Dincel Construction System

3S Structural Engineering Design Manual Revision 6

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3S Structural Engineering Design Manual Revision 6

REVISIONS

Revision 3 February 2007	The 2005 version was certified by the University of New South Wales following company name change.
Revision 4 July 2012	The information certified in Revision 3 has been maintained. The following revisions/additions are introduced. • AS3600 – 2001 reference changed to AS3600 – 2009. • 125mm diameter web holes reduced to 115mm holes for 200mm thick walls. • 110mm wall axial capacity introduced. • Dincel Design Tool complying with EuroCode2 introduced for both 200mm and 110mm thick walls.
Revision 5 April 2014	The information certified in Revision 4 has been maintained. The following revisions/additions are introduced. • 200P-3 Corner Profile introduced. • AS3700 – 2001 reference changed to AS3700 – 2011. • In-Plane horizontal shear capacity and In-Plane vertical shear capacity tables revised. • 110mm and 200mm wall axial capacity tables revised.
Revision 6 December 2023	The information certified in Revision 5 has been maintained. The following revisions/additions are introduced. • AS3600 – 2009 reference changed to AS3600 – 2018 • 155mm and 275mm thick Dincel walls introduced

Introduction

DINCEL®is a patented concrete formwork system that combines an extruded rigid polymer shell as a permanent formwork to accommodate concrete (and reinforcement if required by design) infill.

The Engineering applications of DINCEL® can be utilised in the following areas:

Building Walls	Private residences, villas and townhouses. Basements, lift-stair shafts, party-corridor-façade walls of apartments, offices, retail, industrial, warehouses, hospitals, shopping centres. Excellent corrosion resistance for marine and agricultural building structures such as poultry, piggeries, fertiliser, sewerage plants, irrigation, water management channels and controlling devices. Replacement of conventional precast, tilt-up and masonry block walls.
Retaining Walls	Basement walls below permanent water table, earth retaining, mining, erosion control, river embankment protection, sea walls.
Storage Tanks	Water (detention, retention, stormwater pits), fish farming tanks, waste water, sewerage, sludge, petrol, manure, grain and contaminated soil.
Special Uses	Bushfire Prone Areas, mine subsidence areas, sound barriers, prevent the migration of contaminated ground water, construction in acid sulphate soils, bund walls to protect islands against rising ocean levels, protect fresh water lagoons against sea water invasion, reclaimed lands in coastal areas for developments, energy free flood levies to protect township or generate flood free developable lands.

The benefits for engineers specifying Dincel Construction System are:

- Reduction or elimination of engineers' liability due to wall cracking and durability related problems.
- Load bearing concrete walls which provide:
  - Simpler slab design and detailing which results in significant reduction in engineering input.

- Superior cost and time effectiveness alternative in comparison to frame structures with columns and infill walls which in turn results with significant cost savings hence return business for engineers.

- It is recognised by the world's authorities that the lateral load resistance of a load bearing concrete wall system is significantly stronger than other alternatives.

- Dincel forms are precise factory manufactured forms. The formwork's defective work tolerances built in the concrete codes for design purposes are not relevant for Dincel forms.

- The DINCEL DESIGN TOOL Zone Method for Dincel Wall/Blade Columns based on the EuroCode which is a more reliable design methodology in comparison to AS3600-2018.

- The DINCEL DESIGN TOOL calculates the ultimate strength and various fire ratings for fire on one side or all sides which offer better accuracy and significantly minimises design time for engineers.

- Dincel Wall complies with the requirements of the Building Code of Australia, Australian AS3600-2018, EuroCode 2 and American ACI318.

- Dincel Walls are preferred by the industry because they are lightweight, flexible-versatile, easy and fast to install. Eliminates the majority of occupational, health and safety issues. Refer Dincel's website "Dincel Solution for Construction Safety".

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3S – 1.0 Design Manual Use

This manual has been developed as a technical reference for design Engineers and other similar building professionals. It is not intended to replace the services and expert advice of suitably qualified structural design Engineers. Whilst care has been taken in the preparation of this design manual, errors and / or omissions may occur. **Dincel Construction System Pty Ltd** will not accept any responsibility for any consequence arising from the use of this design manual.

This design manual covers the following applications for structural elements within building structures.

- Unreinforced axially loaded walls.
- Unreinforced column applications.
- Out-of-plane flexural bending capacity of reinforced wall cross sections.
- In-plane shear capacities under axial compressive loads.
- In-plane bending capacity as a deep beam.

Structural engineers may also refer to the Dincel Construction Manual for typical examples of detailing including steel reinforcement.

3S – 2.0 Material and Product Specification

The **Dincel Construction System** comprises a rigid polymer formwork shell, infill concrete with steel reinforcement where required by design.

One of the most important building materials in the construction industry is concrete. Concrete based on Portland cement has the following attributes:

Conventional Concrete

- Materials that make up concrete are abundant and naturally available.
- Used most frequently everywhere.
- Most economical depending on its formwork cost.
- Most versatile, can be formed to any shape with some formwork difficulties.
- Recyclable - the reinforcing bars make it difficult.
- If perfect durability conditions are achieved, concrete can last 50,000 years. Refer http://matse1.matse.illinois.edu/concrete/concrete.html

Concrete with DINCEL®

DINCEL® eliminates formwork installation difficulties, reduces construction related wastages and accidents. The relative cost of wall is reduced by up to 30%.

In most cases DINCEL® walls do not require reinforcing bars.

Durability offered by DINCEL® reduces the need for higher cement content.

DINCEL® enhances concrete performance by eliminating the inherent limitations of concrete.

The limitations of conventional Portland cement based concrete are low flexural strength, low failure strain, low ductility, susceptibility to frost damage and low resistance to chemical attack. These limitations usually result in cracking or degradation of concrete leading to its deterioration.

To limit the extent of cracking, the important factors are:

- Concrete mix-design, curing and quality of materials used.
- Formwork and construction practices (supervision, compaction, etc).
- Structural design, reinforcement detailing and concrete cover.

Inadequate attention or allowance for any these factors will result in the concrete cracking. This cracking is unavoidable in the majority of cases when using concrete based on Portland cement.

The inevitable fact is that concrete cracks. Cracks allow the ingress of water, oxygen, carbon dioxide, chloride and sulphate compounds. The ingress of these items can induce corrosion of the steel reinforcement that in turn leads to spalling of the concrete and the loss of concrete strength.

Therefore, the key concerns are the degradation of the concrete matrix and presence of steel reinforcement and the cracking of the concrete elements. Concrete has low tensile strength and low ductility, reinforcement is therefore used to enhance concrete's inherent low tensile strength and ductility. This is especially the case due to external lateral forces such as wind, earthquake, liquid or earth pressure, flexural stresses by out-of-plane vertical loads or resultant tensile stress cracks due to shrinkage and temperature effects during its service life.

The majority of reinforcement is placed at the external faces of concrete slabs and walls to resist the applied loads. This requirement places the reinforcement closer to the concrete face in which most of the cracking occurs, hence the corrosion of the reinforcement. Therefore, the quality and permeability of the concrete along with concrete cover affects the durability and hence service life of the concrete structure.

With the need to reinforce concrete structures, the issue is to control concrete cracking. This will in turn provide protection to the reinforcement, reduce or eliminate the risk of water / air leakage to the human living environment and to avoid unsightly concrete cracking.

Cracking can be divided into three broad categories:

(A) CRACKS OCCURRING BEFORE AND DURING HARDENING

Conventional Concrete	Concrete with DINCEL®
Formwork Movement The conventional formwork movement depends on the quality of formwork and installation methodology.	DINCEL®'s formwork is factory made, precise dimensions which are not reliant on the workmanship skills.
Settlement Settlement of the cement pastes around the reinforcing bars or aggregate. The bigger the aggregate and reinforcing bars the more pronounced settlement cracks are.	High slump concrete with maximum 10mm aggregate size, eliminated or minimised reinforcement quantity mainly avoids this problem. The tapping of the DINCEL® formwork with a rubber mallet or the use of 25Ø vibrators assists the consolidation of concrete further. The need for vibration can be omitted if Self Compacting Concrete is used.
Plastic Drying Shrinkage Cracking Cracks are influenced by wind velocity, low relative humidity, and high air temperature resulting in rapid loss of water in concrete paste due to evaporation.	DINCEL®'s permanent formwork protects concrete paste against all these factors (particularly sun and wind) resulting in evaporation rate of less than 0.5 kg/m² hour, hence elimination of plastic shrinkage cracking.

(B) CRACKS OCCURRING AFTER HARDENING

Conventional Concrete

- The later stages of Drying Shrinkage.
- Thermal contraction for varying temperature differences.
- Moisture movements due to wetting and drying.
- Chemical reaction:
  - > Carbonation – It is the chemical reaction between cement and carbon dioxide in the air.
  - > Acid attack destroys concrete by converting hardened concrete, and its pore system. Impermeability of concrete is of little consequence in this case.
  - > Sulphate attack, in the presence of water causes expansion of concrete compound resulting in cracking.
  - > Alkali attacks avoided by not using silica containing aggregates.

Concrete with DINCEL®

Dincel Wall has been tested by CSIRO under 6m head of water pressure and certified as waterproof. Dincel Wall has also been tested in accordance with AS 3735, with zero leakage.

The permanent polymer skin of DINCEL® establishes an effective barrier against the ingress of chemicals (chlorides, sulphates, and carbon dioxide), oxygen and moisture movements, especially structures subject to periodic wetting and drying. The permanent polymer skin also allows for a reduced water/cement ratio concrete mix along with a continuation of the cement hydration process. This results in both increased early tensile and compressive strength capacity as well as at later stages, and less porous concrete. This way greatly improved **durability** of concrete is achieved in comparison to concrete with conventional formwork.

(C) CRACKING AS A RESULT OF APPLIED LOADINGS

Conventional Concrete

The vertical reinforcement is provided to resist flexural and direct tensile stresses where the tensile capacity of the concrete is exceeded, resulting in cracking.

Concrete with DINCEL®

The monolithic concrete through the web holes of DINCEL® modules interlocks the concrete and the polymer for composite action between the two materials. The flexural or direct tension loads that crack the concrete also create tension in the polymer because of this composite action. The net affect is the polymer encasement providing additional tensile load carrying capacity of the concrete. Refer **Dincel website Earthquake testing video and the testing carried out at UTS for 275 Dincel** to see the superior composite behaviour.

The permanent polymer shell of DINCEL® increases concrete strength and durability over conventional concrete by providing:

- An effective barrier against chemical attacks.
- Ideal curing conditions resulting in increased impermeability and concrete strength, both in compression and tension. This is explained further in Section 3.2.2 – Unreinforced Concrete Wall Design.

3S – 2.1 DINCEL®-WALL Unit

The DINCEL®-WALL unit is manufactured from rigid polymer composite material. As described in the product manual, the DINCEL®-WALL unit components snap together using a patented snap lock mechanism (an example from a project is shown in **Figure 1)**. The various components that make up the range of 110, 155, 200 & 275 DINCEL®-WALL units are shown in the **Dincel Construction Manual** (publicly available on the Dincel website).



FIGURE 1

3S – 2.2 Reinforcing Steel

Where required by structural analysis, reinforcement shall be manufactured and supplied in accordance with AS/NZS 4671. See Table 3.2.1 of AS3600-2018 (Ref. 1) for the currently available reinforcement types, strengths and ductility class designations. Refer Dincel Construction Manual, for further steel reinforcement information.

3S – 2.3 Concrete Infill

ENGINEERING DESIGN ASSUMPTIONS MAY BE ADOPTED FOR THE CONCRETE MIX DESIGN

(A) Walls for multi-storey building structures

(a) Walls associated with in-situ reinforced or post-tensioned concrete floors poured on removable formwork.

Floor to floor concreting cycle can be as small as 4 days with DINCEL®-WALL. Australian construction practice requires up to 3 consecutive floor formworking/back-propping level to be kept in place for multi storey building construction. This will exert at any time onto DINCEL®-WALL at 3 x 4 days = 12 days dead weight of 3 floor slabs, 3 storeys in height DINCEL®-WALL dead weight and construction live load from the floors. For these reasons compressive strength of DINCEL®-WALL's concrete to be minimum 3 MPa at 7 days or as required by the design engineer.

(b) Walls associated with precast concrete floor systems. This way, DINCEL®-WALL must be poured prior to placement of precast planks.

The time of loading in this case may be limited to a minimum of two days after the concreting of DINCEL®-WALL. The concrete compressive strength to be specified by the design engineer to suit precast flooring installation.

(c) **Walls subjected to lateral loads,** i.e., earthquake, soil/liquid pressure, high wind loading (cases where allowable tensile strength is exceeded). Refer design engineer to specify the design strength for these cases.

(B) Walls for Factory – Warehousing

(a) Walls used for cladding (e.g. similar to steel portals with pre-cast walling) purposes f'c 28 days = 20 Mpa is considered adequate. Design engineer to check final design stresses on wall panels depending on the panel length/depth ratios and wind loading.

(b) Walls replacing tilt-up methodology if roof rafters are propped in such a way that loadings are not exerted onto wet concrete wall panels, the design criteria of (a) above will be applicable. Otherwise, the concrete strength at the time of load application as early as 2 days after concrete pouring is to be specified by the design engineer.

CONCRETE QUANTITY & CONCRETE MIX SPECIFICATION

Refer to the **Dincel Construction Manual** (publicly available on the Dincel website).

COMPLIANCE OF CONCRETE MIX DESIGN TO SATISFY AS3600 – 2018, SECTION 5 FOR STRUCTURAL ADEQUACY

Dincel adopts the Eurocode2 – Zone Method which is a higher tier and more accurate method in accordance with Eurocode2 than Table 5.7.2 of AS3600 which is also a table adopted from the Eurocode.

AS3600/Eurocode's fire design is based on the spalling values of conventional concrete under a cellulosic fire curve, with 3% moisture by weight (as recommended by BS EN 1992 – 1 – 2 : 2004 Clause 4.5.1).

At the time of a fire, if the moisture content is greater than this recommended value by the Eurocode, the spalling will be excessive under cellulosic fire conditions hence premature buckling and structural failure can happen even under small loads. This is why AS3600 – 2018, Clause B2.3 states that if any alternative/performance solution is to be verified by fire testing, the test load shall be 100% equivalent of the design load (i.e. no product as a performance solution can be used above the fire test load).

Can a structural design engineer rely on a fire test report of a performance solution for the determination of the fire resistance period for structural adequacy? The answer is NO. This is because firstly, AS3600 - Appendix B - Clause B2.3 applies and secondly, under real life conditions all conventional building walls are porous and absorb moisture from the ambient unless they are protected by impervious membrane type paints having ongoing maintenance. Relative Humidity (RH) of 90% represents 3% moisture content by weight in any concrete wall, including in-situ, precast, proprietary concrete walls with porous cladding systems (i.e. magnesium oxide, fibre-cement or gypsum). Refer to the "MOISTURE in Concrete and Moisture-sensitive Finishes and Coatings" Datasheet from Cement, Concrete & Aggregates Australia - https://www.ccaa.com.au/common/Uploaded%20files/CCAA/Publications/Datasheets/DS2007MoistureTBR.pdf. This means that the moisture exceeding RH of 90% plus the moisture that already exists in the concrete wall itself exceeds the limitation given by the Eurocode (BS EN 1992 – 1 – 2 : 2004 Clause 4.5.1) hence AS3600 - Table 5.7.2 is adopted from the Eurocode.

A concrete mix design should aim to have 3% water or slightly more content where the excess water not required by hydration will be further reduced by capillary actions of the floor slabs where Dincel walls are placed on. During the life of the structure, impervious/waterproof Dincel walls (refer to CSIRO and AS 3735 waterproof Dincel Wall test results) installed in accordance with the Dincel Construction Manual will avoid any quantity of relative humidity related moisture entering through the Dincel polymer formwork protection; hence Dincel walls will always satisfy the Eurocode's fire spalling design control criteria during the life span required by AS3600. However, this will be impossible for any other non-Dincel wall unless they are protected by true membranes with ongoing maintenance so that they are not affected by conditions of RH > 90%. Engineers need to be aware that all commercial paints, except for true membranes, are porous, i.e. breathable which are not membranes. **Refer to the commentary in Appendix B (Paragraph 26) for further information on the water/cement ratio.**

The Building Code of Australia defines the "Deemed to Satisfy" condition – if the concrete structure can be designed in accordance with AS3600 – Concrete Structures. Dincel Wall can be designed in accordance with AS3600, EuroCode and American Code as verified by the report from the University of New South Wales. It is an obvious fact that if the Dincel polymer is removed from its concrete infill, the remaining concrete wall is identical to the prototype defined by the Eurocode/AS3600.

For further information on this important topic refer to sections 3S – 3.2.1.3 and 3.2.5.

3S – 3.0 Structural Design

Australian construction standards are regulated by the Building Code of Australia, which refers to Australian Standard as AS-3600-2018 for Concrete Structures. *However alternative design methods and material usage are not limited to Engineers provided that their design is based on other recognised building standards such as EuroCode as specifically referenced in Clause 5.3 of AS3600-2018.*

3S – 3.1 Structural Analysis For Wall Design

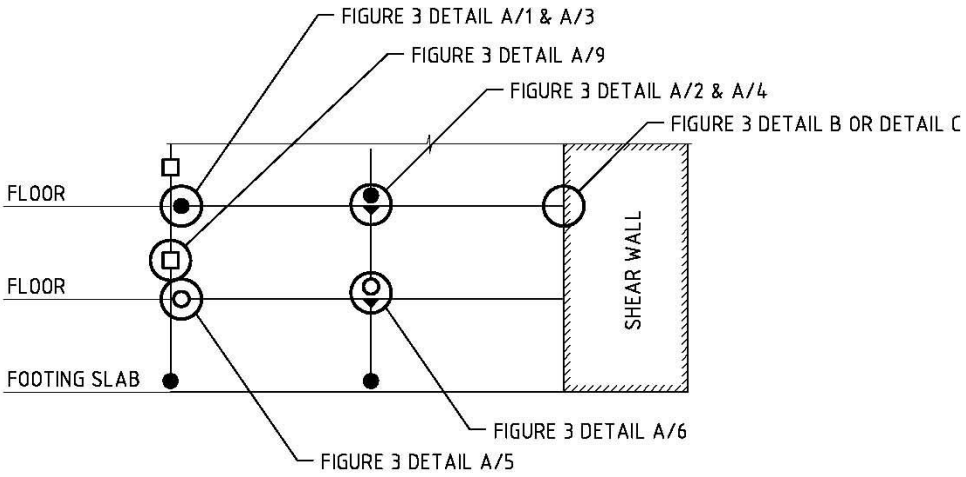
For earthquake loading of a building structure, it is necessary to consider the horizontal component of earthquake loading as well as the vertical component of earthquake loading. The resultant component can be of sufficient magnitude to be a reason for progressive collapse of non-braced walls or columns if the floor plates are not connected to at least the top of the walls / columns.

For earthquake design a building structure can accommodate shear walls at stair and lift shaft locations. These elements are designed by the Structural Engineer to resist the lateral loads induced by an earthquake event. The remaining major walls within the building structure including perimeter façade walls and party walls between sole occupancy units may be designed to support the vertical gravity loads only i.e.; not for lateral loads [walls according to their stiffness attract lateral loads (AS3600-2018 Clause 14.2.10). Walls other than shear walls can be designed as non-ductile walls as per AS3600-2018 Clause 14.4.4.1]. The concrete floors act as diaphragm plate elements to transfer the lateral forces to the shear walls.

