DINCEL STRUCTURAL WALLING

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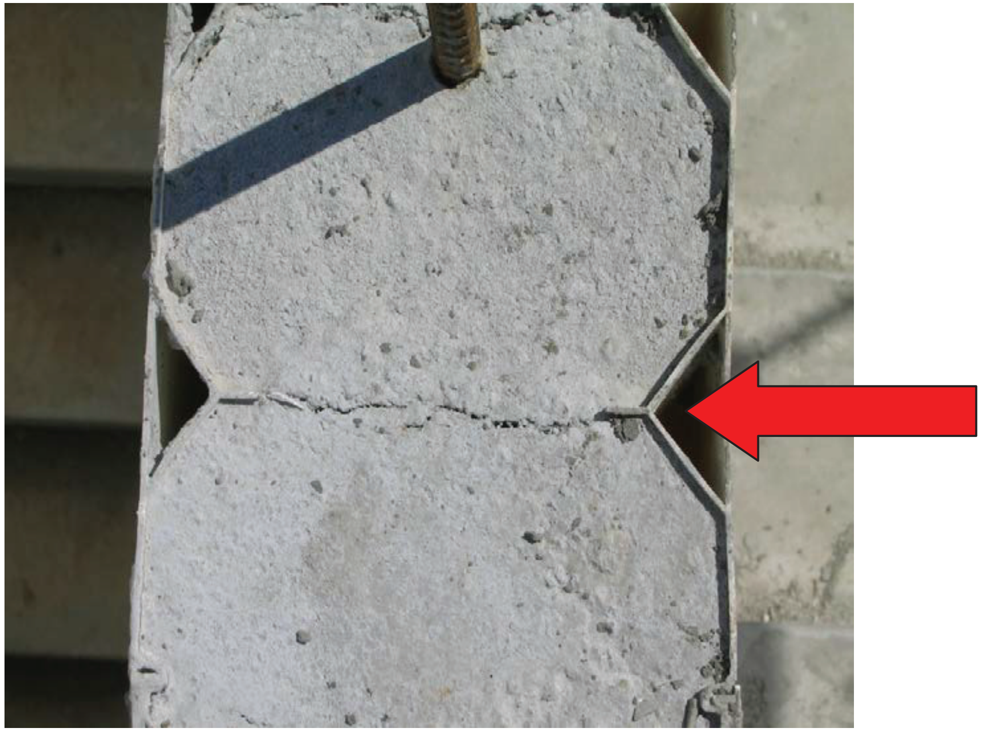
STRUCTURAL ENGINEERING DESIGN CERTIFICATION

WALL JOINTS?

NOT REQUIRED WITH DINCEL-WALLS



CRACK CONTROL JOINTS AT 125MM CENTRES

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

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COMMERCIAL-IN-CONFIDENCE
Supplementary report prepared on behalf of Expert Opinion Services
A business of UNSW Global Pty Limited

CERTIFICATION OF STRUCTURAL SYSTEM

for

Dincel and Associates Pty Ltd

by

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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 Professor Mark A. Bradford of the Centre for Infrastructure Engineering and Safety at the University of New South Wales on behalf of UNSW Global Pty Limited.
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. The Dincel Manuals were originally reviewed by the writer in 2005. The previous revision was required because of the introduction of AS3600 – 2009. A major revision of AS3600 was for fire engineering design. This section of AS3600 has adopted the lower tier approach of Eurocode EC2. Dincel Construction System has developed the Dincel Design Tool in compliance with Eurocode EC2, analysing walls and blade columns with or without fire considerations. This Revision 5 is required for the following reasons:
    - Introduction of 200 mm thick corner profile referred to as 200P-3.
    - Reference to AS3700 – 2011 which supersedes AS3700 – 2001.
    - Removal of reference to designing Dincel® to AS3700 – 2001.
    - Equation for calculating the tensile strength of concrete modified to $0{\cdot}36f'_c{}^{1/2}$.
    - Limitation of shear capacity as being the lesser of ($0{\cdot}2f'_c$, 10 MPa).
    - Pages 47 to 52 now provide compressive strength tables in accordance with Section 11 of AS3600 – 2009.

