DINCEL STRUCTURAL WALLING

COMMON ENGINEERING QUESTIONS

This document has been prepared to assist and answer some of the common engineering related questions. The reader should also refer to the Frequently Asked Questions (FAQ) of Dincel Construction System's website.

CONCRETE

IS ONE GIANT STEP CLOSER TO PERFECTION WITH DINCEL CONSTRUCTION SYSTEM (DCS)

For a better understanding of the following questions and answers, it is recommended that engineers read the following document first.

(Download) – Dincel Solution for Concrete Problems and Cement Minimisation

Apart from offering cheap and fast formworking for walls, the Dincel Construction System (DCS) provides the following:

- Enhances the concrete strength both in tension and compression.
- The permanent polymer skin of 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. Thus eliminating the need for higher grades, i.e. dearer concrete for durability reasons.
- Eliminates the use of crack control steel reinforcement.

The tensile capacity weakness of the most common construction material, concrete, is normally compensated by the addition of steel reinforcing bars. However, the presence of steel bars creates more problems for concrete when considering corrosion. It is nearly impossible to eliminate cracking of conventional concrete walls, which results in steel corrosion and concrete spalling problems especially in severe environments such as marine, sewage or acidic conditions.

Not only are the steel bars subject to corrosion but also the concrete is under attack from environmental conditions unless both concrete and steel are effectively protected. To prevent cracking, corrosion, environmental deterioration and to increase tensile capacity of concrete, functions in the following ways:

1. THE EFFECT OF IMPERVIOUS MEMBRANE ON CONCRETE CURING AND STRENGTH

The best reference for this topic is Properties of Concrete – by A.M. Neville, refer Curing of Concrete pages 307 to 314. Neville states that best concrete is achieved if it is kept saturated for forever. This is what Dincel achieves by having waterproof-permanent polymer formwork encapsulating the concrete infill.

The formwork for concrete walls is normally stripped within 12 to 48 hours, in which time the entire concrete wall thickness is still green, i.e. contains a significant amount of moisture.

At the time of removal of the conventional formwork, the exposed surfaces of concrete will be subjected to rapid loss of moisture by evaporation if subjected to wind, low humidity and high ambient temperature or a combination of all three. When moisture evaporates from the surface of concrete faster than it is replaced by bleed water, the concrete's surface shrinks. Due to restraint provided by the concrete below the drying surface layer, tensile stresses develop in the weak, stiffening concrete, resulting in cracking. These cracks can be shallow cracks or they can extend to the full depth of the concrete wall, depending on how severe the ambient conditions are when the formworks are removed.

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The rate of evaporation for 25°C air temperature, relative humidity 40%, concrete temperature 25°C, and wind velocity 20 km/h conditions is 1.1 kg/m2 hour. Problems with plastic shrinkage cracking emerge after the evaporation rate exceeds 0.5 kg/m2 hour and protection becomes absolutely mandatory after the evaporation rate reaches 1.0 kg/m2 hour. The important point to note is that the above conditions or even worse conditions are often experienced in everyday construction practices.

It is a known fact that the maximum rate of hydration can only proceed under conditions of relatively high saturation – this is why the surrounding air relative humidity of 85% is vital for the continual hardening of concrete. This can only be achieved if the concrete is protected against evaporation by an impervious membrane, such as permanently provided by Dincel Forms.

The object of curing is to keep the concrete saturated as much 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, otherwise the hydration will stop right at the point where the concrete loses its moisture. 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.

However, if 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 which will lead to both a higher compressive and tensile concrete strength along with lower permeability.

Much concrete science literature shows that the compressive strength of concrete is 80% to 100% greater than the strength of concrete which has not been cured at all. The reason for this is that the by-products of ongoing hydration fill the air and water gaps of the concrete, hence achieve denser and less porous concrete.