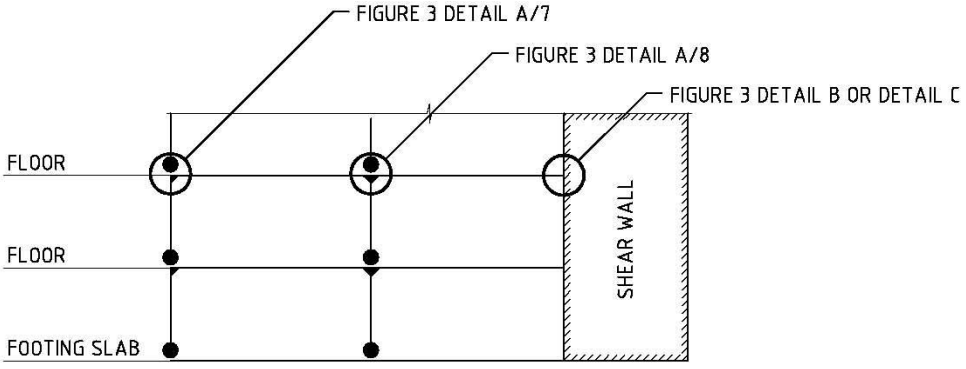
If the floor plate elements experience significant lateral movement during an earthquake event, the load bearing walls carrying gravity loads only, may lose stability and/or experience increased load eccentricity due to floor displacements which may effect the walls axial load carrying capacity therefore resulting in possible progressive collapse. For this reason, DINCEL® recommends for buildings in Australia to use the detailing as shown in **Figure 3** as a minimum standard for building heights which exceed 4 storeys above foundation level for structural walls of a braced building.

As detailed in **Figure 3,** depending upon the reinforcement detailing of DINCEL®**,** the design engineer can have the following design models for wall elements with compression upon the full cross-section of the wall as shown in **Figure 2**.

The design engineer can then adopt the appropriate slenderness ‘k’ value depending upon the adopted design model in relation to AS3600-2018 (Ref. 1). As further reference, the designer may consider the slenderness values in accordance to AS3700-2018 (Ref 2) for the determination of effective wall heights also.



STRUCTURAL MODEL OPTION-A



STRUCTURAL MODEL OPTION-B

LEGEND: REFER TO FIGURE-3 FOR DETAILS

OR — DETAIL A/7 AND A/8 - ROTATIONALLY & TRANSLATIONALLY FIXED JOINT

DETAIL A - OPTION-1 ROTATION FREE, TRANSLATION FIXED
DETAIL A - OPTION-2 & 3 ROTATION & TRANSLATION FIXED

DETAIL A/5 - FOR FLOOR MEMBER: ROTATION FREE, TRANSLATION FIXED
FOR WALL/COLUMN MEMBER: ROTATION & TRANSLATION FIXED

DETAIL A/9 - LIMITED ROTATIONAL FIXITY (ASSUME FREE) TRANSLATIONALLY FIXED

DETAIL A/1, A/3 - FOR FLOOR MEMBER: ROTATION & TRANSLATION FIXED
FOR WALL/COLUMN MEMBER: ROTATION & TRANSLATION FIXED

FIGURE 2 - ENGINEERING MODELS

LATERALLY SWAY PREVENTED BUILDING ELEMENTS BY SHEAR WALLS

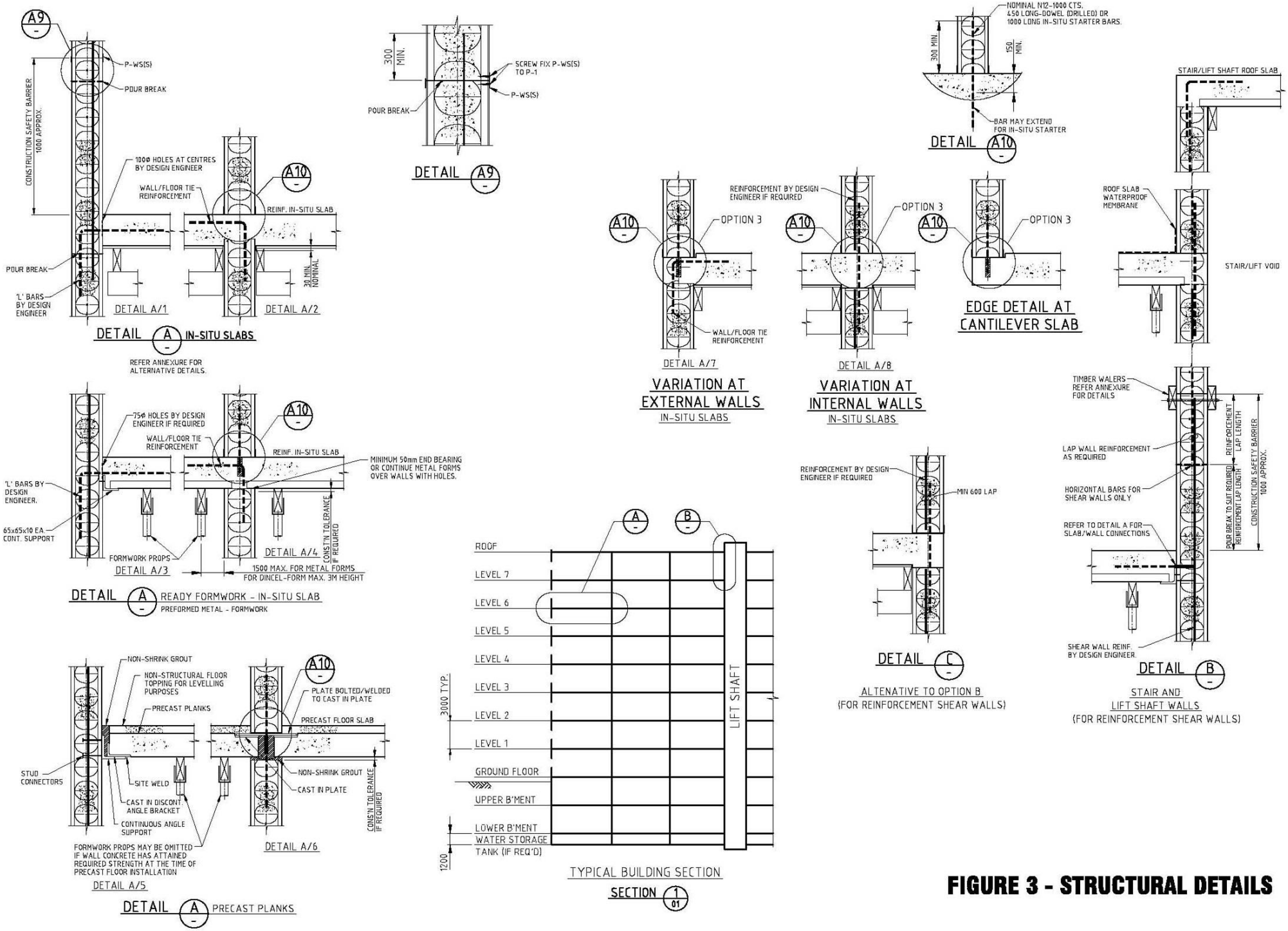


FIGURE 3 - STRUCTURAL DETAILS

3S – 3.2 Design of Axially Loaded Walls Subject to Vertical Loads for Sway Prevented Structures

The following design methodologies are available for engineers to follow for the design of concrete wall elements using DINCEL®:

1. Steel reinforced concrete wall design.
2. Plain concrete wall design (i.e.; unreinforced concrete walls).
3. Polymer reinforced concrete wall design.

3S – 3.2.1 Structural Design of Concrete Walls/Blade Columns

General

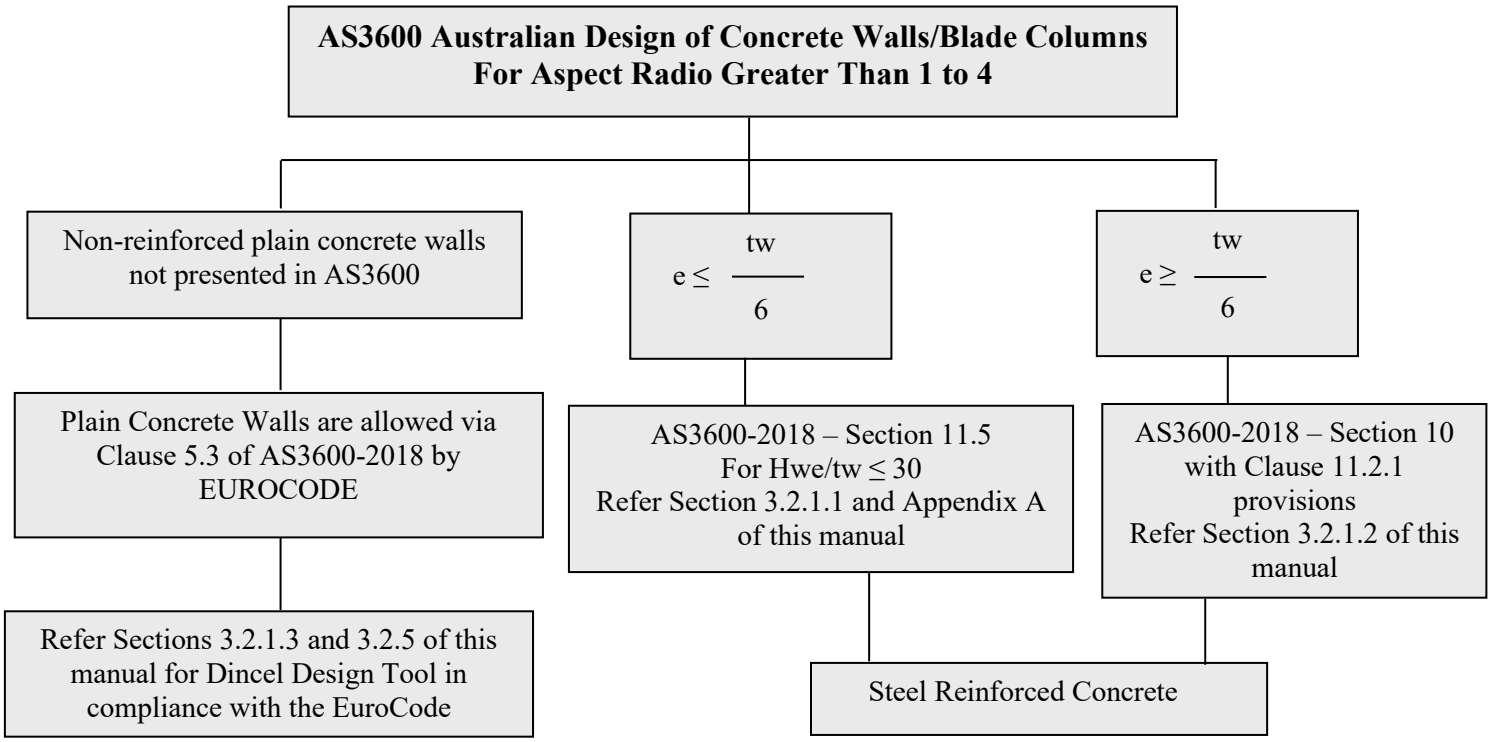
In accordance with AS3600 – 2018 a column can be designed as a wall if the longer dimension of a member is minimum 4 times than the shorter dimension. It is therefore:

Wall = a vertical element where the minimum cross sectional wall length is not less than 4 x tw (wall thickness) - AS3600-2018 Clause 5.6.2.

The structural design of concrete walls must be carried out in conformance with local building codes and the applicable concrete design standard. However, Australian design engineers are not limited to the use of Australian Concrete Structures Code AS3600 provided their design is based on other recognized building standards.

Notation

Imperial	Metric	Definition
	A_c, A_g	= horizontal area of concrete section; (mm^2)
	e	= eccentricity of load measured from centre of member; (mm)
	f 'c	= specified compressive strength of concrete at 28 days; (MPa)
	k	= effective length factor
(l_c)	l_u (Hwu)	= vertical clear distance between supports mm; (in)
	Hwe	= effective height of a wall – k x Hwu mm; (in)
(P_u)	P_f (N*)	= factored axial load; kN (lb force)
	r	= radius of gyration; mm (in)
(h)	t (t_w)	= thickness of member; mm (in)



Note

Building Code of Australia requires –

(i) Structural walls functioning as fire walls to be designed with appropriate fire rating.
(ii) Structural walls **not** functioning as fire walls but are however carrying a fire rated building element such as a floor above, the walls must be designed for minimum appropriate fire rating for the element it is supporting.

For the purposes of fire wall design, wall load limitations are governed by the wall slenderness in accordance to AS3600, Clause 5.7.2 as a “lower tier” approach which is adopted from the EuroCode.

AS3600-2018, Clause 5.3 recommends the use of EuroCode (Zone Method) as a “higher tier” approach.

AS3600, Clause 5.6.2 and its following footnote about double face reinforcement and vertical bars being restrained can be ignored when EUROCODE ZONE METHOD is adopted.

Fire wall design is governed by slenderness, load, concrete grade and design eccentricities.

(a) AS3600-2018, Table 5.7.2 is a lower tier approach which only allows two load cases with very high slenderness ratio of 40. This approach is conservative however in cases of low grade concrete, low load, high eccentricity and slenderness ratio it can be very dangerous.

(b) AS3600-2018, Clause 5.3 allows the use of EuroCode which is a higher tier approach and takes into account all design parameters, i.e. slenderness, applied load, concrete grade and design eccentricities.

This is a more reliable approach adopted by the Dincel Design Tool.

3S – 3.2.1.1 AS3600-2018 Walls/Blade Column Subject to In-Plane Vertical Forces Only and where Wall Eccentricity $e \leq t_w / 6$

The following design methodology only apply to the wall details as shown on **Figure 3** – Details A/1, A/2, A/3 ,A/4, A/6, A/7 and A/8.

For the design of DINCEL®-WALL utilising the polymer shell as a formwork with infill concrete, the design axial strength per metre length of a braced concrete wall in accordance with section 11.5 of AS3600 is:

$$\phi N_u = \phi (t_w - 1.2e - 2e_a) 0.6 f'_c$$

ϕ : capacity reduction factor = **0.65**

e : vertical load eccentricity:
- tw / 6 with floor slab over discontinuous (end walls) – Detail A/1 and A/3 of Figure 3
- tw / 20 with floor slab over continuous (internal walls) – Detail A/2, A/4, A/6, A/7 and A/8 of Figure 3

e_a : additional eccentricity due to slenderness – $(H_{we})^2 / 2500 t_w$

f'_c : characteristic compressive cylinder strength of concrete at 28 days

H_{we} : effective height of braced wall as defined by Clause 11.4:

- both ends having rotational restraint …….. $0.75 H_{wu}$

H_{wu} : wall height between lateral supports

t_w : concrete wall thickness

REFER APPENDIX A FOR DESIGN CHARTS

3S – 3.2.1.2 AS3600-2018 Walls/Blade Column Subject to Combined Bending and Vertical Forces and where Wall Eccentricity e > t_w / 6

The following design methodology can only apply to the wall detail as shown on **Figure 3** – Details A/5 where the applied load wall eccentricity e > t / 6.

AS3600-2018 Clause 11.2.1(a)(ii) states that where a horizontal cross-section of the wall is subject to compression over the entire section, the wall can be designed for horizontal shear forces in accordance with Clause 11.6 and for the vertical compressive forces:

"as a column in accordance with Section 10 where vertical reinforcement is provided in each face, except that Clause 11.7.4 may override the requirements of Clause 10.7.4. The provisions of Clause 10.7.1(a), Clause 11.4 and Clause 11.7 shall still apply."

Alternatively, these walls may be designed in accordance with EuroCode2 (Dincel Design Tool).

AS3600-2018 Clause 11.2.1(b)(ii) states that where a horizontal cross-section of the wall is subject to tension on part of the section, and where the H/L ratio > 2, the wall shall be designed for in-plane bending:

"as a column in accordance with Section 10 where vertical reinforcement is provided in each face, except that Clause 11.7.4 may override the requirements of Clause 10.7.4. The provisions of Clause 10.7.1(a), Clause 11.4 and Clause 11.7 shall still apply."

Unreinforced Axial Wall Capacity

AS3600 Model for (Hwe / tw) ≤ 30, $\phi Nu = 0.65 (tw - 1.2e - 2e_a) 0.6 f'c$ ..... Clause 11.5.3

tw = 195 mm - wall thickness

f'c = 32 Mpa - characteristic design strength

$e_a = (Hwe)^2 / 2500 tw$

AS3600 Model

ϕ Nu (kN / m)

ϕ = 0.65

e = tw / 6

Hwe = 1.00 Hwu

Hwe (m)	ϕ Nu
1.000	1895.68
1.082	1886.90
1.165	1877.43
1.247	1867.26
1.329	1856.39
1.412	1844.84
1.494	1832.58
1.576	1819.64
1.659	1806.00
1.741	1791.66
1.824	1776.63
1.906	1760.91
1.988	1744.49
2.071	1727.38
2.153	1709.57
2.235	1691.07
2.318	1671.87
2.400	1651.98
2.482	1631.40
2.565	1610.12
2.647	1588.14
2.729	1565.47
2.812	1542.11
2.894	1518.05
2.976	1493.30
3.059	1467.86
3.141	1441.71
3.223	1414.88
3.306	1387.35
3.388	1359.13
3.471	1330.21
3.553	1300.60

ACI Building Code American Model

ϕP_{nw} (lb per foot)

ϕ = 0.6

e_O = tw / 6

lc = actual height (in.)

lc (in)	ϕP_{nw}
39.370	116328.95
42.612	115803.13
45.854	115235.73
49.096	114626.73
52.339	113976.15
55.581	113283.98
58.823	112550.22
62.065	111774.87
65.307	110957.93
68.549	110099.40
71.791	109199.28
75.033	108257.58
78.276	107274.29
81.518	106249.40
84.760	105182.93
88.002	104074.87
91.244	102925.23
94.486	101733.99
97.728	100501.16
100.970	99226.75
104.213	97910.75
107.455	96553.15
110.697	95153.97
113.939	93713.21
117.181	92230.85
120.423	90706.90
123.665	89141.37
126.907	87534.24
130.150	85885.53
133.392	84195.23
136.634	82463.34
139.876	80689.86

ϕP_{nw} (kN / m)

Imperial to metric conversion

lc (m)	ϕP_{nw}
1.000	1701.84
1.082	1694.15
1.165	1685.85
1.247	1676.94
1.329	1667.42
1.412	1657.30
1.494	1646.56
1.576	1635.22
1.659	1623.27
1.741	1610.71
1.824	1597.54
1.906	1583.76
1.988	1569.38
2.071	1554.38
2.153	1538.78
2.235	1522.57
2.318	1505.75
2.400	1488.32
2.482	1470.29
2.565	1451.64
2.647	1432.39
2.729	1412.53
2.812	1392.06
2.894	1370.98
2.976	1349.30
3.059	1327.00
3.141	1304.10
3.223	1280.59
3.306	1256.47
3.388	1231.74
3.471	1206.40
3.553	1180.46

Eurocode

Nrd (kN/m)

lw = Floor Clear Height

lw (m)	Nrd
1.000	2146.13
1.082	2125.76
1.165	2095.05
1.247	2064.35
1.329	2033.65
1.412	2002.95
1.494	1972.25
1.576	1941.55
1.659	1910.84
1.741	1880.14
1.824	1849.44
1.906	1818.74
1.988	1788.04
2.071	1757.33
2.153	1726.63
2.235	1695.93
2.318	1665.23
2.400	1634.53
2.482	1603.83
2.565	1573.12
2.647	1542.42
2.729	1511.72
2.812	1481.02
2.894	1450.32
2.976	1419.61
3.059	1388.91
3.141	1358.21
3.223	1327.51
3.306	1296.81
3.388	1266.11
3.471	1235.40
3.553	1204.70

ACI Building Code American Model

$\phi P_{nw} = \phi\ 0.45 f'c Ag (1 - (lc / 32 h)^2)$ ..... Clause 14.5.4.2

ϕP_{nw} = lbs. per foot - design axial strength

h = 7.68 in - thickness of wall cross-section

f'c = *4800.0* psi - specified compressive strength of concrete

ϕ = ACI Building Code reduction factor Clause 21.2.1 ϕ = 0.6

Eurocode Model

Nrd = b × hw × fcd,pl × Ø.....BS EN 1992-1-1:2004 Clause 12.6.5.2

Wall Ultimate Axial Load

b = 1000 mm

fck = 32 Mpa

hw = 195 mm

fcd,pl = (0.8/1.5) x fck = 17.07 Mpa - for Ultimate Strength of unreinforced wall

Replace 0.8 factor with 1.0 in fcd,pl formula if the wall consists reinforcement.

eo = 32.50 mm First Order Eccentricity (hw/6)

Beta = 0.85 Clause 12.6.5.1 (4) and Table 12.1

lo = Beta x Clear Height

ei = lo/400 mm BS EN 1992-1-1:2004 Clause 5.2(9)

etot = eo + ei

Ø = Strength reduction due to eccentricity - Clause 12.6.5.2 (12.11)

Ø = 1.14 x (1 - 2etot/hw) - 0.02 x lo/hw ≤ (1 - 2etot/hw)

3S – 3.2.1.3 COMPARE AS3600 AND EUROCODE

AS3600-2018 – Section 11

The design axial strength for per unit length of a braced wall in compression;
$\emptyset Nu = 0.65 (t_w - 1.2e - 2e_a) 0.6 f'_c$

e_a = the additional eccentricity $(Hwe)^2/2500t_w$

This additional eccentricity is to account for defects related to workmanship issues. Dincel being factory manufactured with precise dimensions eliminates the defects related to workmanship issues resulting in imperfections in formwork.

e = is the eccentricity allowance because of the applied load.