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 Technical 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 AS3600-2009 Concrete Structures Code.

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23rd July 2014

Our Ref: J084829

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PROFESSOR OF CIVIL ENGINEERING
AUSTRALIAN LAUREATE FELLOW
SCIENTIA PROFESSOR

Dear Sirs

Dincel Construction System
Structural Engineering Certification

I have conducted an expert review of the Dincel Construction System's Compliance Manual (Building Code of Australia Compliance Assessment and Certifications as appears in the Dincel website), its Structural Engineering Design Manual (3S Structural Engineering Manual) and its Construction Manual for Designers and Builders.

Specifically, the *Compliance Manual* deals with principles regarding compliance with the Building Code of Australia, while 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 for Designers and Builders* deals with the Dincel Wall components, architectural planning layouts, installation and detailing recommendations.

I note the introduction of a 200mm thick corner profile referred to as 200P-3. I note the reference to AS3700-2011, which supersedes AS3700-2001, and of the removal of designing DINCEL® to AS3700-2011. I note that the equation for calculating the tensile strength of concrete has been modified to 0.36f'c ½. I note the limitation on shear capacity as being the lesser of (0.2f'c, 10 MPa). Finally, I note pages 47 to 52 now provide compressive strength tables in accordance with Section 11 of AS3600-2009, since the limiting values in Clause 5.7.4 (d) (i) in AS3600-2001 have been removed in AS3600-2011.

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 AS 3600-2009 Concrete Structures.

I am satisfied that the walls and blade columns of the Dincel Construction System, when designed in accordance with the *Structural Engineering Design Manual*, will satisfy the Building Code of Australia Volume 1 Specification A2.3 (2) (d) (ii) "deemed to satisfy" definition, being compliant with AS 3600-2009 Concrete Structures.

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

Yours faithfully

Mark Bradford.

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

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REVIEW OF DINCEL CONSTRUCTION SYSTEM – STRUCTURAL ENGINEERINGDESIGN MANUAL

5. The *Dincel Construction System Manual* has been reviewed by the consultant and confirms with current design practice for concrete walls and columns. Because the cross-section of the product is a slight departure from being rectangular (for which many of the design clauses in international codes of practice are formulated, either implicitly or explicitly), a few modifications are needed, and these are indicated within the *Dincel Construction System Manual*. Specifically, the two points considered in the following discussion arise either directly from the nature of the Dincel profile, or from concerns by way of clarification of the use of one or two points within concrete codes for the Dincel product.

UNREINFORCED CONCRETE WALL/BLADE COLUMN DESIGN

3S-3.2.2 Structural Engineering Design Manual

6. AS3600-2009 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, American ACI 318 and British BS 8110.1) do not require reinforcement in this case. When the loading lies outside this 'middle third', AS3600-2009 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 AS3600-2009 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.

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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 AS3600-2009, Section 22.6 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 22.6 of ACI for unreinforced plain concrete walls. There are equivalents to this formulation in the British Standard (BS 8110) and the Canadian Standard (CSA-A23.3). 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 14.5 of ACI 318 if minimum reinforcement is provided for crack control, which will provide a higher load carrying capacity than the provisions of Section 22.6 of ACI 318 or Section 11 of AS3600-2009. 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 22.6 and 14.5 of ACI 318, although being identical formulae, is the load carrying capacity factor of (0·55 × 0·70) / (0·45 × 0·60) = 1·43, so that Section 14.5 with minimum reinforcement provides 43% additional capacity (0·60 and 0·70 are the respective capacity reduction factors of the ACI).

10. The approach adopted in Section 11 of AS3600-2009 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 AS3600-2009 is more conservative than that of Section 22.6 of ACI 318 since it requires minimum reinforcement, so that the provisions of AS3600-2009 should be compared with Section 14.5 of ACI 318 and not with Section 22.6 of the ACI.