Therefore, Dincel:

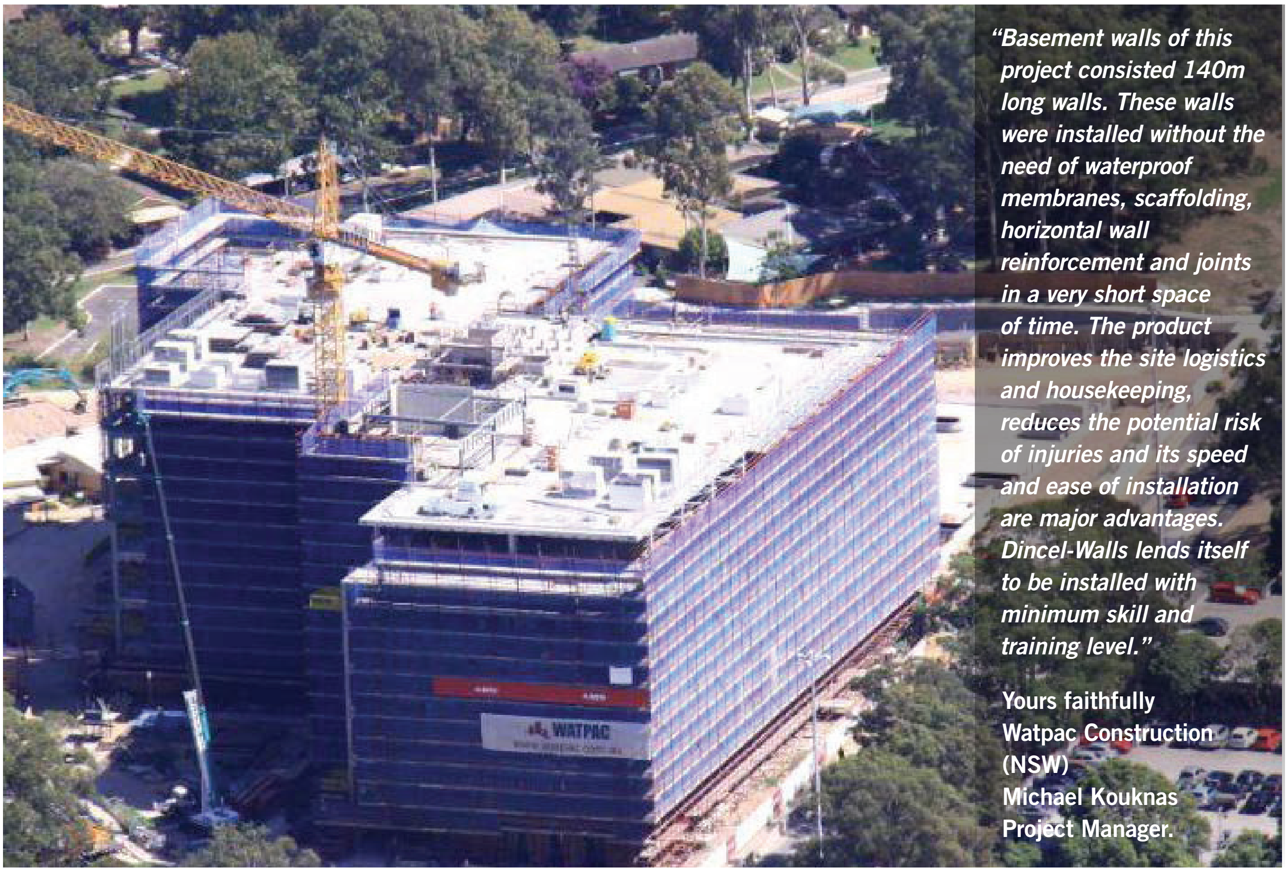
- Requires less water in the concrete mix than mixes normally used with conventional and removable formworks due to the presence of the permanent polymer formwork. Unlike plywood/fibre cement formworks or masonry block walls, Dincel polymer is impermeable hence eliminates the capillary action (i.e. suction) between the concrete water and the formwork. The non-existence of capillary action means significantly reduced friction between the concrete and formwork. This action results in increased workability, elimination of honeycombing and resulting pockets of voids and significant formwork displacements. Holes within the Dincel linking webs will also slow the free fall of concrete thus eliminating concrete segregations.
- Retains water within the "saturated concrete wall" which promotes hydration of cement and increases concrete strength both in tension and compression.
- Delays the effects of drying shrinkage resulting in minimum shrinkage cracking.
- The cracking of concrete is unavoidable unless sufficient joints in the walls are provided. Cracking occurs irrespective of the steel reinforcement that is placed in the wall since there is little bond between concrete and steel within the first 24 hours when 90% of cracking occurs. Each module of Dincel consists of shrinkage and temperature control joints at a maximum of 125mm centres. This results in crack widths of no more than 10 micron at each Dincel-Wall crack inducer at the time of concrete pouring.

