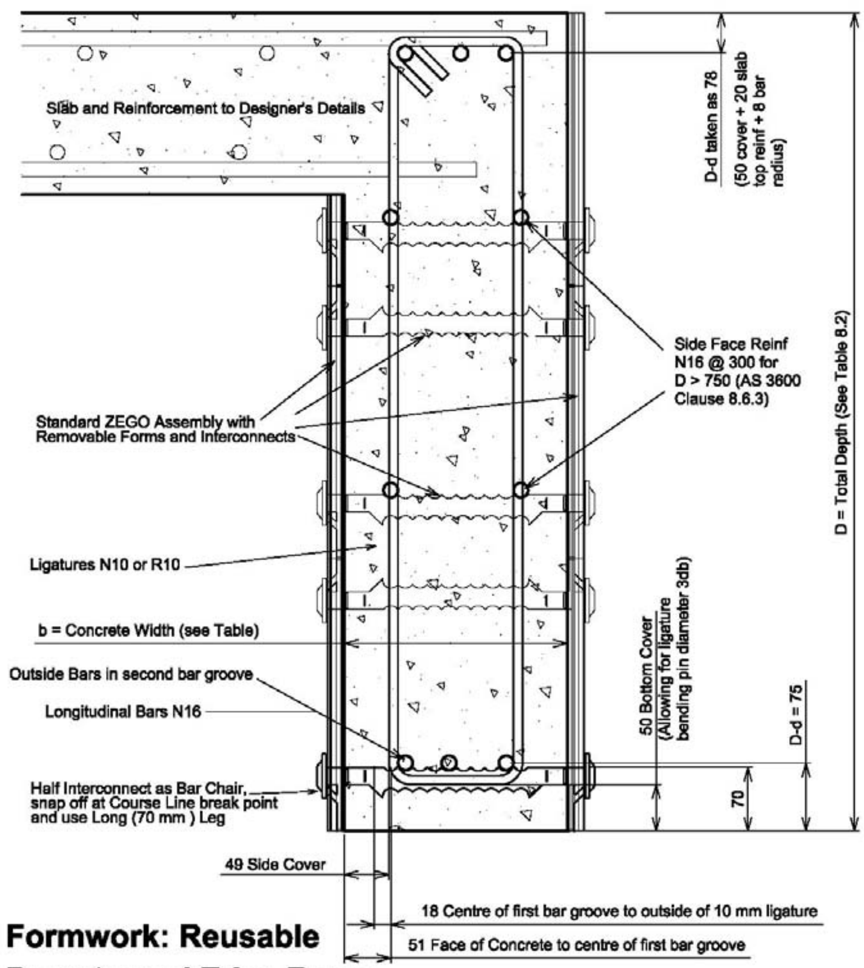
Formwork: ICF
Upturned Edge Beam
Minimum Specified Cover 50 mm