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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 AS3600-2009. Because the crack control mechanism in the Dincel Wall eliminates the need for minimum reinforcing steel, Australian design engineers could use Section 14.5 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 22.6 of ACI 318 and Section 11 of AS3600-2009 without the use of reinforcement.
12. The commentary to Section 22.6 of ACI 318 recommends the use of Section 14.5 rather than Section 22.6 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. The reinforcement detailing shown in the *Dincel Construction System Manual* comprises of both vertical and horizontal steel usage.

(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*.

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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); <u>and</u>
- 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; <u>and</u>
- 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 22.6 of ACI 318.

14. Clause 11.7.2 of AS3600-2009 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 AS3600-2009 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, American ACI 318 and the British BS 8110, and the provisions for unreinforced plain concrete wall design given in these codes can be adopted by Australian practitioners. In fact, it

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is widely-known that many provisions in AS3600 were adopted from the Eurocode, American and British codes.

15. It is of benefit to note the following clauses from BS 8110, which give clarification for the non-use of both horizontal and vertical reinforcement in plain unreinforced concrete walls:

(i) *BS 8110.1 Clause 1.3.4.7 Plain Wall*

"A wall containing either no reinforcement or insufficient to satisfy the criteria in 3.12.5. NOTE: For a 'plain wall' any reinforcement is ignored when considering the strength of the wall"

(ii) *BS 8110.1 Clause 3.9.4 Design of Plain Walls; Clause 3.9.4.19 Cracking of Concrete*

"Reinforcement may be needed in walls to control cracking due to flexure, or thermal and hydration shrinkage......"

16. Supplementary to AS3600-2009 Section 11, BS 8110.1 Clause 3.7.4.19 specifically addresses the need for reinforcement if required for crack control including flexure, shrinkage and temperature purposes for both horizontal and vertical reinforcement.

17. 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 and BS 8110, it is acceptable for design engineers to ignore the minimum reinforcement requirement as defined in AS3600-2009 Clauses 11.6.1 and 11.6.2 when designing a Dincel Construction Systems walling system.

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

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DINCEL WALL DESIGN FOR FLEXURAL BENDING STRENGTH AND DEEP BEAMS

3S-3.3 STRUCTURAL ENGINEERING DESIGN MANUAL

19. The profile of the Dincel Wall cross-section is not rectangular (with a constant depth D), because of the triangular cut-outs (six per metre width of each face of the cross-section, each of area 748 mm^2). It is , however, close to being rectangular. Because of this, the depth must be modified from D to D_{eff} based on either flexural or axial definitions of the effective depth. An axially-derived effective depth arises from the use of ultimate strength design (using rigid plastic assumptions) of the section in flexure, which is assumed to be uniformly stressed at $0.85f'_c$ at ultimate, with regions of the cross-section in tension being fully cracked with the reinforcement only resisting the tensile actions.

20. Using the depth of the Dincel profile as D = 196·4 mm, the effective depth for use in flexural ultimate strength design is defined within the relationship

$$1000 \times D_{eff} = 194 \cdot 6 \times 1000 - 6 \times 748\,,$$

which leads to D_{eff} = 192 mm. On the other hand, design aspects based on pure flexure depend on the effective second moment of area of the cross-section, which in AS3600-2009 for walls is based on a rectangular cross-section for which $I = bD^3/12$. For a 1000 mm width of cross-section, assuming that the centroid of the triangular cut-outs is approximately 9 mm from the face and ignoring the second moment of area of the concrete cut-out about its own axis, the effective depth D_{eff} is defined within the relationship

$$\frac{1000 \times D_{eff}^3}{12} = \frac{196 \cdot 4^3 \times 1000}{12} - \left(\frac{196 \cdot 4}{2} - 9 \cdot 0\right)^2 \times 12 \times 748\,,$$

from which D_{eff} = 189 mm. For ultimate strength calculations, it is therefore recommended that D_{eff} be taken as 192 mm, while for fire purposes it should be taken as 189 mm. The relevant value of D_{eff} may therefore be used in lieu of D in the AS3600-2009 design formulae.