  The polymer encapsulated Dincel-Wall becomes crack free within the first 24 hours after concrete pouring because of the concrete's self healing mechanism called autogenous healing. However, even if the cracks remain, 10 micron or even 100 micron crack widths are not considered structurally significant and the cracked concrete is protected by the polymer for a very long time. (For further information refer to Structural Engineering Manual - Dincel crack controllers).
- The above mentioned polymer protection and crack inducers eliminate the need for crack control reinforcement. Vertical reinforcement may be required for reasons other than crack control purposes. Horizontal wall reinforcement is usually provided for crack control purposes (except shear walls or two-way wall panels under flexural actions) and is not required with Dincel-Walls which are normally the reason for settlement cracking caused by the presence of horizontally placed wall reinforcement steel. The need for good vibration is essential in preventing settlement cracking in walls which consist of horizontal steel reinforcement unlike Dincel - Walls.

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.



COCHLEAR BUILDING – MACQUARIE UNIVERSITY, SYDNEY

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2. THE EFFECT OF STEEL REINFORCEMENT FOR CRACK CONTROL

Concrete is made out of water, cement and aggregates. When wet concrete starts to dry, internal tension develops within the wet concrete mix. 90% of cracking occurs whilst concrete is still wet. This is why these cracks are called plastic shrinkage cracking to explain the state of the concrete. The reinforcing steel bars that are available in plastic (i.e. wet) concrete have no contribution in avoiding plastic shrinkage cracking. There has to be a bond between steel and concrete for steel to resist developed tensile stresses due to drying shrinkage. There cannot be adequate bond strength in concrete while the concrete is still in its plastic stage. Therefore, irrespective of their quantity, steel bars cannot assist in avoiding plastic shrinkage cracking. The minimum steel reinforcement quantity of AS3600 is only to regulate crackings between wall joints after the bond strength develops but not to eliminate these unavoidable crackings. The only way to control this type of cracking is to have shrinkage control joints at close centres.

The increased number of joints in conventional in-situ concrete walls is firstly expensive and secondly creates more problems (i.e. vapour transmission). The common recommendation is to have joints with about 6m to 8m centres (i.e. walls are restrained by the presence of floors) to minimise the shrinkage stress development, hence cracking. The joint spacing can be increased by up to 10m if walls are not restrained. The plastic cracking will still occur in between the wall joints but in much smaller crack widths in comparison to a wall that does not accommodate any joints. The closer the joint intervals the better the crack width becomes. Dincel - Wall provides in-built shrinkage control joints at a maximum of 125mm centres.

THE BUILDING IN THE PHOTO ON THE PREVIOUS PAGE IS OF THE COCHLEAR BUILDING AT MACQUARIE UNIVERSITY, SYDNEY WHICH CONSISTS OF 140M LONG STRAIGHT TWO LEVELS OF BASEMENT WALLS. THESE WALLS HAVE BEEN BUILT WITHOUT WALL JOINT AND HORIZONTAL CRACK CONTROL REINFORCEMENT.