Figure 8.9
Beam Sections



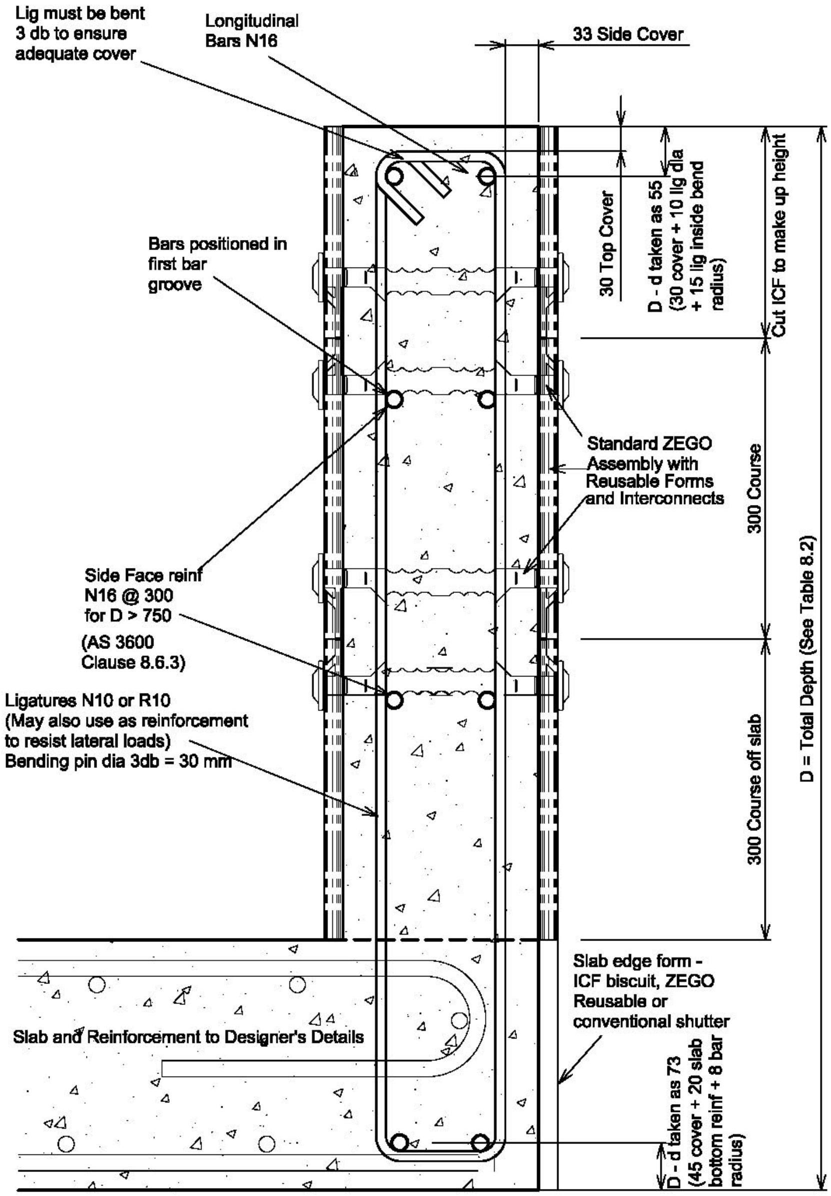
Formwork: Reusable
Downturned Edge Beam
Minimum Specified Cover 30 mm