- It is commonly adopted that for an edge condition, the $e = t_w/6$
- For cast-in-situ floor continuous over the wall, zero, but not less than $e = t_w/20$

EuroCode BS EN 1992-1-1:2004

Nrd = b × hw × fcd,pl × Ø – for ultimate strength axial load capacity.

b × hw = cross sectional area

fcd,pl = f'_c for plain concrete

Ø = the equation for eccentricity including second order effects and normal effects of creep which is based on the:

- e_i = effective length/400 similar to e_a of AS3600 to account for normal execution deviations associated with conventional formworks.

- e_o = first order eccentricity (Mwall/Nwall) determined by a frame analysis. This is adopted as $t_w/6$ or $t_w/20$ in AS3600-2018 which can be significantly over conservative depending on the load and span configuration. There needs to be a small load and big moment on a wall under consideration to have e = moment/load = $t_w/6$. This is one reason why AS3600-Section 11 is considered as a conservative approximation in comparison to the EuroCode based Dincel Design Tool.

3S – 3.2.2 Unreinforced Concrete Wall/Blade Column Design

The permanent, polymer shell of DINCEL® is used as a formwork only for holding the infill wet concrete; the strength of the wall is provided by the concrete in its cured, final hardened state.

The following design methodology for unreinforced walls as described in the Australian Concrete Code AS3600 applies to walls carrying vertical compressive loads in sway prevented structures. Walls subject to horizontal loadings, including tension by flexural action or walls as part of a non-sway prevented structure will need to be designed accordingly with reinforcement.

The design of concrete walls to Section 11 of AS3600 requires minimum flexural, shrinkage and temperature reinforcement to be placed within the concrete wall. Other recognised building codes throughout the world waiver this requirement and allow concrete walls under certain loading conditions to be designed without reinforcement. Refer reference (3), (4), (5), (7) and (8).

AS3600, Section 11, Clause 11.7.1(a) states "*Walls shall have a reinforcement ratio ... in the vertical direction, of not less than the larger of 0.0025 and the value required for strength unless the design axial compressive force does not exceed the lesser of 0.03 f'c and 2 MPa where the limit may be reduced to 0.0015*". It should be noted that the wall design equation of AS3600 Clause 11.5.3 does not include steel reinforcement for strength calculations i.e. the wall strength is evaluated by the concrete only. This design is conditional to the applied loads acting within the middle third of the wall thickness / bearing area. This loading condition is typical to load-bearing type buildings designed in Australia and is applicable to the design of DINCEL®-WALL.

In the internationally recognised American ACI Building Code (Ref 3), Section 14.5 states that walls can be designed as plain concrete elements with no reinforcement provided the wall load(s) are located within the middle third ($e_{max} \leq t_w / 6$) of the overall wall thickness ' t_w ' in the same manner as stated above for AS3600. In the same manner, both the Canadian (Ref 4) and German Code (Ref 5 and 7) and EuroCode2 (Ref 8) adopt a similar methodology for the design of concrete walls also.

It will be advisable for the designer to read the commentary about unreinforced wall design by the University of New South Wales located in Appendix B (3S – 3.2.2) of this Manual.

The wall construction details as shown on Figure 3, with the exception of Detail A/5 of Figure 3, ensure the same maximum eccentricity requirement are not exceeded i.e. $e_{max} \leq t_w / 6$. As the ACI Building Code, German Building Code and EuroCode allow for the design of concrete walls without vertical reinforcement with the same eccentricity conditions for AS3600, it would be deemed acceptable to adopt the same wall design principal and have no vertical reinforcement.

Shrinkage / Thermal Reinforcement

The minimum reinforcement stated in Section 11.7 of AS3600-2018 apply to a braced wall construction is for crack control due to concrete shrinkage and thermal actions. This minimum reinforcement is deemed necessary so that crack widths that may develop do not affect structural performance and serviceability of the wall in its final state.

When crack control can be provided to within an acceptable structural and serviceability limit**,** the concrete wall can be designed to either the German Code, American Code or EuroCode. In the case of DINCEL®**,** it provides both an ideal curing of the concrete element that helps minimises shrinkage along with crack control inducers.

References (7) and (8) state that concrete walls subject to compressive stresses can be designed as unreinforced concrete walls where crack limitation is guaranteed by improved curing. The general practice of concrete wall construction in the building industry is by removable forms that provides very little concrete curing. DINCEL® on the other hand has a permanent, impervious polymer membrane that provides the ideal curing conditions. Following the pre-requisite of AS3600-2018, the crack widths that develop within the DINCEL®-WALL can be controlled and kept within reasonable limits as a result of the improved curing along with crack controllers. It is therefore important to understand the following explanation on extended concrete curing.

The Effect of Impervious Permanent Membrane by DINCEL® On Concrete Curing

The object of curing is to keep the concrete as nearly as saturated as possible until the original water-filled space in the fresh cement paste has been filled to the desired extent by the products of cement hydration.

The necessity of curing arises from the fact that cement hydration takes place only in water-filled capillaries within the concrete. This is why loss of water by evaporation from these water-filled capillaries must be prevented. In the case of conventionally formed wall construction, due to early formwork removal, active curing stops nearly always long before the maximum possible hydration has taken place because of the above described water evaporation.

If however the water-filled space in fresh concrete is greater than the volume that can be filled by the products of hydration, greater hydration will occur that will lead to both a higher compressive and tensile concrete strength along with lower permeability.

It is a known fact that maximum rate hydration can only proceed under conditions of relatively high saturation - this is why the surrounding air relative humidity of 85% is vital for the late hardening of concrete. This can only be achieved if the concrete is protected against evaporation by an impervious membrane that is provided permanently by DINCEL®**.**

Therefore, DINCEL®**:**

- Retains the water within the ‘wet concrete wall that promotes hydration of cement and increase of concrete strength.

- Delays the effects of drying shrinkage until the concrete is strong enough to resist shrinkage cracking.
- Dincel polymer, unlike the other porous formwork does not absorb water from wet concrete. The absence of this capillary action eliminates the friction between concrete and formwork which is one of the main reasons for formwork uplift during concreting and the occurrence of honey combing.

The reader can refer to Table 9.2 of reference (6) where the crack width of 0.2mm covers the most stringent of general building conditions for exposed concrete members, i.e. unprotected members without applied membrane or polymer membranes. In the case of extreme conditions the designer may use additional reinforcement for specific crack control requirements. The crack control mechanism offered by Dincel is explained as follows:

DINCEL® Crack Controllers

In addition to DINCEL® providing a permanent polymer shell for ideal curing, it also provides in plan, crack controllers at maximum 125mm centres. Using the 200 Dincel profile as an example, the triangular service spaces on each face of the polymer wall are interconnected by a web-joiner with 2 × 82mm diameter holes at 150mm centres for the height of the wall module. This one-fourth reduction in cross-section in the vertical plane is adequate to ensure that the cracks occur at this 'weakened' plane location.

The most extreme design shrinkage strain after 30 years for 100mm thickness (minimum concrete thickness for 200 Dincel at a control joint is 150mm) in accordance with AS-3600-2018 table 3.1.7.2 is 720 microstrain for the worst condition represented by f'c 25 MPa and arid environment. Based upon this value the calculated minimum crack size is as follows;

Crack width = Strain multiplied by the distance between crack inducers.

Maximum shrinkage = $720 \times 10^{-6} \times 125\text{mm} <$ **0.1mm**

The assumptions such as 720 microstrain and ignoring the permanent presence of the polymer skin indicates to us that the maximum crack width within a DINCEL®-WALL will not exceed 0.2mm at the crack inducers.

It is therefore considered that the above calculated crack width in conjunction with having the polymer shell as a permanent curing measure, satisfies the requirements for the design of the walls as unreinforced. ***This is also the basis for design of un-reinforced walls as allowed by Eurocode and the German Din Code 1045-1.***

When considering thermal effects, (i.e. thermal expansion), for Australian conditions it would not be unreasonable to consider a total thermal variation of 40 ° C (i.e., +/- 20 ° C). In accordance with AS3600-2018 (Clause 3.2.4), the coefficient of thermal expansion is 12×10^{-6} / ° C. Based upon the above noted values over a length of 125mm which is the maximum spacing of the crack controllers, the maximum total thermal expansion is as follows;

Thermal expansion = Coefficient of thermal expansion x temperature variation x length

$= 12 \times 10^{-6}$ / ° C x 40 ° C x 125 = **0.06mm**

Considering the worst case of combined shrinkage and thermal expansion i.e. the smallest possible shrinkage with the largest possible thermal expansion using a design shrinkage strain after 30 years for 200mm thickness (maximum concrete thickness for 200 Dincel at any cross section is 195mm), the calculated shrinkage in accordance with AS3600-2018, Table 3.1.7.2 of 440 microstrain for minimum shrinkage f'c = 25 MPa, 200mm thickness for tropical, near coastal and coastal environment follows:

Shrinkage = Strain multiplied by the distance between crack inducers.

$= 440 \times 10^{-6} \times 125\text{mm} = 0.055 =$ **0.06mm**

Therefore, the combined worst case effects for combined shrinkage and thermal expansion is as follows:

Total relative movement = Shrinkage - Expansion = 0.06mm – 0.055mm = **0.005mm**

It can be seen from the above shrinkage and thermal expansion calculations that for the worst possible case of combined shrinkage / thermal effects, there is no resultant expansion and therefore no need for any special expansion joint provisions.

Based on the above, one could interpret the Australian Concrete Code requirement for minimum reinforcement for crack control because of the less than "ideal curing conditions" that are typically associated with conventional formwork concrete wall construction.

DINCEL® by contrast offers ideal curing by providing a permanent polymer shell with regularly spaced crack controllers that hide any cracks developed within the concrete. After all, any crack, irrespective of how small the crack width is unsightly. The aesthetic issues due to the use of common brittle wall materials and their wall finishes are another reason why minimum reinforcement is required. In the case of DINCEL®, the polymer shell has the necessary flexibility to hide any cracks.

DINCEL® supports this type of engineering methodology because the omission of wall reinforcement ensures that the concrete and polymer wall materials of DINCEL® can be re-cycled when the building structure is demolished at the end of its useful life to assist our environment.

3S – 3.2.2.1 Non-Ductile Structural Wall reinforcement requirements to AS3600 – 2018

Australian Engineers designing structural walls as non-ductile walls, which are one-way buckling carrying vertical loads, may follow AS3600 – Section 11.

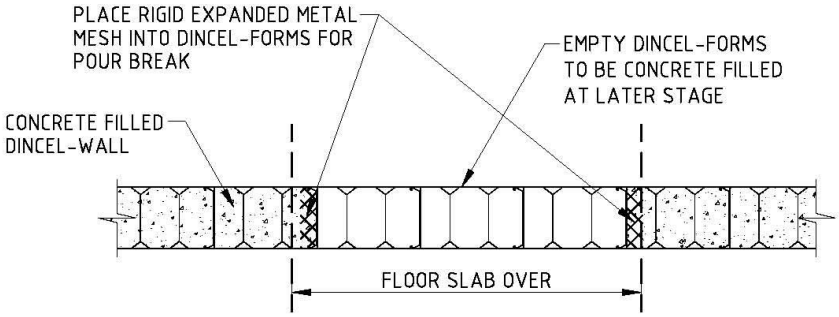
Section 3S – 3.2.2 of this manual explains shrinkage and thermal reinforcement requirements and the function of the Dincel crack inducers/controllers (refer also to Appendix B). Therefore, the horizontal reinforcement requirements of AS3600 – Clause 11.7.2 for crack control do not apply where Dincel walls are used.

In regards to AS3600 – Clause 11.7.1(b), one-way buckling Dincel walls will not require minimum horizontal reinforcement, and this is due to the presence of the Dincel wall crack inducers/controllers being positioned at centres far less than the 2.5 m width limit referenced in Clause 11.7.1(b).

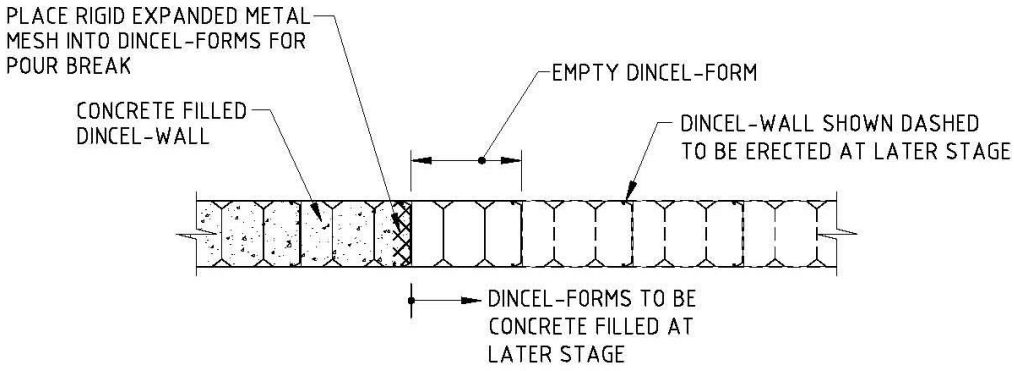
AS3600 – Clause 11.7.1(a), contrary to what EuroCode and ACI 318 allow, requires minimum vertical reinforcement. The minimum required vertical reinforcement ratio is allowed to be reduced from 0.0025 to 0.0015 when the design axial compressive force does not exceed the lesser of 0.03 f'c and 2 MPa. In accordance to the commentary for AS3600 – 2018, the minimum vertical reinforcement is required for robustness purposes.

3S – 3.2.2.2 Control Joints

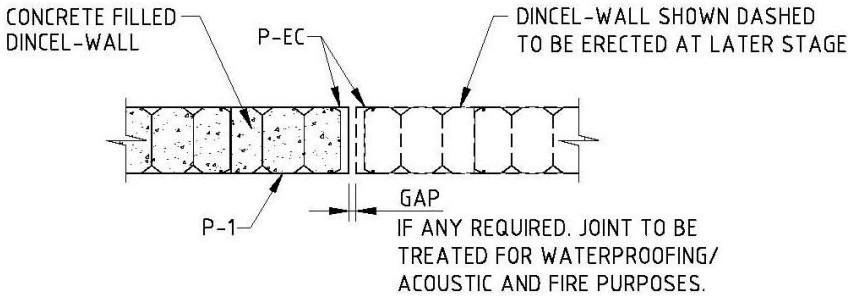
The enclosed environment of DINCEL® polymer keeps the water within the concrete mix during its curing process. This results in much more controlled shrinkage of the concrete filling within the polymer encasement in comparison to conventionally formed walls. Further to permanent polymer membrane shrinkage control, the polymer webs shown in **Figure 4** significantly weaken the concrete cross section hence shrinkage cracking occurs at these controlled locations. Therefore, there is no need to provide additional shrinkage control joints since this provision is provided within every module. Refer to previous **Section 3S - 3.2.2.**
It should however be noted that typical building movement expansion joints within the floor slabs will need to be followed through and incorporated in the DINCEL®-WALL system.



DINCEL-WALL AT FLOOR SLAB POUR-STRIP



HOW TO STOP & START CONCRETING AT DINCEL-WALL



HOW TO STOP & START CONCRETING AT DINCEL-WALL

FIGURE 4

3S – 3.2.3 Polymer Reinforced Design

DINCEL®-WALL and columns are composed of interlocking components that are filled with concrete to create a monolithic wall. The two faces of the components are held together by webs.

The webs of the components are cored at 150mm centres to horizontally align with each other during on-site assembly. The concrete occurring through the cores of the component webs interlocks the concrete fill and the polymer component thus creating composite action between the two materials.

Dincel Construction System Pty Ltd however does not recommend the use of polymer reinforced design in the case of walls subject to fire unless the polymer is covered by a non-combustible and fire rated material. Even though DINCEL® has excellent fire characteristics, the polymer shell will burn if it is subjected to externally applied fire sources (the material does not support its own combustion, it requires an externally on going fire source for itself to burn) resulting in a significant loss of strength provided by the polymer / concrete composite actions, unless the polymer is protected from fire sources.

DINCEL® recommends Engineers to design fire walls (such as sole occupancy corridors, stair walls) and shear walls ignoring the additional capacity provided by the polymer unless it is covered by a non-combustible and fire rated material. However where reserve capacity is required for earthquakes or extreme winds, the contribution of the polymer design may be included as an additional factor of safety given the extreme remoteness of a structure experiencing an earthquake or extreme winds at the same time as a fire. Engineers are to check load combinations provided by codes such as AS1170 which do not show fire plus earthquake, or wind plus fire, or wind plus earthquake plus fire load combinations together.

The tensile forces on the composite structural member for uplift loads (i.e.: wind, earthquake) or horizontal loads (i.e.: shrinkage and thermal effects on concrete) or impact loads or static loads (i.e.: earth pressure or water pressure) creating flexural action within a cross-sectional plane of the member are expected to be significantly resisted by the high tensile capacity of the polymer shell.

This reserve strength, because of the composite action, is demonstrated by various research studies including flexural-beam, earthquake shake table and push over tests in the laboratories of the University of Technology, Sydney. The composite action provides a semi elasto-plastic action by improving the ductility of the concrete element. Further information and test results are available on the Dincel website. Refer "BUILDING SOLUTION FOR EARTHQUAKE PRONE REGIONS" and Video for "DINCEL EARTHQUAKE TESTING".

3S – 3.2.4 Dincel Wall/Blade Column Fire Design

In accordance with Australian Standard AS3600 – Concrete Structures, all structural walls, whether they have a fire separating function or not, need to account for the effect of fire if they are supporting fire rated members such as floors.

AS3600-2018, Clause 5.6.2: A blade column can be designed in accordance with Clause 5.7.2 as a wall provided that the longer cross section dimension of the blade column is 4 times greater than the shorter dimension. Therefore, the minimum dimensions for Dincel blade walls are:

- 275mm Dincel – 270mm (net concrete thickness) x 4 = 1080mm
- 200mm Dincel – 195mm (net concrete thickness) x 4 = 780mm
- 155mm Dincel – 150mm (net concrete thickness) x 4 = 600mm
- 110mm Dincel – 105mm (net concrete thickness) x 4 = 420mm

Dincel Walls have the following fire resisting characteristics in accordance with AS3600 – Concrete Structures Code:

Insulation for Walls/Blade Columns

- 275mm Dincel Wall = 270mm concrete thickness
  > 175mm from AS3600-2018 Table 5.7.1
  = 240 minutes Fire Resistance Period for Insulation

- 200mm Dincel Wall = 195mm concrete thickness
  > 175mm from AS3600-2018 Table 5.7.1
  = 240 minutes Fire Resistance Period for Insulation

- 155mm Dincel Wall = 150mm concrete thickness
  = 150mm from AS3600-2018 Table 5.7.1
  = 180 minutes Fire Resistance Period for Insulation

- 110mm Dincel Wall = 105mm concrete thickness
  > 100mm from AS3600-2018 Table 5.7.1
  = 90 minutes Fire Resistance Period for Insulation

3S – 3.2.5 Structural Adequacy for Walls/Blade Columns

Structural adequacy fire rating is no longer based on the wall thickness alone as referred earlier in the Australian concrete standard versions such as AS1480 and AS3600-2001. The designer is now required to consider slenderness, applied load, load eccentricities and concrete grade under the AS3600-2018 version.