3. THE EFFECT OF DINCEL AS POLYMER REINFORCEMENT ON TENSILE STRENGTH OF CONCRETE

Dincel walls and columns are composed of interlocking components that are filled with concrete to create a monolithic wall. The two faces of the components consist of service spacers which are held together by webs.

The webs of the components are cored at 150mm centres which horizontally align with each other during on-site assembly. Approximately 50% of the concrete is monolithic at the coring of each component. The concrete occurring through the cores of the component webs interlock the concrete fill and the polymer component, thus creating a composite action between the two materials.

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 skin, webs and the additional stiffness contributed by the service spacers at each face of each module.

This reserve strength, because of the composite action, can be highly effective for earthquake or hurricane resisting structures. The composite action provides a semi elasto-plastic action to some degree, improving the ductility of the concrete element.

Dincel however does not recommend considering the contribution of the polymer when considering reinforced design without steel bars in the case of shear walls or walls under flexural actions. 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 ongoing fire source for itself to burn) resulting in significant loss of strength provided by the polymer, unless the polymer is protected from fire sources. Dincel-Polymer is certified by CSIRO – Australia as group 1 material, i.e. allowed to be used even in fire tunnels/escapes as a liner to concrete walls (BCA Specification C.1.10.a). **(Download) – Dincel-Wall Fire Assessment**

Where reserve capacity is required for earthquakes or extreme winds, the contribution of the polymer design can be included given the extreme remoteness of a structure experiencing an earthquake or extreme winds at the same time as a fire. For example, AS1170 Loading Code for Australia does not consider such a combination as design criteria for design engineers' consideration.

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4. WHY IS DINCEL-FORMWORK SUPERIOR TO OTHERS?

Other systems use formwork materials which are porous in nature such as block shells, plywood, fibre-cement or similar porous natured form boards. The subject porous materials unlike Dincel-Polymer absorb water from the wet concrete. As a result systems utilising such formwork materials:

- Require excessive high slump concrete to saturate the porous materials hence the desired workability and flow of concrete is achieved. The higher the water/cement ratio the weaker the concrete becomes.
- The capillary action between wet concrete and porous material develops friction. This friction in lighter formwork such as plywood or fibre-cement sheets is capable of significant formwork movement. However, the main problem of the subject friction is the formation of air pockets which is unavoidable. A rigorous and very careful compaction procedure together with very high slump concrete with no more than 10mm aggregates are normally used to minimise the air pockets. Unlike Dincel-Walls, conventional walls are reinforced both vertically and horizontally. The presence of horizontal bars, especially for wet concrete infill with a thickness less than 180mm tends to experience air pockets and settlement crackings along the horizontal bars. Air pockets are the reason for corrosion, fire, acoustic problems and sometimes even the reason for structural instability problems unless the air pockets, in the case of the subject systems having permanent formwork, are found and appropriately filled.

  The presence of air pockets in the case of removable formwork can be detected early. However, it will be difficult to detect the same air pockets in the case of permanent formwork such as block walls or form-boards such as fibre-cement sheets.

  The above problem cannot happen because the Dincel-Forms consist of an impervious polymer, hence no capillary action and as a result no friction between the Dincel-Polymer and wet concrete is possible.

5. IS THERE A POSSIBILITY OF AIR POCKETS AND COLD JOINTS WHEN DINCEL-FORMS ARE INFILLED WITH CONCRETE MIX?

This question is partly answered in the previous question "Why is Dincel-Formwork superior to others?"

The fundamental difference between Dincel-Wall and conventional concrete walls with removable formwork is the type of material that Dincel-Form uses and its effect on the concrete's behaviour.