Figure 8.10
BeamSections



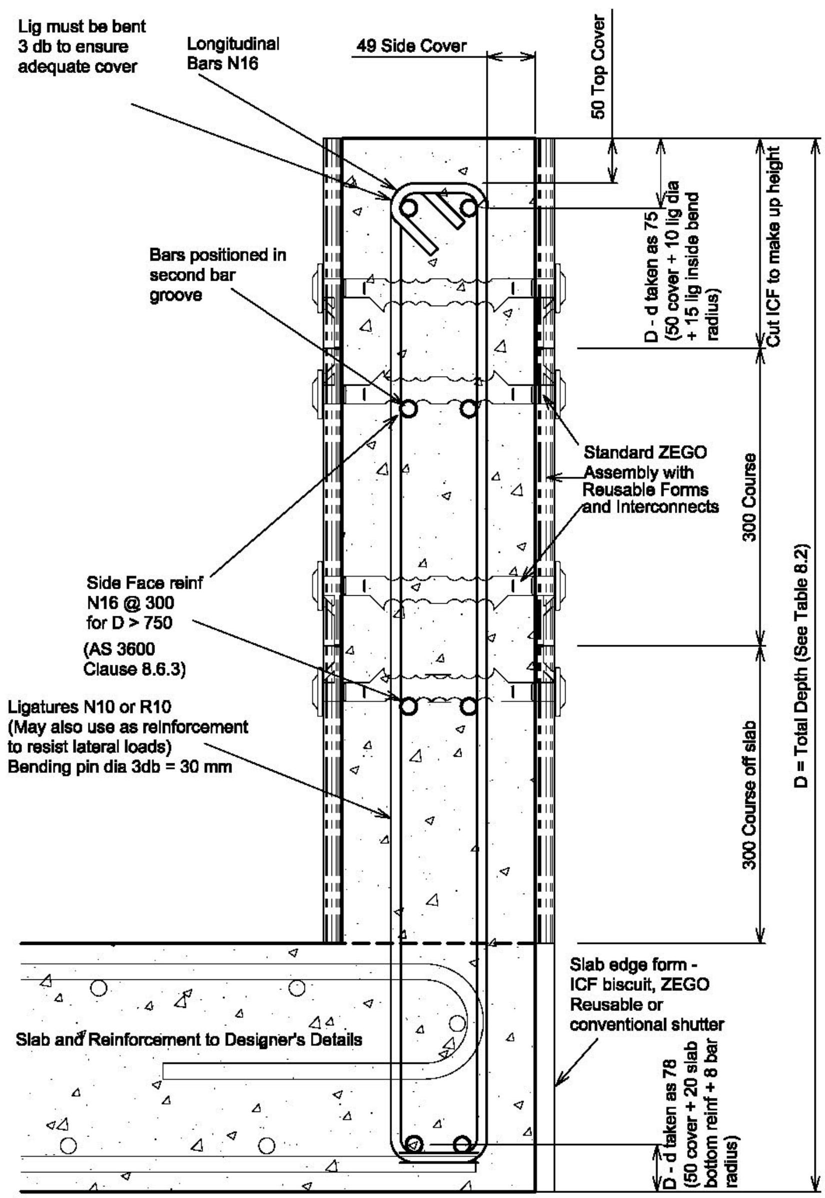
Formwork: Reusable
Downturned Edge Beam
Minimum Specified Cover 50 mm