AS3600-2018 allows two methodologies.

(a) Lower Tier Method – AS3600, Table 5.7.2 which is an adaptation from the EuroCode for conservative approximation.

(b) Higher Tier Method – AS3600, Clause 5.3.1(b) by EuroCode BS EN 1992-1-1:2004. This methodology calculates the ultimate and fire design capacities for walls less than 120mm and thicker walls/blade columns as well.

The higher tier EuroCode Zone Method adopted by the Dincel Design Tool is a calculation method to determine the appropriate fire resistance period for a given wall thickness, wall height, concrete grade, concrete spalling values and first order eccentricity which is much more reliable than Table 5.7.2 of AS3600-2018.

The EuroCode's Zone Method is developed in an Excel Spreadsheet format named as the DINCEL DESIGN TOOL which is available for the engineer's use upon request from Dincel Construction System Pty Ltd.

The DINCEL DESIGN TOOL allows ultimate strength and fire limit state strength checks for:

- One or all sides of the wall/blade column subjected to fire.
- All load combinations including first order eccentricity allowance.
- Varying concrete grades.

THE FOLLOWING PAGES ARE EXAMPLES FROM THE DINCEL DESIGN TOOL

DINCEL WALL Capacity Calculation in Accordance with Eurocode - ZONE METHOD - FIRE ON ONE SIDE

CHOOSE DINCEL PROFILE THICKNESS = 155 - PLEASE CLICK ARROW TO CHANGE PROFILE THICKNESS

Floor Clear Height = lw = 2700 mm
Tributary Width = 7000 mm
Wall Concrete Strength fck = 40 Mpa
Normal Concrete Density = 25 kN/m3
Wall Thickness = hw = 150 mm (Note 2)
$\alpha_{cc,pl}$ = 1.0 - Refer Note 4

Loading

Floor	S Thick mm	SDL kPa	Live Load kPa	Floor H	Slab W	Wall W	SDL	Live Load
Roof				-	0.00	-		
50th				2700	0.00			
49th				2700	0.00			
48th				2700	0.00			
47th				2700	0.00			
46th				2700	0.00			
45th				2700	0.00			
44th				2700	0.00			
43rd				2700	0.00			
42nd				2700	0.00			
41st				2700	0.00			
40th				2700	0.00			
39th				2700	0.00			
38th				2700	0.00			
37th				2700	0.00			
36th				2700	0.00			
35th				2700	0.00			
34th				2700	0.00			
33rd				2700	0.00			
32nd				2700	0.00			
31st				2700	0.00			
30th				2700	0.00			
29th				2700	0.00			
28th				2700	0.00			
27th				2700	0.00			
26th				2700	0.00			
25th				2700	0.00			
24th				2700	0.00			
23rd				2700	0.00			
22nd				2700	0.00			
21st				2700	0.00			
20th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
19th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
18th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
17th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
16th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
15th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
14th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
13th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
12th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
11th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
10th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
9th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
8th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
7th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
6th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
5th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
4th	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
3rd	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
2nd	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
1st	150.0	1.0	1.5	2700	26.25	10.13	7.00	10.50
Grd	-	-	-	2700	-	10.13	-	-
				Total	525.00	212.63	140.00	210.00

Total Permanent Load = 877.63 kN/m
Total Variable (i.e. Live Load) = 210.00 kN/m

Ed = 1.5 LL + 1.35 DL = 1499.79 kN/m **Load Reduction Factor = n =** Edf / Ed = 0.66
Edf = 0.5LL + DL = 982.63 kN/m

Wall Capacity **Clause 12.6.5.1**

hw = 150 mm (refer Note 2)
Beta = 0.85 Clause 12.6.5.1 (4) and Table 12.1
lo = Beta x Clear Height = 2295 mm
i = √(I/A) = 43.30 mm

Slenderness = 53.00 < 86 : OK! Clause 12.6.5.1 (5)

Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 150 mm (refer Note 2)
fcd,pl = (acc,pl/1.5) x fck = 26.67 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9) - (refer Note 3)
eo = 0 mm First Order Eccentricity (refer Note 1)

Ø = 0.75 Strength reduction due to eccentricity - Clause 12.6.5.2 (12.11)

Nrd = 2987.16 kN/m Not Exposed to Fire > Ed = 1499.79 kN/m
Ok

Additional Protective Layer Fire Resistance Level (Applied on All Sides) : 0 Minutes **(NOTE 5)**

Blade Wall Ultimate Axial Load under Fire Loading

240 Minutes Fire on One Side + (Additional FRL from Protective Layer on Both Sides) = **240 Minutes FRL**

kc = 0.9 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
az = 64 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 86 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 86 mm
fcd,pl,fi = (acc,pl/1.0) x fck x kc = 36 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.45 Strength reduction due to eccentricity

n x Nrd = 921.24 kN/m 240min Fire < Edf = 982.63 kN/m
Not Ok!!

Blade Wall Ultimate Axial Load under Fire Loading

180 Minutes Fire on One Side + (Additional FRL from Protective Layer on Both Sides) = **180 Minutes FRL**

kc = 0.95 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
az = 56 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 94 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 94 mm
fcd,pl,fi = (acc,pl/1.0) x fck x kc = 38 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.51 Strength reduction due to eccentricity

n x Nrd = 1199.48 kN/m 180min Fire > Edf = 982.63 kN/m
Ok

Blade Wall Ultimate Axial Load under Fire Loading

120 Minutes Fire on One Side + (Additional FRL from Protective Layer on Both Sides) = **120 Minutes FRL**

kc = 0.99 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
az = 45 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 105 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 105 mm
fcd,pl,fi = (acc,pl/1.0) x fck x kc = 39.6 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.58 Strength reduction due to eccentricity

n x Nrd = 1575.33 kN/m 120min Fire > Edf = 982.63 kN/m
Ok

Blade Wall Ultimate Axial Load under Fire Loading

90 Minutes Fire on One Side + (Additional FRL from Protective Layer on Both Sides) = **90 Minutes FRL**

kc = 1 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
az = 37 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 113 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 113 mm
fcd,pl,fi = (acc,pl/1.0) x fck x kc = 40 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.62 Strength reduction due to eccentricity

n x Nrd = 1830.25 kN/m 90min Fire > Edf = 982.63 kN/m
Ok

Blade Wall Ultimate Axial Load under Fire Loading

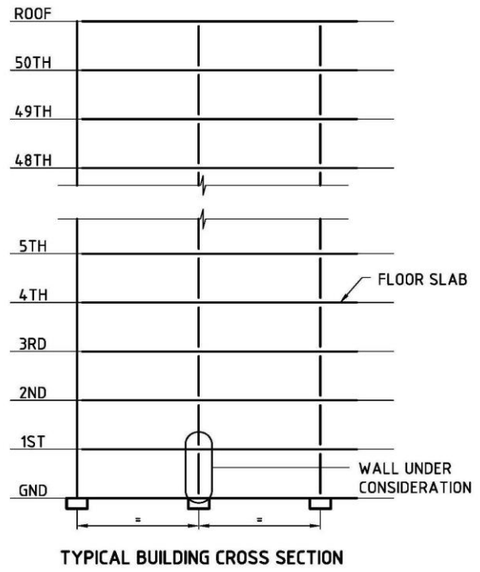
60 Minutes Fire on One Side + (Additional FRL from Protective Layer on Both Sides) = **60 Minutes FRL**

kc = 1 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
az = 27 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 123 mm Effective wall thickness due to fire.

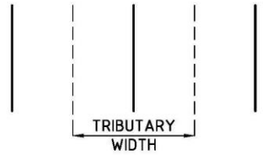
Blade Wall Ultimate Axial Load **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1000 mm
hw = 123 mm
fcd,pl,fi = (acc,pl/1.0) x fck x kc = 40 Mpa (refer Note 4)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.66 Strength reduction due to eccentricity

n x Nrd = 2129.01 kN/m 60min Fire > Edf = 982.63 kN/m
Ok



TYPICAL BUILDING CROSS SECTION



TYPICAL BUILDING PLAN FOR DINCEL WALL DESIGN

Notes:

1 - Moments for walls is zero for equally adjacent spans. Therefore use eo = 0.
Calculate first order eccentricity eo = Moment/Load at the wall being designed for non equal spans or loads. Refer to BS EN 1992-1-1:2004 Clause 12.6.5.2 for eo.
eo is the first order eccentricity including, where relevant, the effects of floors (e.g. possible clamping moments transmitted to the wall from a slab) and horizontal actions.
For further explanation refer to Dincel Engineering Manual.

2 - 110 Dincel Effective Concrete Thickness = 105mm
155 Dincel Effective Concrete Thickness = 150mm
200 Dincel Effective Concrete Thickness = 195mm
275 Dincel Effective Concrete Thickness = 270mm

3 - The eccentricity ei for geometrical imperfection - Clause 5.2(9)
ei = lo / 400 may be adopted to cover normal execution deviations noted in 5.2(4). Dincel is a precise formwork achieving equal or better than Class 1 formwork, as a result ei allowance is not necessary.
However, ei is included for a conservative result.

4 - $f_{cd} = f_{ck} \times \alpha_{cc} / \gamma_c$ - refer to BS EN 1992-1-1:2004 - Clause 3.1.6(1P) - compressive strength
$f_{cd,pl} = (\alpha_{cc,pl} / \gamma_c) \times f_{ck}$ = compressive strength for plain concrete.
$f_{cd,pl,fi} = (\alpha_{cc,pl} / \gamma_{M,fi}) \times f_{ck} \times k_c$ = plain concrete compressive strength for fire purposes.
k_c = compressive strength capacity reduction for fire.
$\alpha_{cc,pl}$ = 0.8 for plain concrete - refer to BS EN 1992-1-1:2004 - Clause 12.3.1(1)
α_{cc} = 1.0 for reinforced concrete - Clause 3.1.6(1P)
γ_c = 1.5 for ultimate limit state - refer to BS EN 1992-1-1:2004 - Clause 2.4.2.4(1) - Table 2.1N
$\gamma_c = \gamma_{M,fi}$ = 1.0 for fire limit state - refer to BS EN 1992-1-2:2004 - Clause 2.3(2P) - Note 1

5 - **FRL increase by addition of Fire Rated Plasterboard**
BS EN 1992-1-2:2004 - Clause 4.7 (1) and Clause 1.5.5 - Eurocode allows for a material or combination of materials to be applied to a structural member for the purpose of increasing its fire resistance.
This is the same as AS3600 - Clause 5.8 (Australian Concrete Structures Code)

1) FRL increase for Structural Adequacy / Integrity / Insulation
16mm Fire Rated Plasterboard = **30** minute increase of FRL
2 × 13mm Fire Rated Plasterboard = **60** minute increase of FRL

Refer to Fire Rated Plasterboard (FRP) manufacturers manual for FRP fixing to concrete.

DINCEL BLADE WALL Capacity Calculation in Accordance with Eurocode - ZONE METHOD - FIRE ON ALL SIDES

CHOOSE DINCEL PROFILE THICKNESS = 275 - **PLEASE CLICK ARROW TO CHANGE PROFILE THICKNESS**

Floor Clear Height = 2700 mm
Wall Concrete Strength fck = 80 Mpa
Normal Concrete Density = 25 kN/m3
α_{cc} = 1.0 - Refer Note 6

Blade Wall Thickness (hw) = 270 mm (Note 2)

Blade Column Length (B) = 1090 Minimum 4 x Thickness (Note 3)
Tributary span Dx = 6700 mm (Note 4)
Tributary span Dy = 6000 mm

Loading

Floor	S Thick mm	SDL kPa	Live Load kPa	Floor H	Slab W	Col SW	SDL	Live Load
Roof				-	0.00	-		
50th				2700	0.00			
49th				2700	0.00			
48th				2700	0.00			
47th				2700	0.00			
46th				2700	0.00			
45th				2700	0.00			
44th				2700	0.00			
43rd				2700	0.00			
42nd				2700	0.00			
41st				2700	0.00			
40th				2700	0.00			
39th				2700	0.00			
38th				2700	0.00			
37th				2700	0.00			
36th				2700	0.00			
35th				2700	0.00			
34th				2700	0.00			
33rd				2700	0.00			
32nd				2700	0.00			
31st				2700	0.00			
30th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
29th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
28th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
27th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
26th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
25th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
24th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
23rd	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
22nd	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
21st	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
20th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
19th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
18th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
17th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
16th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
15th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
14th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
13th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
12th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
11th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
10th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
9th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
8th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
7th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
6th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
5th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
4th	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
3rd	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
2nd	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
1st	150.0	1.0	1.5	2700	150.75	19.87	40.20	60.30
Grd	-	-	-	2700	-	19.87	-	-
				Total	4522.50	615.82	1206.00	1809.00

Total Permanent Load = 6344.32 kN
Total Variable/Live Load = 1809.00 kN

Ed = 1.5 LL + 1.35 DL = 11278.34 kN
Edf = 0.5LL + DL = 7248.82 kN

Load Reduction Factor = n = Edf / Ed = 0.64

Blade Wall Slenderness Check

Clause 12.6.5.1

hw = 270 mm (refer Note 2)
Beta = 0.85 Clause 12.6.5.1 (4) and Table 12.1
lo = Beta x Clear Height = 2295 mm
i = √(I/A) = 77.94 mm
Slenderness = 29.44 < 86 : OK! Clause 12.6.5.1 (5)

Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = 1090 mm Blade Wall Length
hw = 270 mm Blade Wall Width (refer Note 2)
fcd = (αcc/1.5) x fck = 53.33 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9) - (refer Note 5)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.92 Strength reduction due to eccentricity - Clause 12.6.5.2 (12.11)

Nrd = 14464.65 kN Not Exposed to Fire > Ed = 11278.34 kN
Ok

Additional Protective Layer Fire Resistance Level (Applied on All Sides) : 0 Minutes **(NOTE 8)**

Blade Wall Ultimate Axial Load under Fire Loading

240 Minutes Fire on Both Sides + (Additional FRL from Protective Layer on Both Sides) = **240 Minutes Structural Adequacy**

kc = 0.82 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
2 x az = 120 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 150 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = B - 2 x az = 970 mm
hw = 150 mm
fcd,fi = (αcc/1.0) x fck x kc = 65.6 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.75 Strength reduction due to eccentricity

n x Nrd = 4581.29 kN 240min Fire < Edf = 7248.82 kN
Not Ok!!

Blade Wall Ultimate Axial Load under Fire Loading

180 Minutes Fire on Both Sides + (Additional FRL from Protective Layer on Both Sides) = **180 Minutes Structural Adequacy**

kc = 0.91 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
2 x az = 106 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 164 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = B - 2 x az = 984 mm
hw = 164 mm
fcd,fi = (αcc/1.0) x fck x kc = 72.8 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.78 Strength reduction due to eccentricity

n x Nrd = 5892.32 kN 180min Fire < Edf = 7248.82 kN
Not Ok!!

Blade Wall Ultimate Axial Load under Fire Loading

120 Minutes Fire on Both Sides + (Additional FRL from Protective Layer on Both Sides) = **120 Minutes Structural Adequacy**

kc = 0.97 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
2 x az = 88 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 182 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = B - 2 x az = 1002 mm
hw = 182 mm
fcd,fi = (αcc/1.0) x fck x kc = 77.6 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.82 Strength reduction due to eccentricity

n x Nrd = 7421.20 kN 120min Fire > Edf = 7248.82 kN
Ok

Blade Wall Ultimate Axial Load under Fire Loading

90 Minutes Fire on Both Sides + (Additional FRL from Protective Layer on Both Sides) = **90 Minutes Structural Adequacy**

kc = 0.99 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
2 x az = 74 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 196 mm Effective wall thickness due to fire.

Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = B - 2 x az = 1016 mm
hw = 196 mm
fcd,fi = (αcc/1.0) x fck x kc = 79.2 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.84 Strength reduction due to eccentricity

n x Nrd = 8505.46 kN 90min Fire > Edf = 7248.82 kN
Ok

Blade Wall Ultimate Axial Load under Fire Loading

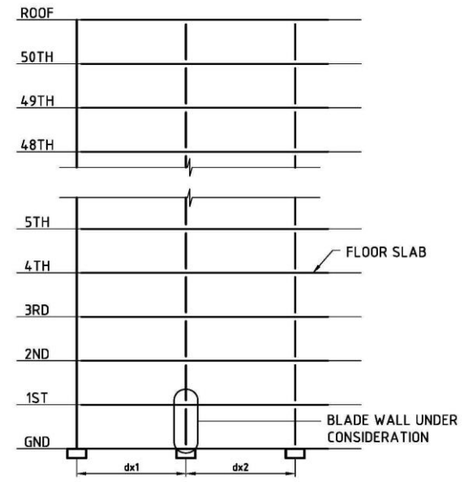
60 Minutes Fire on Both Sides + (Additional FRL from Protective Layer on Both Sides) = **60 Minutes Structural Adequacy**

kc = 1 BS EN 1992-1-2:2004 Annex B2 Figure B5(a)
2 x az = 54 mm BS EN 1992-1-2:2004 Annex B2 Figure B5(c)
hw = 216 mm Effective wall thickness due to fire.

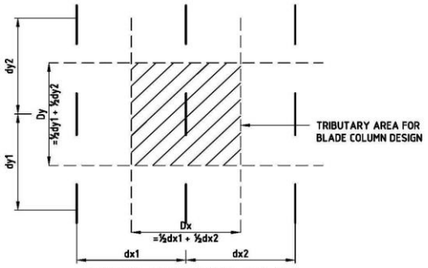
Blade Wall Ultimate Axial Load — **BS EN 1992-1-1:2004 Clause 12.6.5.2**

b = B - 2 x az = 1036 mm
hw = 216 mm
fcd,fi = (αcc/1.0) x fck x kc = 80 Mpa (refer Note 6)
ei = 5.74 mm BS EN 1992-1-1-1:2004 Clause 5.2(9)
eo = 0 mm First Order Eccentricity (refer Note 1)
Ø = 0.87 Strength reduction due to eccentricity

n x Nrd = 9975.02 kN 60min Fire > Edf = 7248.82 kN
Ok



TYPICAL BUILDING CROSS SECTION



TYPICAL BUILDING PLAN FOR DINCEL WALL DESIGN

WHERE dx1 IS NOT EQUAL TO dx2, DETERMINE MOMENT TO BE TAKEN BY THE WALL TO CALCULATE e0=MOMENT/LOAD dy1 AND dy2 MAY NOT HAVE EQUAL VALUES

Notes:

1 - Moments for blade walls is zero for equally adjacent design span Lx.
Therefore use eo = 0.
Calculate first order eccentricity eo = Moment/Load at the wall being designed for non equal spans or loads. Refer to BS EN 1992-1-1:2004 Clause 12.6.5.2 for eo.
eo is the first order eccentricity including, where relevant, the effects of floors (e.g. possible clamping moments transmitted to the wall from a slab) and horizontal actions.
For further explanation refer to Dincel Engineering Manual.

2 - 110 Dincel Effective Concrete Thickness = 105mm
155 Dincel Effective Concrete Thickness = 150mm
200 Dincel Effective Concrete Thickness = 195mm
275 Dincel Effective Concrete Thickness = 270mm

3 - Minimum blade wall dimensions as required by the Codes is 4 x Blade Wall Thickness

4 - Change slab thickness 150mm when tributary span Lx = 7000 is exceeded. The 150mm thick slab is minimum Australian acoustic requirement. Refer Dincel Construction website for certification for 150mm thick slab.

5 - The eccentricity ei for geometrical imperfection - Clause 5.2(9)
ei = lo / 400 may be adopted to cover normal execution deviations noted in 5.2(4). Dincel is a precise formwork achieving equal or better than Class 1 formwork, as a result ei allowance is not necessary.
However, ei is included for a conservative result.