Dincel-Polymer is an impervious material and as a result maximum water is maintained for hydration purposes. The majority of water present in the wet concrete mix is for workability, but only a small proportion is required for hydration purposes which are well known by engineers. The hydration process will not continue if the relative humidity in the surrounding environment is less than 85%. This is usually the case for conventional concrete walls for the period after removal of the formwork. A significant amount of water content increase is required for workability purposes since the porous formwork materials (such as masonry block walls, plywood or fibre cement sheet form-boards) absorb the water of the wet concrete mix. The suction developed between the porous forms and concrete mix is the reason for friction, hence honeycombing and air pockets.

Unlike removable formwork, the Dincel-Polymer encapsulation can stay for 100 years + life. Conventional formwork is normally removed within 12 to 48 hours time after concreting. The polymer encapsulation increases curing time, hence the period of the hydration process is for a very long time. The chemical process called hydration and its by-products fill the air and water voids available within the concrete matrix with time. The end result is denser concrete, i.e. stronger both in compression and tension.

There is not even a remote possibility of having cold joints if Dincel - Walls concrete filling is finalised within 12 hours of concreting. The presence of the Dincel-Polymer Form protection to concrete eliminates the wind evaporation effect and provides shade from direct sunlight, hence achieves a much reduced evaporation rate for concrete, so the concrete's surface does not dry faster than the rate of bleed water. When the next concrete pour occurs within a maximum of 12 hours, the previous pour is still hydrating and capillary action between the two pours will ensure that cold joints do not form.

6. LIGHTWEIGHT CONCRETE WITH DINCEL

The flowability, i.e. workability requirement of concrete increases with the size and shape of coarse aggregates. The elimination of coarse aggregates significantly increases the flowability of the remaining water, sand and fine aggregate mix. The presence of aeration agents as in the case of aerated concrete further increase workability and reduce the water/cement ratio which is a significant factor for concrete strength. The aeration agents form air bubbles which replace the coarse aggregate of normal weight concrete. The end product is lighter and more energy efficient (i.e. increased 'R' value but decreased "thermal mass" efficiency) concrete than normal density concrete. The density and strength of concrete reduces with increased aeration.

The use of aerated concrete poured in-situ has never been effective until the availability of Dincel Construction System which only now provides effective curing, protection of concrete for common durability problems and significant reduction in steel reinforcement usage. The ongoing hydration offered by Dincel ensures that the aerated concrete achieves maximum possible concrete strength.

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7. DURABILITY REQUIREMENT OF AUSTRALIAN AS3600 CONCRETE STRUCTURES CODE

The Australian Concrete Structures Code AS3600, Clause 4.3 (also refer commentary) does not recognise the commonly commercially available paint/render systems as protection to the concrete walls for durability purposes as the moisture flow, due to their porous nature, cannot be avoided.

The Australian AS3600 Concrete Structures Code's minimum durability requirement is the use of 20 Mpa concrete. The controlling criteria is the minimum cement content which is approximately 280 kg/m3 of concrete. The code requires an increase in the cement content with harsher environments to control the porosity of concrete. For example, 40 Mpa concrete use is required if the exposed concrete to environmental conditions is within 1km of the coastline.

AS3600 accepts the fact that conventional vertical removable forms for elements such as walls are to be removed within 12 to maximum 48 hours' time. The much needed hydration process begins to diminish at the time of removal of the formwork. Therefore, AS3600 code (in fact all worldwide codes) assume that the increased cement content within the available time of hydration reduces the concrete's porosity. This increased cement content generates increased tensile strains which further promote the plastic shrinkage phenomenon.

Dincel increases the hydration time without the removal of formwork which reduces the porosity without having the need for the increased cement content. As a result, cement content which is much less than 280kg/m3 is possible to use with Dincel with lightweight or normal density concrete as the Dincel-Polymer is impervious and protects the concrete infill, hence durability of concrete is no longer a concern.