Figure 8.11
Beam Sections



Formwork: Reusable
Upturned Edge Beam
Minimum Specified Cover 30 mm

Figure 8.12
Beam Sections

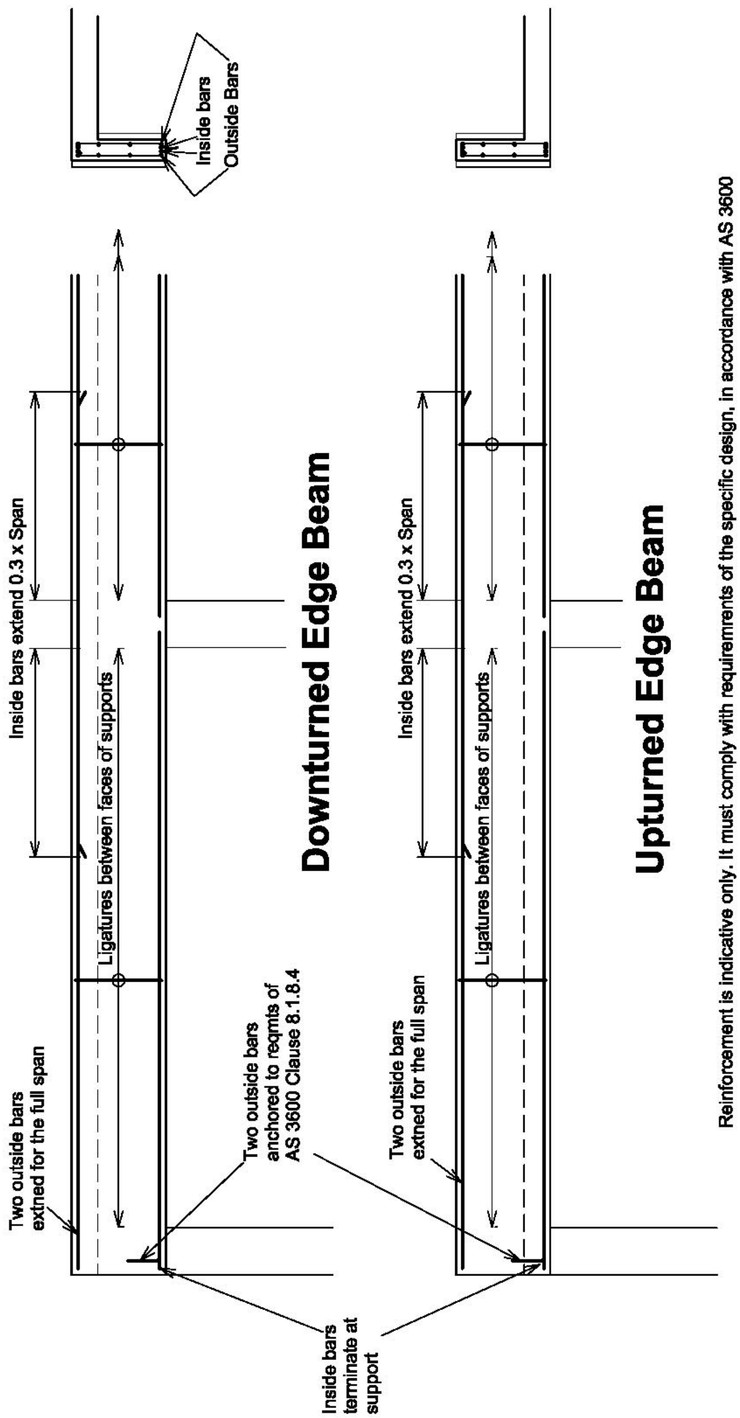


Formwork: Reusable

Upturned Edge Beam

Minimum Specified Cover 50 mm

Figure 8.13
Beam Elevations



APPENDIX 1

FIRE RESISTANCE LEVEL OF ZEGO FIREFORM WALLS

BRANZ REPORT FAR 2649

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ASSESSMENT REPORT ON ZEGO® FIRE FORM™ INSULATED CONCRETE FORMWORK (ICF'S)

1. CLIENT

ZEGO Pty Ltd
GPO Box 4774
Sydney 2001
Australia

2. INTRODUCTION

This report gives BRANZ's assessment of the fire resistance of ZEGO's Fire Form™ Insulated Concrete Forms (ICFs) in accordance with AS1530.4-1997 and compliance with AS 3600-2001.

The wall system consists of insulated formwork manufactured from expanded polystyrene with plastic webs. The core is then filled with concrete complying with AS 3600-2001.

3. BACKGROUND

If a concrete wall is built to comply with AS 3600-2001 from, for example, a minimum of 120 mm thick concrete it is deemed to be able to achieve an Insulation rating of 120 minutes if tested in a fire resistance test (Section 5.7.2). If the wall is built to comply with the requirements of section 5.7.4 "Structural Adequacy for walls" it is deemed to achieve Structural Adequacy for 120 minutes. If the wall complies with AS 3600-2001, section 5.7.2 and 5.7.4 it is deemed the wall will maintain the Integrity criteria of the test standard for 120 minutes.

4. DISCUSSION

4.1 General

It is proposed that a ZEGO ICFs wall will comply with AS 3600-2001 except that the ZEGO insulated formwork with plastic webs are used. The ICFs consist of expanded polystyrene panels nominally 60 mm wide with a plastic web slotted into each panel forming a cavity which is than filled with concrete. Other insulating panels available are 52 mm, 64 mm, and 100 mm thick along with fully strippable and reusable panels. The profile of the concrete – ICFs interface consists of 8 mm deep ribbing on 50 % of each side. other

The plastic webs are nominally 19 mm high x 4.5 mm wide and spaced at 192 mm horizontal centres and between 107 and 193 mm vertical centres.

4.2 Fire Resistance

In accordance with AS 1530.4 the failure criteria is as follows:

Structural adequacy – when the specimen fails to maintain the applied load.

Integrity – When the specimen fails structural adequacy. When flaming to the unexposed face occurs, for longer than 10 seconds, when hot gases can pass through the specimen to the unexposed face.

PBC ES

Insulation – When the average temperature on the unexposed face rises by more that 140 K or when the maximum temperature is in excess 180 K.

4.3 Structural Adequacy

The cavity of the ICFs over the range of thicknesses represents a larger cross sectional area excluding the area of the plastic webs, than the minimum defined in AS 3600-2001 Table 5.7.2. Therefore it is considered on the condition that the concrete meets the requirements of section 5.7.4 of AS 3600-2001 the ICFs walls would meet the fire resistance rating for structural adequacy listed in table 5.7.2.