6 - $f_{cd} = f_{ck} \times \alpha_{cc} / \gamma_c$ - refer to BS EN 1992-1-1:2004 - Clause 3.1.6(1P) - compressive strength
$f_{cd,pl} = (\alpha_{cc,pl} / \gamma_c) \times f_{ck}$ = compressive strength for plain concrete.
$f_{cd,pl,fi} = (\alpha_{cc,pl} / \gamma_{M,fi}) \times f_{ck} \times k_c$ = plain concrete compressive strength for fire purposes.
k_c = compressive strength capacity reduction for fire.
$\alpha_{cc,pl}$ = 0.8 for plain concrete - refer to BS EN 1992-1-1:2004 - Clause 12.3.1(1)
α_{cc} = 1.0 for reinforced concrete - Clause 3.1.6(1P)
γ_c = 1.5 for ultimate limit state - refer to BS EN 1992-1-1:2004 - Clause 2.4.2.4(1) - Table 2.1N
$\gamma_c = \gamma_{M,fi}$ = 1.0 for fire limit state - refer to BS EN 1992-1-2:2004 - Clause 2.3(2P) - Note 1

7 - Isolated blade walls to have nominal vertical bars (minimum 0.002 ratio) to accommodate robustness criterion in areas such as basements for possible impact loads from vehicles. If reinforced blade walls are used, load carrying capacities can be increased by a factor of (1 / 0.8). Refer to note 6 for α_{cc}.

8 - **FRL increase by addition of Fire Rated Plasterboard**
BS EN 1992-1-2:2004 - Clause 4.7 (1) and Clause 1.5.5 - Eurocode allows for a material or combination of materials to be applied to a structural member for the purpose of increasing its fire resistance.
This is the same as AS3600 - Clause 5.8 (Australian Concrete Structures Code)

1) FRL increase for Structural Adequacy / ..... / .....
16mm Fire Rated Plasterboard = **30** minute increase of Structural Adequacy
2 × 13mm Fire Rated Plasterboard = **60** minute increase of Structural Adequacy

Note - Integrity / Insulation is not a requirement for isolated blade walls/columns (i.e. not part of a fire wall)

Refer to Fire Rated Plasterboard (FRP) manufacturers manual for FRP fixing to concrete.

3S – 3.3 Dincel Wall Design for Flexural Bending Strength and Deep Beams

The design flexural bending strength per metre length of a wall subjected to out-of-plane horizontal forces is in accordance to Clause 11.1(b)(i). The concrete wall is designed as a slab to section 9 of AS3600. The design flexural strength of a concrete flexural element by first principles (reference 'Reinforced Concrete' 3rd Edition Warner, Rangan and Hall):

$$\phi M_u = \phi A_{st} f_{sy} d \left(1 - 0.6 A_{st} f_{sy} / b d f'_c \right)$$

ϕ : capacity reduction factor = **0.85**

A_{st} : area of tensile reinforcement steel – **mm^2 per metre**

f_{sy} : minimum yield strength of reinforcement - **500 MPa**

D : Net concrete thickness without polymer skin

d : effective depth of reinforcement

b : design width of wall section – **1000 mm**

f 'c : characteristic compressive cylinder strength of concrete at 28 days

The following design tables give ultimate flexural bending capacities for various reinforcement arrangements and concrete grades.

275mm Dincel Concrete Wall Design - AS3600 - 2018
Flexural Bending Capacity

tw = Concrete Thickness = **270mm** (275mm - 2 × 2.5mm external polymer skin thickness)
Φ = 0.85 **fsy =** 500 Mpa

Φ Mu = 0.85 × fsy × Ast × d × (1 - 0.6(p × fsy / f'c))

p = Ast / (bd)
b = 1000 mm

f'c = Characteristic compressive strength - Mpa
Note: Design strength f'c for 25, 32, and 40 Mpa shown only

Φ Mu (kNm per metre strip)

			20mm concrete cover			50mm concrete cover		
Tensile Vertical Reinforcement	Area of reinforcement (mm^2 per metre strip)	f'c	**25**	**32**	**40**	**25**	**32**	**40**
N16 @ 275mm	731		72.46	73.05	73.48	63.14	63.73	64.16
N20 @ 275mm	1,142		109.83	111.29	112.33	95.27	96.73	97.77
2×N20 @ 275mm	2,284		206.36	212.18	216.34	177.24	183.06	187.22

Note: 275 Dincel Wall = 270mm thick concrete for design for out-of-plane flexural bending in the primary direction. The above table gives capacities for example combinations of varying concrete grades, reinforcement bar concrete cover arrangements, and reinforcement bar size and spacing arrangements. Structural Engineers may also consider other concrete grades, concrete cover arrangements, or reinforcement arrangements in their design to AS 3600.

200mm Dincel Concrete Wall Design - AS3600 - 2018
Flexural Bending Capacity

tw = Concrete Thickness = **195mm** (200mm - 2 × 2.5mm external polymer skin thickness)
Φ = 0.85 **fsy =** 500 Mpa

Φ Mu = 0.85 × fsy × Ast × d × (1 - 0.6(p × fsy / f'c))

p = Ast / (bd)
b = 1000 mm

f'c = Characteristic compressive strength - Mpa
Note: Design strength f'c for 25, 32, and 40 Mpa shown only

Φ Mu (kNm per metre strip)

			20mm concrete cover			**50mm concrete cover**		
Tensile Vertical Reinforcement	Area of reinforcement (mm^2 per metre strip)	f'c	**25**	**32**	**40**	**25**	**32**	**40**
N12 @ 333mm	339		23.47	23.60	23.69	19.15	19.28	19.37
N16 @ 333mm	603		40.43	40.84	41.13	32.74	33.15	33.44
N20 @ 333mm	942		60.73	61.72	62.43	48.72	49.71	50.42
N16 @ 166mm	1,206		77.15	78.78	79.93	61.78	63.40	64.56

Note: 200 Dincel Wall = 195mm thick concrete for design for out-of-plane flexural bending in the primary direction. The above table gives capacities for example combinations of varying concrete grades, reinforcement bar concrete cover arrangements, and reinforcement bar size and spacing arrangements. Structural Engineers may also consider other concrete grades, concrete cover arrangements, or reinforcement arrangements in their design to AS 3600.

155mm Dincel Concrete Wall Design - AS3600 - 2018
Flexural Bending Capacity

tw = Concrete Thickness = **150mm** (155mm - 2 × 2.5mm external polymer skin thickness)
Φ = 0.85 **fsy =** 500 Mpa

Φ Mu = 0.85 × fsy × Ast × d × (1 - 0.6(p × fsy / f'c))

p = Ast / (bd)
b = 1000 mm

f'c = Characteristic compressive strength - Mpa
Note: Design strength f'c for 25, 32, and 40 Mpa shown only

Φ Mu (kNm per metre strip)

			20mm concrete cover			50mm concrete cover		
Tensile Vertical Reinforcement	Area of reinforcement (mm^2 per metre strip)	f'c	**25**	**32**	**40**	**25**	**32**	**40**
N12 @ 333mm	339		17.28	17.41	17.50	12.96	13.09	13.18
N16 @ 333mm	603		29.41	29.82	30.11	21.72	22.13	22.42
N20 @ 333mm	942		43.52	44.51	45.21	31.51	32.50	33.20

Note: 155 Dincel Wall = 150mm thick concrete for design for out-of-plane flexural bending in the primary direction. The above table gives capacities for example combinations of varying concrete grades, reinforcement bar concrete cover arrangements, and reinforcement bar size and spacing arrangements. Structural Engineers may also consider other concrete grades, concrete cover arrangements, or reinforcement arrangements in their design to AS 3600.

3S – 3.3.1 Dincel Wall Deep Beam Design

155mm, 200mm and 275mm thick Dincel Walls offer the opportunity to utilise the element as a deep beam. Deep beam action can be achieved by utilising the Dincel Wall alone or by engaging the floor slab at the top and bottom edges of the wall as flanges to create an "I" beam.

Deep beams are advantageous where there is a need to transfer high loads from floor levels above or to utilise the depth of the wall to span large distances.

The principles of deep beam design are in accordance with AS3600 – 2018, Section 12 – Design of Non-Flexural Members, End Zones and Bearing Surfaces.

When designing deep beams utilising strut tie action it is important to consider the following:

- Check bearing stresses at the supports (refer AS3600 – 2018, Clause 12.6).

- Calculate tension tie force in bottom of beam and provide necessary tension zone reinforcement (refer AS3600 – 2018, Clause 2.2.4).

- Calculate compression strut forces – note that typically for an applied UDL at the top of the wall the maximum compression strut stress will occur above the support element bearing surface. The compression strut shall be checked in accordance with AS3600 – 2018, Clause 7.2.3.

- Check vertical shear capacity giving consideration to shear plane at Dincel web element.

3S – 3.4 Dincel Wall In-Plane Horizontal Shear Capacity

The design for in-plane horizontal shear under lateral loads for a braced concrete wall where Dincel Wall is placed on a concrete slab or footing is as follows:

The design for in-plane horizontal shear stress will be reduced if the Dincel Guide Track (PG) is used at the base of Dincel Wall. Dincel does not recommend the use of 'PG' for this reason. Therefore, we design accounting for the full cross section.

The design for in-plane horizontal shear stress strength of the concrete wall per metre length of wall is calculated as follows:

$$\phi\,\tau_u \text{ where -}$$
$$\tau_u = \mu\,(A_{sf}\,f_{sy} / s b_f + g_p / b_f) + k_{co}\,f'_{ct}$$
$$\leq \text{lesser of } (0.2\,f'_c,\ 10\text{MPa})$$

ϕ **:** capacity reduction factor for shear = **0.75**

g_p = permanent distributed load normal to the shear interface per unit length, newtons per millimetre (N/mm). For a conservative result $g_p = 0$ is adopted

μ = coefficient of friction. Refer Table 8.4.3.

k_{co} = cohesion coefficient. Refer Table 8.4.3.

b_f = width of the shear plane (mm)

A_{sf} = area of fully anchored shear reinforcement crossing the interface (mm^2).

f_{sy} = minimum yield strength of reinforcement - **500 MPa**

s = spacing of anchored shear reinforcement crossing interface (mm)

f'_{ct} = characteristic principal tensile strength of the concrete

The following design tables give in-plane horizontal shear capacities for various reinforcement arrangements and concrete grades.

275mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Horizontal Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu (A_{sf} f_{sy} / sb_f + g_p / b_f) + k_{co} f'ct \leq$ lesser of $(0.2 f'c , 10MPa)$ ..... Clause 8.4.3

- design horizontal / longitudinal shear strength per metre length of wall
- model adopted to calculate in-plane shear at the interface of base wall-to-floor.
- it is not possible to produce the tabulated value below if $g_p = 0$ is not adopted.

Designer may adopt $g_p = 0$ for a conservative result or calculate the values below manually for a given g_p value.

bf = 270 ***mm*** ***f'ct $_{f'c}$ = 0.36 f'c$^{1/2}$ at 28 days ....Clause 3.1.1.3***

- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

f'ct $_{50\ MPa}$ = 2.55 ***Mpa***

fsy = 500 Mpa ***d = length of section adopted under horizontal shear - 1000mm***

f'c = characteristic design strength of concrete in MPa as listed below ***ϕ =*** 0.75 ***- for shear***

μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre length of wall at wall base-to-floor interface based on 270mm width × 1000mm length / metre = 270000 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre length of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	182.25
32.0	206.19
40.0	230.53
50.0	257.74

ϕ Vuf (kN per metre length of wall) ..... Reinforced

Refer to Figure 1.0

Vertical Steel: N12 - 275	
25.0	317.39
32.0	341.33
40.0	365.67
50.0	392.88

Refer to Figure 2.0

Vertical Steel: 2N12 - 275	
25.0	452.52
32.0	476.46
40.0	500.80
50.0	528.01

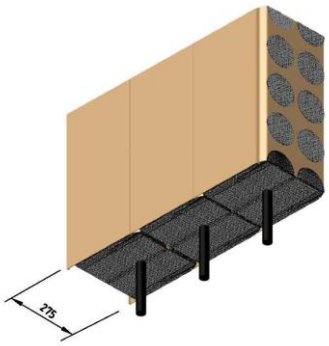


Figure 1.0 - Central Vertical Steel Across Horizontal Shear Face

Vertical Steel: N16 - 275	
25.0	427.95
32.0	451.89
40.0	476.23
50.0	503.44

Vertical Steel: 2N16 - 275	
25.0	673.65
32.0	697.59
40.0	721.93
50.0	749.14

Vertical Steel: N20 - 275	
25.0	563.09
32.0	587.03
40.0	611.37
50.0	638.58

Vertical Steel: 2N20 - 275	
25.0	943.92
32.0	967.86
40.0	992.20
50.0	1019.41

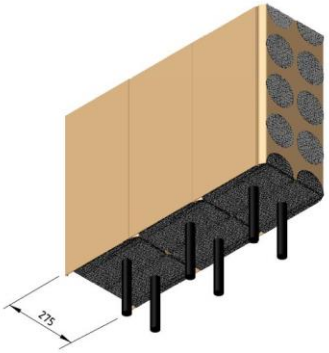


Figure 2.0 - Vertical Steel Each Face Across Horizontal Shear Face

200mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Horizontal Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu\,(A_{sf}\,f_{sy} / sb_f + g_p / b_f) + k_{co}\,f'ct \le$ lesser of $(0.2\,f'c\,,\ 10MPa)$ ..... Clause 8.4.3

- design horizontal / longitudinal shear strength per metre length of wall
- model adopted to calculate in-plane shear at the interface of base wall-to-floor.
- it is not possible to produce the tabulated value below if $g_p = 0$ is not adopted.

Designer may adopt $g_p = 0$ for a conservative result or calculate the values below manually for a given g_p value.

bf = 195 ***mm***

f'ct $_{f'c}$ = 0.36 f'c$^{1/2}$ at 28 days ....Clause 3.1.1.3
- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

f'ct $_{50\ MPa}$ = 2.55 ***Mpa***

fsy = 500 Mpa ***d = length of section adopted under horizontal shear - 1000mm***

f'c = characteristic design strength of concrete in MPa as listed below ***ϕ =*** 0.75 ***- for shear***

μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre length of wall at wall base-to-floor interface based on 195mm width × 1000mm length / metre = 195000 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre length of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	131.63
32.0	148.92
40.0	166.49
50.0	186.15

ϕ Vuf (kN per metre length of wall) ..... Reinforced

Refer to Figure 1.0

Vertical Steel: N12 - 333	
25.0	243.00
32.0	260.29
40.0	277.87
50.0	297.52

Refer to Figure 2.0

Vertical Steel: 2N12 - 333	
25.0	354.38
32.0	371.67
40.0	389.24
50.0	408.90

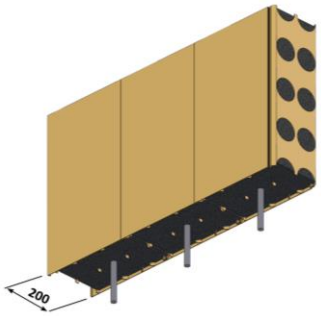


Figure 1.0 - Central Vertical Steel Across Horizontal Shear Face

Vertical Steel: N16 - 333	
25.0	334.13
32.0	351.42
40.0	368.99
50.0	388.65

Vertical Steel: 2N16 - 333	
25.0	536.63
32.0	553.92
40.0	571.49
50.0	591.15

Vertical Steel: N20 - 333	
25.0	445.50
32.0	462.79
40.0	480.37
50.0	500.02

Vertical Steel: 2N20 - 333 (*)	
25.0	731.25
32.0	776.67
40.0	794.24
50.0	813.90

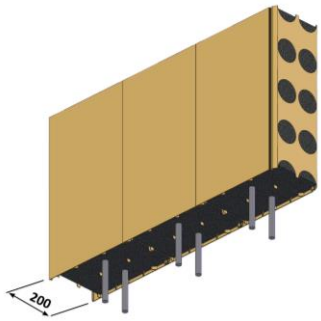


Figure 2.0 - Vertical Steel Each Face Across Horizontal Shear Face

(*) - At least one value in this table is limited by (0.2 f 'c , 10MPa)

155mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Horizontal Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu (A_{sf} f_{sy} / sb_f + g_p / b_f) + k_{co} f'ct \leq$ lesser of (0.2 f 'c , 10MPa) ..... Clause 8.4.3

- design horizontal / longitudinal shear strength per metre length of wall
- model adopted to calculate in-plane shear at the interface of base wall-to-floor.
- it is not possible to produce the tabulated value below if $g_p = 0$ is not adopted.

Designer may adopt $g_p = 0$ for a conservative result or calculate the values below manually for a given g_p value.

bf = 150 ***mm***

f'ct $_{f'c}$ = 0.36 f'c$^{1/2}$ at 28 days ....Clause 3.1.1.3
- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

fsy = 500 **Mpa** ***d =*** ***length of section adopted under horizontal shear - 1000mm***

Asf = ***area of single reinforcement bar - N12 = 110mm^2 ; N16 = 200mm^2; N20 = 310mm^2***

f'c = ***characteristic design strength of concrete in MPa as listed below*** **ϕ =** 0.75 ***- for shear***

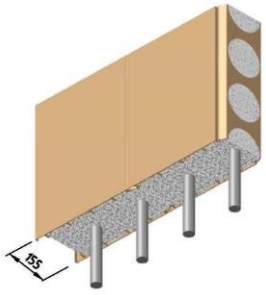
μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre length of wall at wall base-to-floor interface based on 150mm width × 1000mm length / metre = 150000 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre length of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	101.25
32.0	114.55
40.0	128.07



Vertical Steel Across Horizontal Shear Face

ϕ Vuf (kN per metre length of wall) ..... Reinforced

Vertical Steel - N12 - 333		*Vertical Steel - N12 - 166*	
25.0	212.63	25.0	324.00
32.0	225.93	32.0	337.30
40.0	239.45	40.0	350.82

Vertical Steel - N16 - 333		*Vertical Steel - N16 - 166*	
25.0	303.75	25.0	506.25
32.0	317.05	32.0	519.55
40.0	330.57	40.0	533.07

Vertical Steel - N20 - 333		*Vertical Steel - N20 - 166 (*)*	
25.0	415.13	25.0	562.50
32.0	428.43	32.0	720.00
40.0	441.95	40.0	755.82

(*) - At least one value in this table is limited by (0.2 f 'c , 10MPa)

3S – 3.5 Dincel Wall In-Plane Vertical Shear Capacity

The design for in-plane vertical shear **stress** when designing deep beams shall account for the reduced direct vertical shear capacity which occurs at the polymer cross webs and in accordance with the provisions for longitudinal shear strength in beams Clause 8.4 of AS3600 – 2018. The same formula is adopted for the design of in-plane vertical shear **stress** of the concrete wall.

The shear stress capacity per metre height of wall is calculated as follows:

$$\phi\,\tau_u \text{ where -}$$
$$\tau_u = \mu\,(A_{sf}\,f_{sy} / sb_f + g_p / b_f) + k_{co}\,f'_{ct}$$
$$\leq \text{lesser of } (0.2\,f'_c,\ 10\text{MPa})$$

ϕ : capacity reduction factor for shear = **0.75**

g_p = permanent distributed load normal to the shear interface per unit length, newtons per millimetre (N/mm). In case of vertical shear g_p = 0 (e.g. no prestressing force).

μ = coefficient of friction. Refer Table 8.4.3.

k_{co} = cohesion coefficient. Refer Table 8.4.3.

b_f = Equivalent width of the shear plane (mm) accommodating Dincel web holes

A_{sf} = area of fully anchored shear reinforcement crossing the interface (mm^2).

f_{sy} = minimum yield strength of reinforcement - **500 MPa**

s = spacing of anchored shear reinforcement crossing interface (mm)

f'_{ct} = characteristic principal tensile strength of the concrete

The following design tables give in-plane vertical shear capacities for various reinforcement arrangements and concrete grades.

275mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Vertical Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu (A_{sf} f_{sy} / sb_f + g_p / b_f) + k_{co} f'ct \leq$ lesser of $(0.2 f'c , 10MPa)$..... Clause 8.4.3

- design longitudinal shear strength per metre height of wall
- $g_p = 0$ for vertical shear

tw = 94.5 ***mm***

f'ct $_{fc}$ = 0.36 f'c $^{1/2}$ at 28 days ....Clause 3.1.1.3
- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

f'ct $_{50\ MPa}$ = 2.55 ***Mpa***

fsy = 500 **Mpa** ***d =*** ***height of section adopted under longitudinal shear - 1000mm***

f'c = ***characteristic design strength of concrete in Mpa as listed below*** **ϕ =** 0.75 ***- for shear***

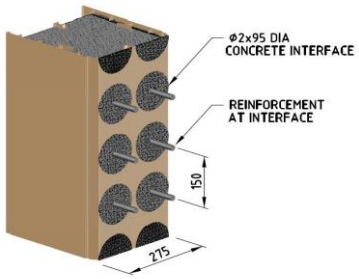
μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre height of wall based on 6.67 x (2 x 95mm) holes at 150mm centres - (b_f d) eqv. / metre = 94510 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre height of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	63.79
32.0	72.17
40.0	80.69
50.0	90.22



Horizontal Steel Across Vertical Shear Face

ϕ Vuf (kN per metre height of wall) ..... Reinforced

	Horizontal Steel: 2N12 - 300	*Horizontal Steel: 2N12 - 150 (*)*
25.0	311.05	354.41
32.0	319.43	453.65
40.0	327.95	567.06
50.0	337.47	585.47

	Horizontal Steel: 2N16 - 300 (*)	*Horizontal Steel: 2N16 - 150 (*)*
25.0	354.41	354.41
32.0	453.65	453.65
40.0	530.24	567.06
50.0	539.77	708.82

	Horizontal Steel: 2N20 - 300 (*)	*Horizontal Steel: 2N20 - 150 (*)*
25.0	354.41	354.41
32.0	453.65	453.65
40.0	567.06	567.06
50.0	708.82	708.82

(*) - At least one value in this table is limited by (0.2 f 'c , 10MPa)

200mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Vertical Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu\,(A_{sf}\,f_{sy} / sb_f + g_p / b_f) + k_{co}\,f'ct \le$ lesser of $(0.2\,f'c\,,\ 10MPa)$..... Clause 8.4.3

- design longitudinal shear strength per metre height of wall
- $g_p = 0$ for vertical shear

tw = 70.4 ***mm***

f'ct $_{f'c}$ = 0.36 f'c$^{1/2}$ at 28 days ....Clause 3.1.1.3

- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

f'ct $_{50\ MPa}$ = 2.55 ***Mpa***

fsy = 500 **Mpa** ***d =*** ***height of section adopted under longitudinal shear - 1000mm***

f'c = ***characteristic design strength of concrete in Mpa as listed below*** ***ϕ =*** 0.75 ***- for shear***

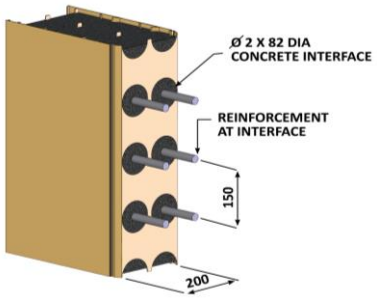
μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre height of wall based on 6.67 x (2 x 82mm) holes at 150mm centres - (b_f d) eqv. / metre = 70413 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre height of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	47.53
32.0	53.77
40.0	60.12
50.0	67.22



Horizontal Steel Across Vertical Shear Face

ϕ Vuf (kN per metre height of wall) ..... Reinforced

Horizontal Steel: 2N12 - 300 (*)		*Horizontal Steel: 2N12 - 150 (*)*	
25.0	264.05	**25.0**	264.05
32.0	301.03	**32.0**	337.98
40.0	307.37	**40.0**	422.48
50.0	314.47	**50.0**	528.10

Horizontal Steel: 2N16 - 300 (*)		*Horizontal Steel: 2N16 - 150 (*)*	
25.0	264.05	**25.0**	264.05
32.0	337.98	**32.0**	337.98
40.0	422.48	**40.0**	422.48
50.0	516.77	**50.0**	528.10

Horizontal Steel: 2N20 - 300 (*)		*Horizontal Steel: 2N20 - 150 (*)*	
25.0	264.05	**25.0**	264.05
32.0	337.98	**32.0**	337.98
40.0	422.48	**40.0**	422.48
50.0	528.10	**50.0**	528.10

(*) - At least one value in this table is limited by (0.2 f 'c , 10MPa)

155mm Dincel Concrete Wall Design - AS3600 - 2018

In-Plane Vertical Shear Capacity for Reinforced and Unreinforced Walls

$\tau_u = \mu (A_{sf} f_{sy} / sb_f + g_p / b_f) + k_{co} f'ct \leq$ lesser of (0.2 f 'c , 10MPa)..... Clause 8.4.3
- design longitudinal shear strength per metre height of wall
- g_p = 0 for vertical shear

bf = 69.2 ***mm***

f'ct $_{fc}$ = 0.36 f'c $^{1/2}$ at 28 days ....Clause 3.1.1.3
- characteristic tensile strength of concrete at 28 days

f'ct $_{25\ MPa}$ = 1.80 ***Mpa*** ***f'ct $_{32\ MPa}$ =*** 2.04 ***Mpa*** ***f'ct $_{40\ MPa}$ =*** 2.28 ***Mpa***

fsy = 500 **Mpa** ***d =*** ***height of section adopted under longitudinal shear - 1000mm***

Asf = ***area of single reinforcement bar - N12 = 110mm ^{2} ; N16 = 200mm ^{2}; N20 = 310mm ^{2}***

f'c = ***characteristic design strength of concrete in Mpa as listed below*** ***ϕ =*** 0.75 ***- for shear***

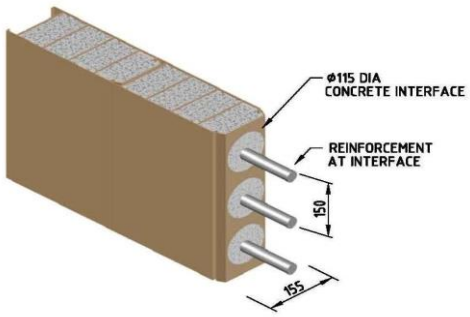
μ = 0.90 **..... Table 8.4.4** **k_{co} =** 0.50 **..... Table 8.4.3**

Equivalent concrete shear interface area per metre height of wall based on 6.67 x 115mm diameter holes at 150mm centres - (b_f d) eqv. / metre = 69245 **mm^2 / metre**

s = **.... reinforcement spacing, see reinforced wall tables below**

ϕ Vuf (kN per metre height of wall) ..... Unreinforced

f'c	*Unreinforced*
25.0	46.74
32.0	52.88
40.0	59.12



Horizontal Steel Across Vertical Shear face

ϕ Vuf (kN per metre height of wall) ..... Reinforced

Horizontal Steel - N12 - 300	
25.0	170.37
32.0	176.51
40.0	182.75

Horizontal Steel - N12 - 150 (*)	
25.0	259.67
32.0	300.50
40.0	306.75

Horizontal Steel - N16 - 300 (*)	
25.0	259.67
32.0	277.66
40.0	283.90

Horizontal Steel - N16 - 150 (*)	
25.0	259.67
32.0	332.38
40.0	415.47

Horizontal Steel - N20 - 300 (*)	
25.0	259.67
32.0	332.38
40.0	407.52

Horizontal Steel - N20 - 150 (*)	
25.0	259.67
32.0	332.38
40.0	415.47

(*) - At least one value in this table is limited by (0.2 f 'c , 10MPa)

3S – 3.6 Earthquake and Ductility Provisions

The basic structural model that is considered for analysis utilising Dincel Wall under earthquake design is outlined in Section 3S – 3.1 – Structural Analysis for Walls of this manual.

This model relies on shear wall elements being sufficiently located throughout the building structure to resist earthquake induced loads.

The earthquake actions to be considered are clearly defined in AS1170, Part 4 – Earthquake Actions in Australia.

The Dincel shear wall elements are designed in accordance with AS3600 – 2018 (Section 14). For simplicity of design purposes, the structural design engineer can assume that all the non-shear walls are non-ductile walls which can be designed in accordance to Section 11 – Design of Walls (Ref: AS3600 - Clause 14.4.4.1), and in accordance with Section 3S – 3.4 and 3.5 of this manual.

All other vertical load carrying elements that do not resist lateral earthquake loads must be designed to satisfy the requirements of AS1170.4, Section 5, Earthquake Design and in particular Clause 5.2.4 – Walls, which require walls to be restrained at all floors and anchored at the roof.

The structural design engineer may choose to design the shear walls in accordance with AS3600 – Section 14.6 for limited ductile shear walls, or AS3600 – Section 14.7 for moderately ductile shear walls.

List of References

Reference 1	AS 3600 – 2018	Australian Standard Concrete Structures
Reference 2	AS 3700 – 2018	Australian Standard Masonry Structures
Reference 3	ACI Standard 318	American Building Code Requirements
Reference 4	CSA Standard A23.3	Canadian Building Code Requirements
Reference 5	DIN 1045-1	German Building Code Requirements
Reference 6	Concrete Structures (1998)., Warner R.F., Rangan B.V., Hall A.S., Faulkes K.A.	
Reference 7	Simplified Non- Linear Design of Unreinforced Walls., Darmstadt, Concrete 18 (2003).,Christian Glock, Carl-Alexander Graubner.	
Reference 8	EuroCode2	

APPENDIX Tables of Axial Load Capacities for Walls

APPENDIX A

Table A1 **275mm Dincel Wall Axial Capacity**

Table A2 **200mm Dincel Wall Axial Capacity**

Table A3 **155mm Dincel Wall Axial Capacity**

Table A4 **110mm Dincel Wall Axial Capacity**

APPENDIX B

Certification by the University of New South Wales.

275mm Dincel Concrete Wall Design - AS3600 - 2018 Table A1

Axial Wall Capacity

- this table provides compressive strength in accordance with AS3600-2018, Section 11 and does not include FRL considerations (i.e AS3600-2018, Section 5). Refer to section 3.2.4 of this manual for FRL requirements.
- for walls subject to in-plane vertical forces only

tw = 270 *mm - concrete thickness* ϕ = 0.65

k = 0.75 *Effective design heights: 0.75 Hw for rotational restraint at end of walls;*

	ϕ Nu (kN / m) e_{min} = 0.05 tw			ϕ Nu (kN / m) e = tw / 6		
Hw \ f'c	25.0	32.0	40.0	25.0	32.0	40.0
1.000	2458.30	3146.62	3933.28	2089.75	2674.88	3343.60
1.219	2450.41	3136.53	3920.66	2081.86	2664.78	3330.98
1.438	2440.97	3124.44	3905.55	2072.42	2652.70	3315.87
1.656	2429.97	3110.37	3887.96	2061.42	2638.62	3298.28
1.875	2417.42	3094.30	3867.87	2048.87	2622.56	3278.19
2.094	2403.31	3076.24	3845.30	2034.76	2604.50	3255.62
2.313	2387.65	3056.19	3820.24	2019.10	2584.45	3230.56
2.531	2370.43	3034.15	3792.69	2001.88	2562.41	3203.01
2.750	2351.66	3010.12	3762.66	1983.11	2538.38	3172.98
2.969	2331.33	2984.10	3730.13	1962.78	2512.36	3140.45
3.188	2309.45	2956.09	3695.12	1940.90	2484.35	3105.44
3.406	2286.01	2926.09	3657.61	1917.46	2454.35	3067.93
3.625	2261.01	2894.10	3617.62	1892.46	2422.36	3027.94
3.844	2234.47	2860.12	3575.15	1865.92	2388.37	2985.47
4.063	2206.36	2824.14	3530.18	1837.81	2352.40	2940.50
4.281	2176.70	2786.18	3482.72	1808.15	2314.43	2893.04
4.500	2145.49	2746.22	3432.78	1776.94	2274.48	2843.10
4.719	2112.72	2704.28	3380.35	1744.17	2232.53	2790.67
4.938	2078.39	2660.34	3325.43	1709.84	2188.60	2735.75
5.156	2042.51	2614.42	3268.02	1673.96	2142.67	2678.34
5.375	2005.08	2566.50	3208.12	1636.53	2094.76	2618.44
5.594	1966.09	2516.59	3145.74	1597.54	2044.85	2556.06
5.813	1925.54	2464.69	3080.87	1556.99	1992.95	2491.19
6.031	1883.44	2410.80	3013.50	1514.89	1939.06	2423.82
6.250	1839.78	2354.92	2943.66	1471.23	1883.18	2353.98
6.469	1794.57	2297.05	2871.32	1426.02	1825.31	2281.64
6.688	1747.81	2237.19	2796.49	1379.26	1765.45	2206.81
6.906	1699.49	2175.34	2719.18	1330.94	1703.60	2129.50
7.125	1649.61	2111.50	2639.37	1281.06	1639.76	2049.69
7.344	1598.18	2045.67	2557.08	1229.63	1573.92	1967.40
7.563	1545.19	1977.84	2472.30	1176.64	1506.10	1882.62
7.781	1490.65	1908.03	2385.04	1122.10	1436.28	1795.36
8.000	1434.55	1836.22	2295.28	1066.00	1364.48	1705.60

ϕNu = 0.65 (tw - 1.2e - 2e$_a$) 0.6 f'c ..... Clause 11.5.3

e = eccentricity of load in accordance to Clause 11.5.4 in mm

e$_a$ = (Hwe)^2 / 2500 tw - Hwe being effective design wall height in mm

f'c = characteristic design strength of concrete - Mpa

tw = concrete thickness in mm

Effective Heights: Both ends of wall restrained against rotation; 0.75 Hw

Hw = actual wall height in metres Hwe = 0.75 Hw

200mm Dincel Concrete Wall Design - AS3600 - 2018 Table A2

Axial Wall Capacity

- this table provides compressive strength in accordance with AS3600-2018, Section 11 and does not include FRL considerations (i.e AS3600-2018, Section 5). Refer to section 3.2.4 of this manual for FRL requirements.
- for walls subject to in-plane vertical forces only

tw = 195 ***mm - wall thickness*** **ϕ =** 0.65

Maximum effective height to thickness (Hwe / tw) ≤ 30

k = 0.75 *Effective design heights: 0.75 Hw for rotational restraint at end of walls;*

	ϕ Nu (kN / m) e_{min} = 0.05 tw			ϕ Nu (kN / m) e = tw / 6		
f'c	**25.0**	**32.0**	**40.0**	**25.0**	**32.0**	**40.0**
Hw (m)						
1.000	1764.68	2258.78	2823.48	1498.50	1918.08	2397.60
1.170	1756.37	2248.16	2810.20	1490.20	1907.46	2384.32
1.340	1746.77	2235.87	2794.84	1480.60	1895.17	2368.96
1.510	1735.87	2221.92	2777.40	1469.70	1881.21	2351.52
1.680	1723.67	2206.30	2757.87	1457.50	1865.59	2331.99
1.850	1710.17	2189.02	2736.27	1443.99	1848.31	2310.39
2.020	1695.37	2170.07	2712.59	1429.19	1829.36	2286.71
2.190	1679.26	2149.46	2686.82	1413.09	1808.75	2260.94
2.360	1661.86	2127.18	2658.97	1395.68	1786.48	2233.09
2.530	1643.15	2103.24	2629.05	1376.98	1762.53	2203.17
2.700	1623.15	2077.63	2597.04	1356.98	1736.93	2171.16
2.870	1601.84	2050.36	2562.95	1335.67	1709.66	2137.07
3.040	1579.24	2021.43	2526.78	1313.06	1680.72	2100.90
3.210	1555.33	1990.83	2488.53	1289.16	1650.12	2062.65
3.380	1530.13	1958.56	2448.20	1263.95	1617.86	2022.32
3.550	1503.62	1924.63	2405.79	1237.44	1583.93	1979.91
3.720	1475.81	1889.04	2361.30	1209.64	1548.33	1935.42
3.890	1446.70	1851.78	2314.72	1180.53	1511.08	1888.84
4.060	1416.29	1812.86	2266.07	1150.12	1472.15	1840.19
4.230	1384.58	1772.27	2215.34	1118.41	1431.56	1789.46
4.400	1351.58	1730.02	2162.52	1085.40	1389.31	1736.64
4.570	1317.26	1686.10	2107.62	1051.09	1345.39	1681.74
4.740	1281.65	1640.52	2050.65	1015.48	1299.81	1624.77
4.910	1244.74	1593.27	1991.59	978.57	1252.57	1565.71
5.080	1206.53	1544.36	1930.45	940.36	1203.66	1504.57
5.250	1167.02	1493.78	1867.23	900.84	1153.08	1441.35
5.420	1126.21	1441.54	1801.93	860.03	1100.84	1376.05
5.590	1084.09	1387.64	1734.55	817.92	1046.93	1308.67
5.760	1040.68	1332.07	1665.09	774.50	991.37	1239.21
5.930	995.96	1274.83	1593.54	729.79	934.13	1167.66
6.100	949.95	1215.94	1519.92	683.78	875.23	1094.04
6.270	902.63	1155.37	1444.22	636.46	814.67	1018.34
6.440	854.02	1093.14	1366.43	587.84	752.44	940.55
6.610	804.10	1029.25	1286.56	537.93	688.55	860.68
6.780	752.89	963.69	1204.62	486.71	622.99	778.74
6.950	700.37	896.47	1120.59	434.19	555.77	694.71
7.120	646.55	827.59	1034.48	380.38	486.88	608.60
7.290	591.43	757.03	946.29	325.26	416.33	520.41
7.460	535.01	684.82	856.02	268.84	344.11	430.14
7.630	477.29	610.94	763.67	211.12	270.23	337.79
7.800	418.28	535.39	669.24	152.10	194.69	243.36

ϕNu = 0.65 (tw - 1.2e - 2e$_a$) 0.6 f'c ……. Clause 11.5.3

e = eccentricity of load in accordance to Clause 11.5.4 in mm

e$_a$ = (Hwe)^2 / 2500 tw - Hwe being effective design wall height in mm

f'c = characteristic design strength on concrete - Mpa

tw = reduced wall thickness in mm - to account for vertical voids
- Clause 5.7.1.b, 5.7.4.3.b and 5.7.4.2.a.