8. WHAT IS THE CONCRETE STRENGTH TO SPECIFY?

A 10 Mpa 28 days compressive strength would normally be adequate compressive strength for say, load bearing walls of 8 to 10 storeys high buildings under compression loads. There are many examples for load bearing brick walls of up to 8 to 10 storeys high buildings with maximum 8 Mpa compressive strength at the mortar joints. For compression load capacity, the availability of 20 Mpa concrete walls therefore offers at least double the load carrying capacity of brick walls.

The reason why engineers use in excess of 20Mpa concrete is because of durability reasons. A 20 Mpa at 28 days compressive strength limit given by AS3600 – Concrete Structures Code places a minimum quantity limit on the cement use in the concrete mix to control the minimum level of concrete porosity. Conditions such as the structure within 1km of the coastal zone require 40 Mpa concrete in accordance with AS3600 for durability reasons.

The engineer will only need to consider the compressive strength capacity of concrete but not the durability because of the permanent polymer protection offered by Dincel-Forms.

9. CAN HIGH COMPRESSIVE STRENGTH CONCRETE BE SPECIFIED WITH DINCEL-FORMS?

Yes. The engineer must remember that the upper limit of compressive strength by AS3600 - 2009 is 100 Mpa. Dincel with 80 Mpa concrete has been used in the construction of a 27 storey building during year 2011.

10. WHAT ARE THE DESIGN PRINCIPLES OF DINCEL CONSTRUCTION SYSTEM (DCS)?

The structural modelling of DCS as explained more in detail in our Structural Engineering Design Manual consists of the following:

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

(2) The rest of the concrete walls can be designed unreinforced if they are part of the sway prevented structure, i.e. shear walls are provided. However, this is subjected to the following conditions as well:

(i) Dincel-crack inducers provide crack control; hence the horizontal reinforcement is unnecessary.

(ii) The wall already cracked by the presence of crack initiators must be connected to the floor slab above with 'L' bars and dowel bars at the bottom of the wall. These reinforcement provisions establish the joint ductility of a wall having a pin connection at the bottom and translational lateral restraint at the top as shown in the Design Manual. This is also the requirement of AS1170.4 – 2007 Earthquake Code.

(iii) The subject non-shear wall already without horizontal reinforcement and cracked by the presence of DCS crack inducers which can be designed without vertical reinforcement subject to the following further provisions:

- The loading eccentricity $e<t / 6$, i.e. the load acting on the middle third of the cross section, and
- The subject cross section is in compression (we therefore do not rely on the tensile capacity of concrete or polymer skin), and
- There are no loads available to create long term creep effects (for example vertical reinforcement usage is required for lateral soil pressure). In the case of axial compression for creep effect the level of stress within the wall's cross-section is relatively low, and

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- The subject wall is not subject to wind loadings creating tensile stress on the cross section, earth or liquid retaining loads. These walls to have vertical, but no horizontal reinforcement for crack control unless the horizontal reinforcement used by the design engineer for flexural purposes as well.

Please consider this as an engineer – what is the difference of the Dincel - Wall (unreinforced) with masonry wall's structural behaviour as long as the sway control mechanism is provided? The one issue that is different is the uncontrolled cracking of conventional concrete walls which is the concern of all building codes. However, it is clearly demonstrated that Dincel - Wall crack inducers eliminates this concern. In fact, we all know that the reinforcement does nothing for plastic shrinkage cracking; hence minimum reinforcement is there to control concrete so the width of the cracks will not cause structural or durability problems. **(Download) – Structural Engineering Design Certification**

11. **CAN CRACK CONTROL REINFORCEMENT BE ELIMINATED WHEN USING DINCEL CONSTRUCTION SYSTEM (DCS)?**

The report from the University of New South Wales **(Download) – Structural Engineering Design Certification** presented in our current Structural Engineering Design Manual states that the use of minimum reinforcement for concrete walls for crack control purposes for both vertical and horizontal bars has been waived by Dincel - Wall.