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AS3600 REQUIREMENT OF DOUBLE FACE REINFORCEMENT WITH DINCEL WALL

21. Concrete walls which are not subjected to out-of-plane flexural actions can be reinforced centrally. Shear walls or walls subjected to compressive stresses can be reinforced centrally both in the vertical and horizontal directions in conventional concrete walls.

22. The Australian Standard AS3600 – Concrete Structures Code, Clause 11.7.3 (a) requires double face reinforcement in conventionally formed concrete walls where the wall thicknesses exceeds 200 mm. The reason for this requirement is that the centrally placed reinforcement will not be effective for crack control purposes if the unreinforced thickness of the concrete is excessive on either side of the centrally placed reinforcement in a conventional wall cross-section. With the use of Dincel's waterproof permanent polymer protection, the cracking, hence durability associated problems with conventional concrete walls is eliminated even if the Dincel Wall is thicker than the code's allowance of 200 mm.

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 300 mm produces an insignificant stiffness increase in comparison to that achieved with an increase in length.

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25. There is therefore no need to exceed a 200 mm 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 is an example of this. The fire section of AS3600 – 2009 adopts the principles of Eurocode EC2. The Eurocode EC2 BS EN 1992 - 1 - 2 : 2004 - Clasue 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/cement ratio of 0.4 ~ 0.45; 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 concrete materials science that when a concrete mix with water/cement ratio exceeding 0.7 is used, the moisture content of the concrete will exceed 3%, even after very long periods of time. In addition, designers should be aware that a relative humidity greater than 90% alone will provide 3% moisture content. As a result, a concrete mix having water/cement ratio greater than 0.5 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. A detailed discussion is presented on this subject in the Dincel website – *"Common Engineering Questions"*, Item No: 27, AS3600 – Eurocode for Dincel Walls. 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.

USE OF EUROCODE EC2

27. The major revision for AS3600 - 2009 was for Section 5, Fire engineering design and definition of column in Clause 5.6.2 (b). The previous codes only considered wall thickness for structural fire adequacy purposes. AS3600 – 2009, 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

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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 – 2009, Clause 5.3 offers Eurocode's EC2 more refined solutions for higher tier design methodology.

28. 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-3.2.1.2 and 3S-3.2.4). 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. (Refer water/cement ratio requirement of Eurocode EC2 in Item 7 of this report).

29. 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 – 2009, 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

30. The structural engineering certification issued at the beginning of this report states that the Dincel Wall complies with the BCA, Volume 1, Specification A 2.3 (2) (d) (ii) "deemed to satisfy" definition.

31. 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).

32. 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.

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

(i) Compliance with the "deemed to satisfy" condition of the BCA which is Specification A 2.3 (2) (d) (ii), or

(ii) An alternative solution in accordance with BCA Part A0.10. For the purposes of structural engineering, the alternative solution must demonstrate that it is at least the equivalent of the "deemed to satisfy" provisions. This therefore requires an alternative solution to demonstrate by the method of testing as shown in AS3600 – 2009, Appendix B (Clause B 2.3), i.e. the test load shall simulate 100% of the design loads.

34. 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:

- The BCA Specification C 1.10, Fire Hazard Properties, Clause 4 requires that wall liners (i.e. Dincel's polymer formwork) comply with Table 3 and Clause 4 (c) of Specification C1.10. The Dincel Construction System provides a test report from CSIRO, shown in its Compliance Manual, demonstrating that the Dincel polymer can be used under any fire condition without protection.

- 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 (see Structural Engineering Design Manual, Clause 3S-3.2.3) strength purposes; however the waterproofing quality verified by the CSIRO tests can be utilised to assist the durability Section 4 of AS3600 – 2009.

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- 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 4.10.3.7 and 14.2 require 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 – 2009, Section 5.

35. 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.

36. A design that is complaint with AS3600 means that it is in compliance with the "deemed to satisfy" condition of the BCA, Volume 1, Specification A 2.3 (d) (ii). It is

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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

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

Mark Bradford.