4.4 Integrity

In accordance with section 5.7.3, and previous test experience on concrete wall systems, it is considered that insulation failure usually occurs before integrity failure. Therefore it is considered the ICFs system will maintain the integrity criteria of the test standard for at least the insulation ratings of the wall systems.

4.5 Insulation

If the wall complies with section 5.7.2 then it is considered it would not exceed the insulation criteria of the test standard before that listed in Table 5.7.2 from AS 3600-2001 which is reproduced as follows:

ZEGO ICFs structural cavity concrete thickness	AS3600-2001	
	Effective thickness	Fire resistance rating
104 mm	100	90 minutes
120 mm	120	120 minutes
150 mm	150	180 minutes
184 mm	170	240 minutes

5. CONCLUSION

It is considered that a concrete wall manufactured using the ZEGO® Fire Form™ ICFs system would provide at least the fire resistance in accordance with AS 1530.4-1997 as given in AS 3600-2001 for the appropriate concrete core thickness as shown in the following table.

ICFs Cavity thickness	AS3600-2001 Fire resistance rating
104 mm	90 minutes
120 mm	120 minutes
150 mm	180 minutes
184 mm	240 minutes

6. LIMITATIONS

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The wall will be designed in accordance with AS 3600-2001.

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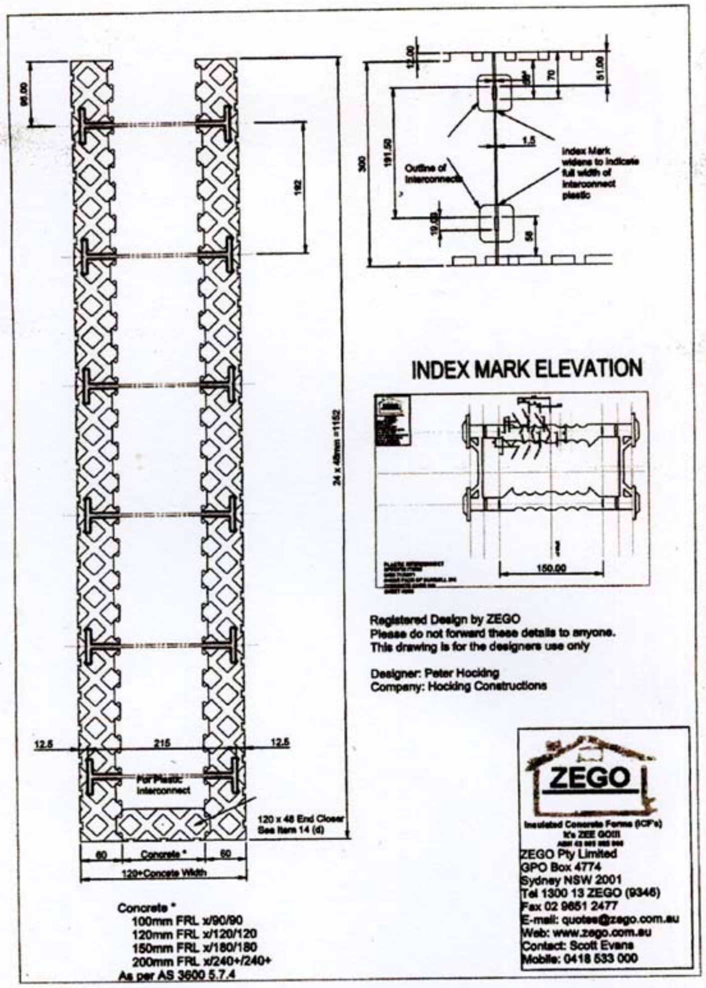