Effective Heights: Both ends of wall restrained against roatation; 0.75 Hw

Hw = actual wall height in metres Hwe = 0.75 Hw

155mm Dincel Concrete Wall Design - AS3600 - 2018 Table A3

Axial Wall Capacity

- this table provides compressive strength in accordance with AS3600-2018, Section 11 and does not include FRL considerations (i.e AS3600-2018, Section 5). Refer to section 3.2.4 of this manual for FRL requirements.
- for walls subject to in-plane vertical forces only

tw = 150 ***mm - concrete thickness*** **ϕ =** 0.65

Maximum effective height to thickness (Hwe / tw) ≤ 30

k = 0.75 *Effective design heights: 0.75 Hw for rotational restraint at end of walls;*

		ϕ Nu (kN / m) e_{min} = 0.05 tw			ϕ Nu (kN / m) e = tw / 6		
	f'c	25.0	32.0	40.0	25.0	32.0	40.0
Hw	1.000	1345.50	1722.24	2152.80	1140.75	1460.16	1825.20
(m)	1.125	1337.73	1712.30	2140.37	1132.98	1450.22	1812.77
	1.250	1329.05	1701.18	2126.48	1124.30	1439.10	1798.88
	1.375	1319.45	1688.90	2111.12	1114.70	1426.82	1783.52
	1.500	1308.94	1675.44	2094.30	1104.19	1413.36	1766.70
	1.625	1297.51	1660.82	2076.02	1092.76	1398.74	1748.42
	1.750	1285.17	1645.02	2056.28	1080.42	1382.94	1728.68
	1.875	1271.92	1628.06	2035.07	1067.17	1365.98	1707.47
	2.000	1257.75	1609.92	2012.40	1053.00	1347.84	1684.80
	2.125	1242.67	1590.62	1988.27	1037.92	1328.54	1660.67
	2.250	1226.67	1570.14	1962.68	1021.92	1308.06	1635.08
	2.375	1209.76	1548.50	1935.62	1005.01	1286.42	1608.02
	2.500	1191.94	1525.68	1907.10	987.19	1263.60	1579.50
	2.625	1173.20	1501.70	1877.12	968.45	1239.62	1549.52
	2.750	1153.55	1476.54	1845.68	948.80	1214.46	1518.08
	2.875	1132.98	1450.22	1812.77	928.23	1188.14	1485.17
	3.000	1111.50	1422.72	1778.40	906.75	1160.64	1450.80
	3.125	1089.11	1394.06	1742.57	884.36	1131.98	1414.97
	3.250	1065.80	1364.22	1705.28	861.05	1102.14	1377.68
	3.375	1041.57	1333.22	1666.52	836.82	1071.14	1338.92
	3.500	1016.44	1301.04	1626.30	811.69	1038.96	1298.70
	3.625	990.39	1267.70	1584.62	785.64	1005.62	1257.02
	3.750	963.42	1233.18	1541.48	758.67	971.10	1213.88
	3.875	935.54	1197.50	1496.87	730.79	935.42	1169.27
	4.000	906.75	1160.64	1450.80	702.00	898.56	1123.20
	4.125	877.04	1122.62	1403.27	672.29	860.54	1075.67
	4.250	846.42	1083.42	1354.28	641.67	821.34	1026.68
	4.375	814.89	1043.06	1303.82	610.14	780.98	976.22
	4.500	782.44	1001.52	1251.90	577.69	739.44	924.30
	4.625	749.07	958.82	1198.52	544.32	696.74	870.92
	4.750	714.80	914.94	1143.68	510.05	652.86	816.08
	4.875	679.61	869.90	1087.37	474.86	607.82	759.77
	5.000	643.50	823.68	1029.60	438.75	561.60	702.00
	5.125	606.48	776.30	970.37	401.73	514.22	642.77
	5.250	568.55	727.74	909.68	363.80	465.66	582.08
	5.375	529.70	678.02	847.52	324.95	415.94	519.92
	5.500	489.94	627.12	783.90	285.19	365.04	456.30
	5.625	449.26	575.06	718.82	244.51	312.98	391.22
	5.750	407.67	521.82	652.28	202.92	259.74	324.68
	5.875	365.17	467.42	584.27	160.42	205.34	256.67
	6.000	321.75	411.84	514.80	117.00	149.76	187.20

ϕNu = 0.65 (tw - 1.2e - 2e$_a$) 0.6 f'c ……. Clause 11.5.3

e = eccentricity of load in accordance to Clause 11.5.4 in mm

e$_a$ = (Hwe)^2 / 2500 tw - Hwe being effective design wall height in mm

f'c = characteristic design strength of concrete - Mpa

tw = concrete thickness in mm

Effective Heights: Both ends of wall restrained against rotation; 0.75 Hw

Hw = actual wall height in metres ***Hwe = 0.75 Hw***

110mm Dincel Concrete Wall Design - AS3600 - 2018 Table A4

Axial Wall Capacity

- this table provides compressive strength in accordance with AS3600-2018, Section 11 and does not include FRL considerations (i.e AS3600-2018, Section 5). Refer to section 3.2.4 of this manual for FRL requirements.
- for walls subject to in-plane vertical forces only

tw = 105 ***mm - wall thickness*** **ϕ =** 0.65

Maximum effective height to thickness (Hwe / tw) / 30

k = 0.75 *Effective design heights: 0.75 Hw for rotational restraint at end of walls;*

	ϕ Nu (kN / m) e_{min} = 0.05 tw			ϕ Nu (kN / m) e = tw / 6		
Hw \ f'c	25.0	32.0	40.0	25.0	32.0	40.0
1.000	920.54	1178.29	1472.86	777.21	994.83	1243.54
1.100	911.76	1167.06	1458.82	768.44	983.60	1229.50
1.200	902.15	1154.76	1443.45	758.83	971.30	1214.13
1.300	891.71	1141.39	1426.73	748.38	957.93	1197.41
1.400	880.43	1126.94	1408.68	737.10	943.49	1179.36
1.500	868.31	1111.43	1389.29	724.98	927.98	1159.97
1.600	855.35	1094.85	1368.57	712.03	911.40	1139.25
1.700	841.56	1077.20	1346.50	698.24	893.75	1117.18
1.800	826.94	1058.48	1323.10	683.61	875.03	1093.78
1.900	811.48	1038.69	1298.37	668.15	855.24	1069.05
2.000	795.18	1017.83	1272.29	651.86	834.38	1042.97
2.100	778.05	995.90	1244.88	634.73	812.45	1015.56
2.200	760.08	972.91	1216.13	616.76	789.45	986.81
2.300	741.28	948.84	1186.05	597.95	765.38	956.73
2.400	721.64	923.70	1154.62	578.31	740.24	925.30
2.500	701.16	897.49	1121.86	557.84	714.03	892.54
2.600	679.85	870.21	1087.77	536.53	686.76	858.45
2.700	657.71	841.87	1052.33	514.38	658.41	823.01
2.800	634.73	812.45	1015.56	491.40	628.99	786.24
2.900	610.91	781.96	977.45	467.58	598.51	748.13
3.000	586.25	750.40	938.01	442.93	566.95	708.69
3.100	560.76	717.78	897.22	417.44	534.32	667.90
3.200	534.44	684.08	855.10	391.11	500.63	625.78
3.300	507.28	649.32	811.65	363.95	465.86	582.33
3.400	479.28	613.48	766.85	335.96	430.03	537.53
3.500	450.45	576.58	720.72	307.12	393.12	491.40
3.600	420.78	538.60	673.25	277.46	355.15	443.93
3.700	390.28	499.56	624.45	246.95	316.10	395.13
3.800	358.94	459.44	574.30	215.61	275.99	344.98
3.900	326.76	418.26	522.82	183.44	234.80	293.50
4.000	293.75	376.00	470.01	150.43	192.55	240.69
4.100	259.91	332.68	415.85	116.58	149.23	186.53
4.200	225.22	288.29	360.36	81.90	104.83	131.04

ϕNu = 0.65 (tw - 1.2e - 2e$_a$) 0.6 f'c …….. Clause 11.5.3

e = eccentricity of load in accordance to Clause 11.5.4 in mm

e$_a$ = (Hwe)^2 / 2500 tw - Hwe being effective design wall height in mm

f'c = characteristic design strength on concrete - Mpa

tw = reduced wall thickness in mm - to account for the pvc parts
- Clause 5.7.2.b, 5.12.3.b and 5.12.2.a.

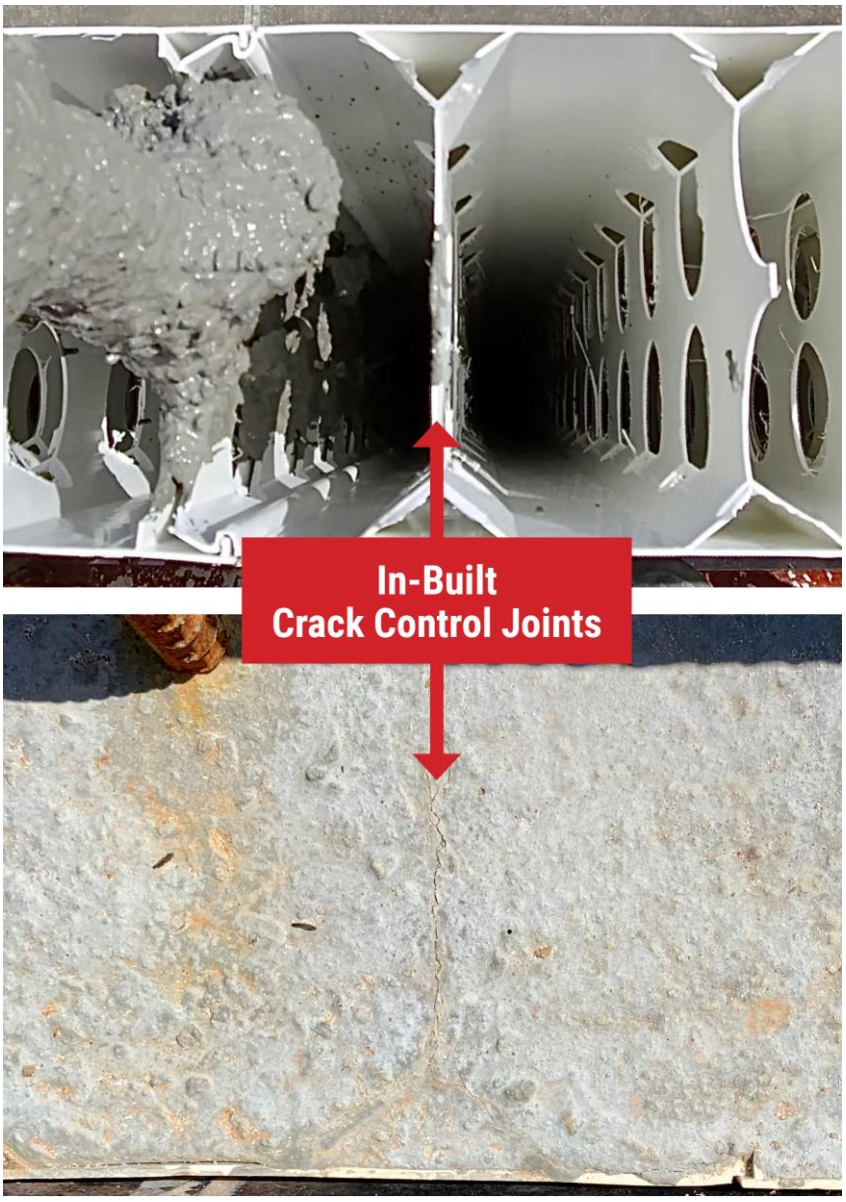
Effective Heights: Both ends of wall restrained against roatation; 0.75 Hw or 0.75 L$_l$

Hw = actual wall height in metres Hwe = 0.75 Hw

APPENDIX B Certification of Dincel Construction System by Professor Mark Bradford, University of New South Wales

WALL JOINTS ?

NOT REQUIRED WITH DINCEL WALLS



EUROCODE, AMERICAN, GERMAN AND OTHER INTERNATIONAL ENGINEERING CODES ALL ALLOW UNREINFORCED PLAIN CONCRETE WALLS PROVIDED CRACK CONTROL MEASURES ARE ADOPTED.

COMMERCIAL-IN-CONFIDENCE
Report prepared on behalf of Unisearch Expert Opinion Services
A business of the University of New South Wales

CERTIFICATION OF STRUCTURAL SYSTEM

for

Dincel Construction System
Your reference: Berkay Dincel

by

Emeritus Professor Mark Bradford
Emeritus Scientia Professor
Founding Director, Centre for Infrastructure Engineering & Safety

Date of Issue: 25 January 2024
Our Reference: UN207742

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APPENDIX A: Curriculum Vitae

SCOPE AND SUMMARY

1 This report outlines a structural appraisal, for the purposes of certification, of the patented concrete formwork system of Dincel Construction System Pty Limited. It was undertaken by Scientia Professor Mark A. Bradford of the Centre for Infrastructure Engineering and Safety at the University of New South Wales on behalf of Unisearch Expert Opinion Services.

2 It presents firstly a letter of certification of the product, and then addresses in more detail the Engineering Manual of the Dincel formwork product.

3 This Revision 6 is required for the following reasons:
The introduction of AS3600 – 2018.
The introduction of 155 mm thick and 275 mm thick Dincel Walls.

4 The report concludes that, on the basis of the methodology used in the assessment, the Dincel formwork system performs satisfactorily when used in conjunction with the Dincel Construction System Manuals, and that the Structural Engineering Design Manual are consistent with design clauses and practice in relevant international structural engineering codes of practice, in particular the widely-used Eurocode EC2 and American ACI 318 Building Code Requirement, and the AS3600-2018 Concrete Structures Code.

LETTER OF CERTIFICATION

15th January 2024

Our Ref: UN207742

Scientia Professor Mark A. Bradford
RESEARCH DIRECTOR
Centre for Infrastructure Engineering and Safety

Dincel Construction System Pty Limited
PO Box 104
St Clair, NSW 2759

Dear Sirs

Dincel Construction System
Structural Engineering Certification

I have conducted an expert review of the Dincel Construction System's Structural Engineering Design Manual (3S Structural Engineering Manual) and its Construction Manual.

Specifically, the *Structural Engineering Design Manual* addresses material properties as well as the structural design of axially loaded walls subjected to vertical loading in sway prevented structures, flexural members that are subjected to bending and shear effects and shear walls. The *Construction Manual* deals with the Dincel Wall components, architectural planning layouts, installation and detailing recommendations.

I am satisfied that the design principles and methodologies in these manuals are appropriate and consistent with the design clauses in the relevant and frequently used international structural engineering codes of practice, such as the ACI 318 and Eurocode EC2 mentioned in the Dincel Construction System's Engineering Manual, and in particular with AS3600 - 2018 Concrete Structures.

I am satisfied that the walls and columns of the Dincel Construction System, when designed in accordance with the *Structural Engineering Design Manual*, will comply with AS3600 - 2018 Concrete Structures. Dincel Walls and Columns will comply with the Deemed-to-Satisfy Provisions B1D4 and Specification 1 (S1C2) from Volume 1, Specification 1 (S1C2) from Volume 2, and Part 2.2.4 from the Housing Provisions of the Building Code of Australia.

Based on the aforementioned evaluation and review, I certify that the use of the Structural Engineering Design Manual complies for the purposes of structural engineering design.

Yours faithfully

Mark Bradford.

MARK A BRADFORD
BSc BE PhD DSc FTSE FIStructE FIEAust Dist.MASCE

REVIEW OF DINCEL CONSTRUCTION SYSTEM – STRUCTURAL ENGINEERING DESIGN MANUAL

5 The *Dincel Construction System Manual* has been reviewed by the consultant and conforms with current design practice for concrete walls and columns.

UNREINFORCED CONCRETE WALL/BLADE COLUMN DESIGN

3S-3.2.2 STRUCTURAL ENGINEERING DESIGN MANUAL

6 AS3600-2018 requires a minimum reinforcement ratio for concrete walls in structural design, as stated in Section 11.7. When the point of application of a load in a rectangular cross-section of depth d is such that its eccentricity *e* (relative to the geometric centroid defined by the depth *d*/2) is such that

$$-\tfrac{1}{3}(d/2) \le e \le \tfrac{1}{3}(d/2),$$

the combined effects of pure compression and bending do not result in tensile forces, and most design codes (such as the Eurocode EC2 and American ACI 318) do not require reinforcement in this case. When the loading lies outside this ‘middle third’, AS3600 - 2018 requires the wall design to include bending effects and the consequent need for reinforcement, as in Section 11.2.

7 The minimum reinforcement requirement in AS3600 - 2018 relates to shrinkage effects, and to the cracking that may occur because of shrinkage deformations. It is also based on thermal requirements in concrete walls where the concrete is exposed directly to fire. These shrinkage deformations are more profound in situations which result in rapid moisture egress during curing, such as hot dry conditions which may be present at the time of removal of conventional formwork. The presence of the impervious membrane in the Dincel system retains moisture during curing, and produces a benign environment for concrete curing, and thereby eliminates the inherent difficulties that such shrinkage cracks which are present in conventional concrete walls.

8 The comparison between Section 11 of AS3600 - 2018, Section 14.5 of ACI 218 and Section 12.6.5 of Eurocode EC2 for wall design that is given in the *Dincel Structural Engineering Design Manual* demonstrates very close agreement between these Standards. The formulation of ACI 318 shown in the *Dincel Structural Engineering Design Manual* is the empirical formula given in Section 14.5 of ACI for unreinforced plain concrete walls. These formulations provide conservative results for the load carrying capacity of walls, because no reinforcement is provided in the formulations, even for the purposes of crack control. The design engineer may therefore choose Section 11.5 of ACI 318 if minimum reinforcement is provided for crack control, which will provide a higher load carrying capacity than the provisions of Section 14.5 of ACI 318 or Section 11 of AS3600 - 2018. Eurocode EC2 offers a similar approach by adopting a capacity reduction factor of 0.8 or 1.0 for unreinforced and reinforced cross-sections.

9 The difference between Sections 14.5 and 11.5 of ACI 318, although being identical formulae, is the load carrying capacity factor of (0.55 × 0.65) / (0.45 × 0.60) = 1.32, so that Section 11.5 with minimum reinforcement provides 32% additional capacity (0.60 and 0.65 are the respective capacity reduction factors of the ACI).

10 The approach adopted in Section 11 of AS3600 - 2018 for wall design, although being the same as that of ACI 318, requires minimum reinforcement for crack control. Therefore, it is clear that the approach of AS3600 - 2018 is more conservative than that of Section 14.5 of ACI 318 since it requires minimum reinforcement, so that the provisions of AS3600 - 2018 should be compared with Section 11.5 of ACI 318 and not with Section 14.5 of the ACI.

11 The crack inducers and the permanent polymer enclosure in the Dincel Wall ensure that the crack control mechanism is established, and **so there is no need for additional minimum vertical and horizontal reinforcing steel requirements for crack control** for a cross-section in compression for a design based on Section 11 of AS3600 - 2018. Because the crack control

mechanism in the Dincel Wall eliminates the need for minimum reinforcing steel, Australian design engineers could use Section 11.5 of ACI 318 with the Dincel Wall product for higher load carrying capacity directly, even without the use of minimum reinforcement since crack control is provided. However, the Dincel Wall capacity conservatively adopts Section 14.5 of ACI 318 and Section 11 of AS3600-2018 without the use of reinforcement.

12 The commentary to Section 14 of ACI 318 recommends the use of Section 11.5 rather than Section 14.5 if the walls of multi-storey buildings or major structures subject to differential settlement, wind, earthquake or other unforeseen loading conditions are required to possess the same ductility and ability to maintain their integrity when cracked. It must be borne in mind by the design engineer that the Dincel Wall recommends the use of unreinforced wall design under the following conditions:

(i) The sway is prevented by the presence of shear walls which are reinforced, both vertical and horizontally, by steel reinforcement.

(ii) The remainder of the concrete walls can be designed as being unreinforced if Dincel Walls are part of the sway-prevented structure, i.e. when shear walls are provided. However, this is subject to the following additional conditions and considerations:

a. Dincel crack inducers provide crack control and hence uncontrolled cracking is not an issue with the structural behaviour.

b. The wall that is already cracked by the presence of the crack initiators must be connected to the floor slab above it with ‘ L ‘ bars, and with dowel bars at the bottom of the wall. These reinforcement provisions establish the joint ductility of a wall which has a pin connection at its bottom and a translational lateral restraint at the top, as shown in the *Dincel Construction System Manual*.

c. Dincel Wall that is used as a non-shear wall without horizontal reinforcement and that is cracked can be designed without vertical reinforcement subject to the following further provisions:

- The loading eccentricity $e < t/6$, i.e. the load acts within the middle-third of the cross-section of thickness t.

- The cross-section in question is in compression (the Dincel Wall therefore does not rely on the tensile capacity of concrete or of the polymer skin); and
- There are no sustained loads present that will develop long-term creep effects (for example, Dincel Wall requires vertical reinforcement usage for lateral soil pressure), and if it is the axial compression that causes creep, the stress level within the cross-section of the wall is relatively low; and
- The wall in question is not subjected to wind or earthquake loading that creates tensile stress on the cross-section, or to earth or liquid retaining loads. As specified clearly in the *Dincel Construction System Manual*, these walls require vertical reinforcement, but do not require horizontal reinforcement for crack control unless horizontal reinforcement is specified by the design engineer for flexural purposes.

13 The designer should also note that the Dincel Wall's polymer encapsulating concrete enhances the ductility of plain concrete, because the benign curing environment that it creates produces a higher tensile capacity and reduced brittleness. The provisions of the Dincel Wall address the concerns of the commentary to Section 14.5 of ACI 318.