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APPENDIX A

Curriculum Vitae

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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	• **Research Director and Founding Director** Centre for Infrastructure Engineering and Safety The University of New South Wales • **Australian Laureate Fellow** • **Scientia Professor** The University of New South Wales • **Professor of Civil Engineering** The University of New South Wales
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) • Member, Australian Institute of Company Directors • Member, American Concrete Institute • Chartered Professional Engineer (CPEng), Australia • Chartered Engineer (CE), UK • Professional Engineer (PE), USA

Employment Experience

2011-	**Australian Laureate Fellow** The University of New South Wales
2010	**Dean, Faculty of Engineering and Information Technology** University of Technology, Sydney
2004–2009	**Federation Fellow**
2002–2004	**Australian Professorial Fellow** The University of New South Wales
1998-	**Professor of Civil Engineering** The University of New South Wales
1992–1998	**Associate Professor in Civil Engineering** The University of New South Wales
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

Profile

Scientia Professor Mark Bradford is Director of Research and the Founding Director of the Centre for Infrastructure Engineering and Safety and Professor of Civil Engineering at The University of New South Wales.

His research areas are in structural engineering, primarily in steel structures, composite steel-concrete structures and in numerical applications. He was awarded in 2004 a highly prestigious Federation Fellowship by the Australian Government to undertake research in the general area of fire loading on engineering structures, and in 2010 an equally prestigious Australian Laureate Fellowship to lead a research team in sustainable framed building design. He is the only structural engineer to hold either a Federation or Laureate Fellowship, and was the first civil engineer to hold an Australian Professorial Fellowship when awarded in 2001. Also in 2004, The University of New South Wales conferred its "Scientia" title on Professor Bradford; a title awarded by the university after international peer evaluation for its pre-eminent professorial scholars.

Professor Bradford's work has had significant impact, both internationally and nationally. Of a membership that exceeds 145,000, Professor Bradford is only the second Australian Distinguished Member of the American Society of Civil Engineers in its over 160 year history. He serves on the editorial board of a dozen international journals, and on four Standards Australia committees in the areas of structural engineering and metallurgy. He is the author of a number of books in steel and composite structures which are used around the world. Professor Bradford has also presented many seminars, keynote and invited talks at international symposia and research institutions and was Engineers Australia's Eminent Speaker in 2013. He has extensive experience as a consultant in many aspects of structural engineering, and particularly in providing expert opinion in cases of litigation.

Service

- Member and Immediate Past Chairman, Committee BD/23 Structural Steel, Standards Australia (SA)
- Member, Committee BD/1 Steel Structures, SA
- Member, Committee BD/32 Composite Construction, SA
- Member Committee BD/92 Evaluation of Structures, SA
- Member, College of Experts for Engineering, Mathematics and Informatics, Australian Research Council (2010-2012)
- Member, Expert Advisory Committee of Engineering and Environmental Science, Australian Research Council (2001–2003)
- Vice President, ASCCS (2000)
- Secretary, International Conference on Structural Stability and Design (1995)
- Chair, 16th Australasian Conference on Mechanics of Structures and Materials (1999)
- Co-Chair, Conference on Advances in Structures: Steel, Concrete Composite and Aluminium (2003)
- Chairman, Composite Structures VII (2013)
- Vice President and President Elect, American Society of Civil Engineers Australia Section (2013-)
- Deputy Chair, National Committee for Mechanical and Engineering Sciences, Australian Academy of Science (2012-)

Editorial & Advisory Boards

- *International Journal for Numerical Methods in Engineering*
- *Computers and Structures*
- *Thin-Walled Structures*
- *International Journal for Structural Stability and Dynamics*
- *Engineering Structures*
- *Advances in Structural Engineering*
- *Structures; Institution of Structural Engineers*
- *Steel and Composite Structures*
- *Interaction and Multiscale Mechanics*
- *Australian Journal of Structural Engineering*

- *Electronic Journal of Structural Engineering*
- *Advanced Steel Structures*
- *Institution of Engineers, Singapore (Journal A)*

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