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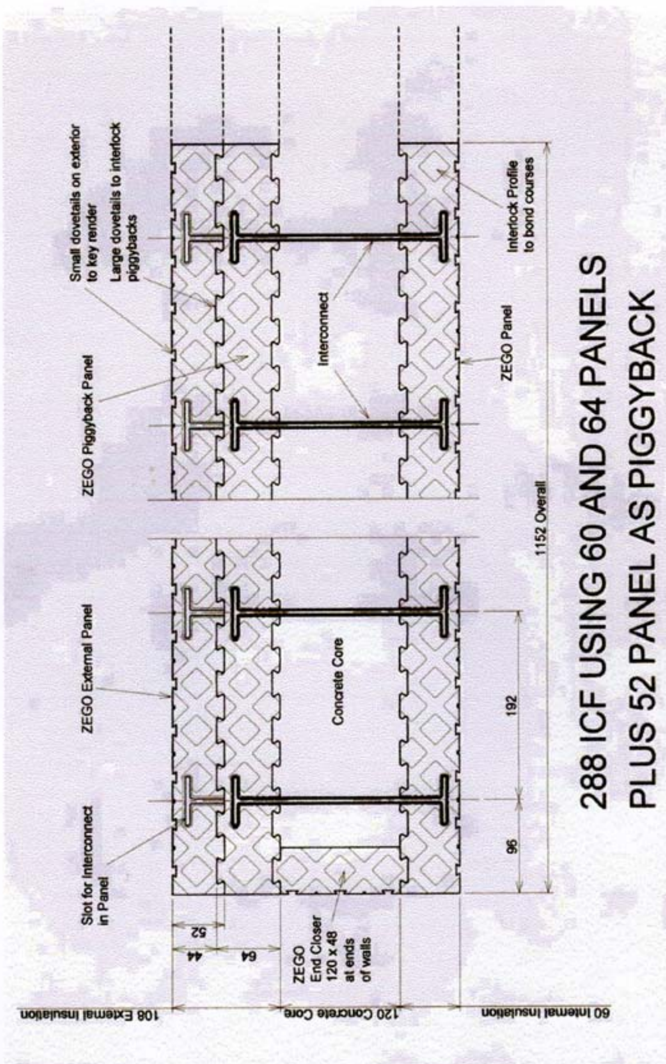

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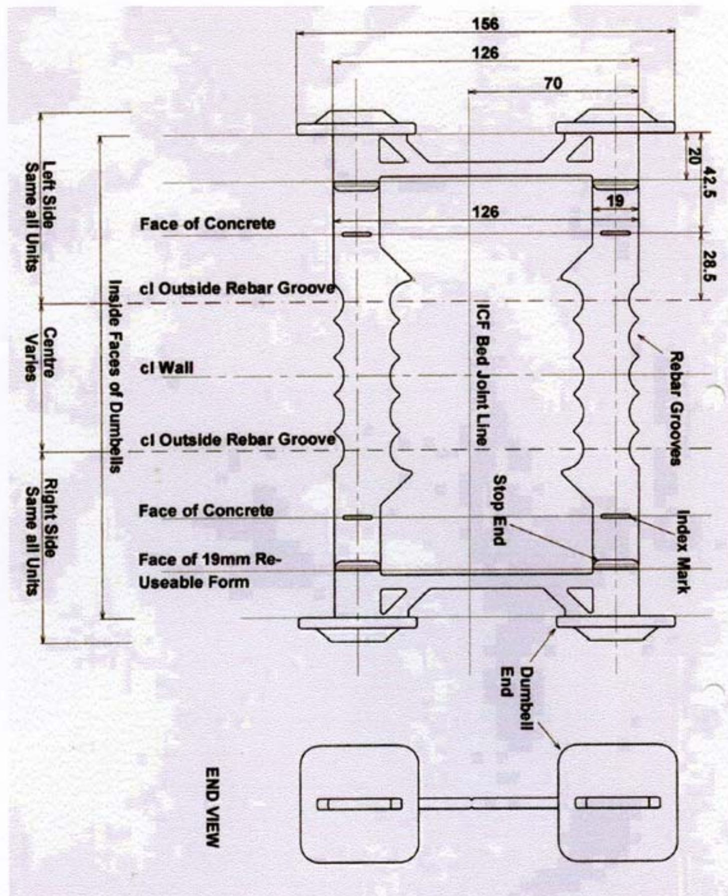

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