14 Clause 11.7.2 of AS3600 - 2018 clearly defines that the specified minimum horizontal reinforcement is for crack control due to shrinkage and temperature effects. However, the same clarification for minimum vertical reinforcement usage in Clause 11.7.1 of AS3600 - 2018 is not defined, and this appears to cause some confusion amongst AS3600 code users. Australian practice does not restrict the use of other well-accepted codes, such as the Eurocode EC2 and American ACI 318, and the provisions for unreinforced plain concrete wall design given in these codes can be adopted by Australian practitioners. In fact, it is widely-known that many provisions in AS3600 were adopted from the Eurocode and American codes.

15 It should be noted that Dincel Construction Systems crack inducers and permanent polymer formwork as designed under the previously described conditions will not require the use of both vertical and horizontal reinforcement. Based on the clarification above provided by ACI 318, it is acceptable for design engineers to ignore the minimum reinforcement requirement as defined in AS3600 - 2018 Clauses 11.7.1 and 11.7.2 when designing a Dincel Construction Systems walling system.

16 ***The Consultant agrees with the engineering methodology presented in Section 3.2.2 – Unreinforced Concrete Wall Design of the Dincel Construction Systems Manual as being technically sound and appropriate.***

NON-DUCTILE STRUCTURAL WALL REINFORCEMENT REQUIREMENTS TO AS3600 - 2018

17 AS3600 – Clause 14.2.10 states that structural walls may be considered as Non-Ductile, Limited Ductile or Moderately Ductile. Clause 14.4.4.1 communicates that non-shear walls subjected to vertical compression forces, buckling in a one-way direction, can be designed as non-ductile walls of a sway prevented structure in accordance with Section 11.

18 Clause 11.5.2 lists certain limitations on the use of Clause 11.5.3. For example, Clause 11.5.2(a) states that structural walls designed using Clause 11.5.3 shall "be limited to a maximum design axial stress of 3 MPa unless vertical and horizontal reinforcement is provided on both wall faces……" However, the formula within Clause 11.5.3 does not refer to any reinforcement usage (i.e. there is no area of steel within this formula). Therefore, the design engineer must look to Clause 11.7 in order to seek the minimum reinforcement required.

19 Section 3.2.2 of the Dincel Construction System Structural Engineering Design Manual explains shrinkage and thermal reinforcement requirements and the function of the Dincel crack inducers/controllers. **Therefore, the**

horizontal reinforcement requirements of AS3600 – Clause 11.7.2 for crack control do not apply when designing a Dincel Wall.

20 Clause 11.7.1(b) states that for a wall designed for one-way buckling, and where there is no restraint against horizontal shrinkage or thermal movements, the use of horizontal reinforcement may be reduced to zero if the wall is less than 2.5 m wide. This represents the case for all Dincel Walls as the crack inducers/controllers are at spacings far less than the 2.5 m width referred to in this clause. **Therefore, the horizontal reinforcement requirements of AS3600 – Clause 11.7.1(b) do not apply when designing a Dincel Wall for one-way buckling.**

21 Clause 11.7.1(a), contrary to what EuroCode and ACI 318 allow, requires minimum vertical reinforcement. The minimum required vertical reinforcement ratio is allowed to be reduced from 0.0025 to 0.0015 when the design axial compressive force does not exceed the lesser of 0.03 f'c and 2 MPa. In accordance to the commentary for AS3600 – 2018, the minimum vertical reinforcement is required for robustness purposes for a lateral force resisting system.

22 **Therefore, even when the design axial stress is greater than 3 MPa, Dincel Wall in a sway prevented structure can be designed as a non-ductile wall with zero horizontal reinforcement and minimum vertical reinforcement to satisfy AS3600 Clauses 11.5.3, 11.7.1(a), 11.7.1(b), and 11.7.2.**

SHEAR WALL THICKNESS

23 The earthquake tests conducted by the University of Technology Sydney, available on the Dincel website, clearly demonstrate that significant lengths of shear walls are required to resist major earthquakes. The length of shear walls commonly available in building lift shafts is very much less than the shear wall length that is normally required for significant earthquake design loads. For this reason, engineers often introduce additional lengths of shear walls.

24 Experienced earthquake design engineers would know that the stiffness of a shear wall is achieved by increasing the length of the wall and not necessarily by increasing its width. The increase of wall thickness from 200 mm to 250 mm or even 350 mm produces an insignificant stiffness increase in comparison to that achieved with an increase in length.

25 There is therefore no need to exceed a 275 mm Dincel Wall thickness for a shear wall, provided that the compressive stresses are resisted by providing an adequate length of Dincel Wall.

WATER/CEMENT RATIO IN CONCRETE MIX DESIGN

26 Fire engineering and fire fighting systems are in a constant state of upgrading, and hence the fire requirements of engineering codes are also being upgraded. The upgrade of the fire section in AS3600 – 2009 was an example of this. The fire section of AS3600 now adopts the principles of Eurocode EC2. The Eurocode EC2 BS EN 1992 – 1 – 2 : 2004 – Clause 4.5.1 recommends 3% moisture content by weight to control the spalling of concrete under cellulosic fire conditions. This correlates approximately to a water/cementitious (water/binder) ratio of 0.4 ~ 0.45 (by weight); however considering the time of construction prior to occupancy of the structure, this ratio should not exceed 0.5 when fire in a structural design is considered. It is known in concrete materials science that when a concrete mix with water/binder ratio exceeding 0.7 (by weight) is used, the moisture content of the concrete will exceed 3% (by weight), even after very long periods of time.

In addition, designers should be aware that a relative humidity greater than 90% alone will provide 3% (by weight) moisture content. As a result, a concrete mix having water/cement ratio greater than 0.5 (by weight) will exceed the limit given by Eurocode EC2, unless the concrete is covered by an impervious membrane for ambient moisture conditions of the surrounding environment not to be absorbed by the porous concrete. It is therefore recommended that design engineers should specify the water/cement ratio in addition to 28 days concrete compressive strength normally specified to comply with AS3600 or Eurocode EC2.

27 One way to ensure the quality of supplied concrete for critical members such as walls is to specify Self Compacting Concrete (SCC), which will guarantee that the concrete use will have water/binder ratio ≤ 0.5 (by weight).

USE OF EUROCODE EC2

28 The major revision for AS3600 – 2009 was for Section 5, Fire engineering design and definition of column in Clause 5.6.2. The previous codes only considered wall thickness for structural fire adequacy purposes.
AS3600 – 2018, Clause 5.7.2 for structural adequacy under fire conditions is based on the lower tier method of Eurocode EC2 which currently requires an engineer to consider the applied loads and slenderness in addition to wall thickness. This very approximate method of Table 5.7.2 of AS3600 may not be considered appropriate; in fact, not applicable for, particularly lightly loaded members with high slenderness and increased load eccentricities.
AS3600 – 2018, Clause 5.3 offers Eurocode's EC2 more refined solutions for higher tier design methodology.

29 A higher tier design offered in Eurocode EC2 consists of the Zone Method which is adopted by the Dincel Design Tool (refer Dincel Structural Engineering Design Manual, Clauses 3S-3.2.1.3 and 3S-3.2.5). For structural adequacy purposes this higher tier method requires consideration of applied loads, slenderness ratio, applied load eccentricity for first order and allowance for geometrical imperfections and concrete's compressive strength.

30 Any structure under fire loads shall be more critical than when subjected to axial gravity loads only. It is therefore acceptable for an Australian engineer to adopt the use of Eurocode EC2 in lieu of AS3600 – 2018, Section 11 strength design without fire as well. I have reviewed the Dincel Structural Engineering Manual which includes the Dincel Design Tool incorporating the use of Eurocode EC2 for walls and blade columns.

DINCEL WALL COMPLIANCE WITH THE "DEEMED TO SATISFY" DEFINITION OF THE BCA

31 The structural engineering certification issued at the beginning of this report states that Dincel Wall can be designed to AS3600 and complies with the BCA.

32 For the benefit of non-technical or less experienced engineers, Dincel Construction System has requested a further explanation of whether the Dincel Wall complies with the "deemed to satisfy" definition of the Building Code of Australia (BCA).

33 This explanation is required so that the design engineer understands that Dincel Wall is no different from conventional concrete walls defined in structural engineering codes.

34 The Building Code of Australia's (BCA) approval methods for concrete walls are as follows:

(i) Compliance with the "deemed to satisfy" definition of the BCA by designing to AS 3600, or

(ii) A performance solution being carried out. For the purposes of structural engineering, the performance solution must demonstrate that it is at least the equivalent of the "deemed to satisfy" provisions. This therefore requires a performance solution to demonstrate by the method of testing as shown in AS3600 – 2018, Appendix B, i.e. the test load shall simulate 100% of the design loads.

35 The only difference between a Dincel Wall/blade column and a conventional wall is the presence of a permanent polymer membrane. The following comments would therefore be relevant:

- Dincel's polymer formwork has been tested, with a CodeMark Certificate of Conformity being issued for fire compliance with the relevant BCA provisions.
- The Dincel Structural Engineering Design Manual, Clause 3S-3.2.3, Polymer Reinforced Design clearly states that the permanent polymer formwork is not included in any strength design or for fire design purposes. If the Dincel polymer is stripped, the remaining component is concrete with or without reinforcement. Therefore, the designer can ignore the presence of the Dincel permanent polymer for axial, flexural or shear strength purposes; however the waterproofing quality verified by the CSIRO and AS3735 tests can be utilised to assist the durability Section 4 of AS3600 – 2018.
- The prototypes tested throughout the evolution of structural concrete to develop the reinforced or unreinforced concrete science of today consisted only of either plain concrete, or reinforced concrete consisting of steel bars. If steel reinforcement bars are used, they must have adequate concrete cover to suit the exposure conditions for durability. AS3600, Clause 4.10.3 requires prescribed concrete cover to any steel reinforcement or metallic embedded component built into the concrete for durability purposes, since AS3600 does not consider membrane systems or even galvanising to avoid its concrete cover requirement. The steel bars or metallic components will always have a minimum of 20 mm of concrete cover, even though the Dincel polymer and joints offer a waterproof membrane at each face of the wall. Polymers, unlike metals, do not require any concrete cover for corrosion protection. Therefore, there is no issue as to why Dincel Wall cannot be treated the same as the prototype forms on the basis of conventional concrete walls.
- During a fire event, the additional concrete spalling because of the expansion of steel bars/embedded metallic components without adequate concrete cover in a concrete wall/blade column, particularly under

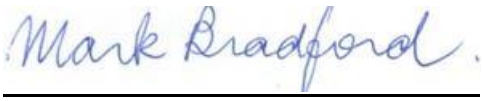
compression, can lead to premature structural slenderness failure depending on the applied load level. As a result, AS3600, Section 5 requires a minimum concrete cover to control concrete spalling under fire conditions. Therefore, the designer should ensure that the concrete cover to the steel bars/metallic components is in accordance with AS3600 – 2018, Section 5.

36 As a result and as confirmed in this report, Dincel Wall can be engineered to comply with AS3600, ACI and Eurocode EC2. The prototypes which formed the basis of engineering codes such as ACI and Eurocode EC2 are identical with Dincel Wall with the exception of the permanent polymer formwork. Design engineers can therefore consider the presence of the waterproof Dincel polymer as permanent formwork which improves the curing of the concrete and eliminates the durability concern of plain or reinforced concrete, offering longer life sustainable structures.

37 A design that is compliant with AS3600 means that it is in compliance with the “deemed to satisfy” definition of the BCA. It is therefore clear that Dincel Wall with or without reinforcement can be engineered to comply with ACI or Eurocode or AS3600, and hence complies with the “deemed to satisfy” definition of the BCA.

CONCLUSION

38 I agree with the engineering methodology presented in the Dincel Structural Engineering Manual as being technically sound and appropriate for use by Australian engineers.



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APPENDIX A

Curriculum Vitae

Unisearch Expert Opinion Services

CURRICULUM VITAE	Professor Mark BRADFORD

Qualifications

- Bachelor of Science (BSc), University of Sydney, 1977
- Bachelor of Engineering (BE) (Hons 1), University of Sydney, 1979
- Doctor of Philosophy (PhD), University of Sydney, 1984
- Doctor of Science (DSc), University of New South Wales, 1988

Present Position

Scientia Professor and Professor of Civil Engineering
Centre for Infrastructure Engineering and Safety (CIES)
School of Civil and Environmental Engineering,
University of New South Wales

Principal
Advanced Structural Consulting Pty Limited, Sydney

Areas of Expertise/ Special Interests

- Structural Engineering
- Steel
- Concrete and Composite Structures
- Engineering Mechanics
- Numerical Modelling

Affiliations

- Fellow, Australian Academy of Technological Sciences and Engineering (FTSE)
- Distinguished Member, American Society of Civil Engineers
- Fellow, Institution of Engineers, Australia
- Fellow, Institution of Structural Engineers (UK)
- Chartered Professional Engineer (CPEng), Australia
- Chartered Engineer (CE), UK
- Professional Engineer (PE), USA

Employment Experience

2016 - Current	**Expert Assessor** European Research Council, Brussels
2000 - Current	**Principal** Advanced Structural Consulting Pty limited, Sydney
2018 - 2020	**Distinguished Professor** Guangzhou University, China
2010 - 2015	**Australian Laureate Fellow** The University of New South Wales
2010 - 2012	**College of Experts** Australian Research Council
2010	**Dean, Faculty of Engineering and Information Technology** University of Technology, Sydney
2009	**Visiting Professor** The University of Hong Kong
2009	**Visiting Professor** City University of Hong Kong
2008	**Visiting Professor** Yonsei University Korea
2006	**Visiting Professor** The University of Toronto, Canada
2006 - 2010	**Foundation Director** CIES, The University of New South Wales
2004 - 2009	**Federation Fellow** The University of New South Wales
2002 - 2004	**Australian Professorial Fellow** The University of New South Wales
2001 - 2003	**Expert Advisory Committee** Australian Research Council

1999 - 2010	**Professor of Civil Engineering** The University of New South Wales
1996	**Visiting Professor** The University of Strathclyde, UK
1994	**Visiting Professor** The University of Edinburgh, UK
1992 - 1998	**Associate Professor in Civil Engineering** The University of New South Wales
1990	**Visiting Associate Professor** University of Minnesota, USA
1986 - 1992	**Lecturer / Senior Lecturer in Civil Engineering** The University of New South Wales
1985	**Postdoctoral Fellow** University of Warwick, UK
1984	**Postdoctoral Fellow** University of Sydney
1983	**Engineer** Wholohan Grill and Partners, Sydney

Editorial & Advisory Boards

- International Journal for Numerical Methods in Engineering
- Structures (Associate Editor)
- Engineering Structures
- Computers and Structures
- Thin-Walled Structures
- Progress in Structural Engineering and Mechanics
- International Journal of Structural Stability and Dynamics
- Advances in Structural Engineering
- Interaction and Multiscale Mechanics
- Steel and Composite Structures
- Advanced Steel Construction
- Electronic Journal of Structural Engineering

Standards Australia Committees

- BD/1 Steel Structures
- BD/23 Structural Steel (immediate past Chair)
- BD/32 Composite Construction
- BD/92 Evaluation of Structures

Awards and Fellowships

- NSW Premier's Award for Excellence in Engineering and Information and
- Communications Technologies (2015)
- Distinguished Member, American Society of Civil Engineers (2013)
- Engineers Australia's Structural College Eminent Speaker (2012-2013)
- Connell Gold Medal of Engineers Australia (2012)
- Shortridge Hardesty Award of the ASCE (2011)
- Australian Research Council's College of Experts (2010-2012)
- Australian Laureate Fellowship (2010-2014)
- Scientia Professorship (renewed) (2011-2016)
- Australia/Korea Visiting Fellowship (2008)
- Fellowship of the Australian Academy of Technological Sciences and Engineering (2007)
- Faculty of Engineering Research Excellence Award (2006)
- Australian Academy of Science Visiting Fellowship to North America (2006)
- Federation Fellowship (2004-2009)
- Scientia Professorship (2004-2010)
- Australian Professorial Fellowship (2002-2006)
- Australian Research Council's Expert Advisory Committee (2001-2003)
- Doctor of Science (1998)
- Royal Society Visiting Fellowship (1996)
- British Council Visiting Fellowship (1985)

University Committees (UTS)

- Vice-Chancellor's Committee (2010)
- Academic Board (2010)
- Faculty Board (Chair) (2010)
- FEIT Executive Committee (Chair) (2010)
- Industry Advisory Network (2010)

University Committees (UNSW)

- Council of The University of New South Wales (2006-2008)
- Vice-Chancellor's Postdoctoral Committee (1995-1999; 2004-2006)
- Qualifications Committee for Promotion to Professor, UNSW (2001-2003)
- Scientia Professorial Selection Committee (2002)
- Academic Board of The University of New South Wales (1992-1996)

Faculty and School Committees (UNSW)

- School of Civil and Environmental Engineering Research Management
- Committee (1996-2019)
- School of Civil and Environmental Engineering Senior Management Committee (1998-2010)
- Faculty of Engineering Research Committee (2001)
- Faculty Promotions Committee to Associate Professor (1995-1997)
- Faculty of Engineering Executive Committee (1992-1999)
- School Curriculum Review Committee (1991)
- Faculty of Engineering Higher Degree Committee (1988-1992)
- School Postgraduate Committee (1989-1992)
- Third Year Management Committee (1987-1990)
- Fourth Year Management Committee (1992-1995)

Professional Committees

- Australian Academy of Technological Sciences and Engineering, Membership Committee (2017-2019)
- Immediate Past President, ASCE Australia Section (2017-2018)
- Australian Academy of Science, Chairman, National Committee for Mechanical and Engineering Sciences (2016-date)
- President, ASCE Australia Section (2015-2016)
- Australian Academy of Science, Deputy Chairman, National Committee for Mechanical and Engineering Sciences (2016-date)
- Universities Australia-Elsevier Scopus Young Researcher Panel (2010-2014)
- Chairman, Composite Construction in Steel and Concrete VII (2013)
- Co-Chairman, International Conf. on Structures: Steel, Concrete, Composite and Aluminium, Sydney (2003)
- Vice-President, Association for Int. Cooperation and Research in Steel-Concrete Composite Structures (2000-2003)
- Chairman, 18th Australasian Conf. on Mechanics of Structures and Materials, Sydney (1999)
- Secretary, Int. Conf. on Structural Stability and Design, Sydney (1995)
- Board of Directors, The Univ. of New South Wales Club Ltd. (1993-1995)
- Chair of TAFE Migrant Education in Eng. Accreditation Committee (1992)

Publications

Books (Authored and Edited): 19

Chapters in Books: 21

Refereed Journals: ~ 460

Conferences: ~ 290

Recent Non-Confidential Consultancies

- Conzpec Civil Pty Ltd v Taylor Constructions Group Pty Ltd (2022)
  McCabe Curwood
- Museum of Contemporary Art ats Marilee Callister (2021)
  Barry Nilsson Lawyers
- Resolution Rigging Services Pty Ltd & anor ats Hamish Lawson (2021)
  McCabe Curwood
- Warren Sydney King v Insurance Australia Ltd (2021)
  McMahon Lawyers
- AddBuild Master Builders Pty Ltd ats Lucy Walker (2015)
  Curwood Lawyers
- Mohammed Ali Mourad e/b Wollongong GPT (2015)
  Kells
- Dispute between Dematic Pty Ltd and Nedcon Magazijninrichting PV (2014)
  TressCox – before the Hon. G.E. Fitzgerald AC QC
- R&D PanelForm Pty Ltd & ors -ats- Gillespies Crane Nominees Pty Ltd (2014)
  Yates Beaggi Lawyers
- Sweetie Developments Pty Ltd v RHB Stage 6 Lessor Pty Ltd and ors (2014)
  Holman Webb
- CSR Building Products – AFS LogicWall® System. Corrosion Durability Review (April 2014)
- Dincel & Associates Pty Limited. Certification of a Structural System (2014)
- John Bowman v Dana Steel Pty Ltd and ors (2012)
  RMB Compensation
- The Owners SP 61288 v Brookfield Australia Investments Ltd and ors (2012)
  Grange Lawyers