Clause 11.6.2 of AS3600 clearly defines that the specified minimum horizontal reinforcement is for crack control due to shrinkage and temperature purposes. However, AS3600 is not defining clearly why the minimum vertical wall reinforcement of Clause 11.6.1 is used. This has raised some questions by fellow engineers and required clarification.

The horizontal reinforcement is for crack control, and it is not necessary because of crack inducers and perfect curing conditions (i.e. continuing hydration process) offered by the permanent polymer of DCS. In fact, to date, DCS has built up to 140m long walls without any joints; the crack inducers without crack control reinforcement are working, hence eliminating the need for joints.

The report prepared by the University of New South Wales (Professor Mark Bradford) clarifies the minimum reinforcement usage of AS3600 for both vertical and horizontal reinforcement. The interesting outcome of the report by Professor Mark Bradford is that AS3600 – Section 11 with the use of minimum reinforcement is not the equivalent of Section 22.6 of ACI 318 even though they both use identical formulas. If reinforcement is used, Section 14.5 of ACI 318 should be adopted because it clearly gives a higher load carrying capacity. **Therefore, using AS3600 with minimum reinforcement in Australia, the walls are being designed much smaller than their capacity.**

Professor Bradford offers to fellow engineers explanations and references from ACI 318 and BS 8110 in the report. These codes, unlike AS3600, allow design for unreinforced walls. The elimination of horizontal reinforcement (except for shear walls) makes the installation of the Dincel system much simpler. So, it is important to minimize the use of horizontal reinforcement as much as possible. The University of New South Wales provided a certificate and the abovementioned report accordingly for the concerned engineer's peace of mind on how the vertical and horizontal bars could be omitted.

12. **DOES THE MINIMUM VERTICAL REINFORCEMENT OF 0.0015 (CLAUSE 11.6.1 – AS3600) NEED TO BE PLACED TO APPLY THE EMPIRICAL FORMULA OF AS3600 – CLAUSE 11.4.4 WHERE DINCEL WALLS ARE USED?**

No, because of the following. The basis of the empirical formula given is AS3600 clause 11.5.1 for design axial strength of a wall based on the following:

- The AS 3600 formula has been developed from ACI 318 and BS 8110.
- In the DCS Structural Design Manual we provide a comparison of the AS 3600 and ACI 318 codes formulas which are almost identical.
- The ACI 318 formula as defined in chapter 22 clause 22.6.5.2 has been specifically developed for structural plain concrete. (Refer ACI 318 commentary clause R22.6).
- ACI 318 chapter 22 – structural plain concrete does not require any minimum reinforcement for shrinkage or other purposes.
- ACI 318 chapter 2 – Definition, defines plain concrete as "structural concrete with no reinforcement or with less reinforcement than the minimum amount specified for reinforced concrete".
- BS 8110 requires minimum wall reinforcement for crack control purposes for conventionally formed concrete walls.
- ACI 318 has three methodologies for wall design – Section 22, Section 14 and Section 10. If the wall is designed to comply with Section 14 and Section 10, then ACI requires minimum or required reinforcement usage.

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- The above methodology of ACI 318, Section 22 is also identical to the Canadian CSA Standard A23.3 clause 22.4.1.3 plain concrete usage without reinforcement is allowed.
- In DCS's structural engineering manual, page 16 shows the relevant ACI and CSA diagrams.
- 2006 International Building Code is also very clear and is based on the ACI 318 clause 22.6.

We can therefore conclude that it is acceptable to design with DCS wall system utilising AS 3600 clause 11.5.1 to determine the design axial strength of a wall without providing vertical or horizontal reinforcement as the Australian Standard for this provision has been based upon Section 22 of the ACI 318 method of design which has been developed for plain concrete walls with no requirement for reinforcement. The engineer may also refer to (Download) – Structural Engineering Design Certification

13. WHAT IS THE THICKNESS OF A SHEAR WALL?

The earthquake tests conducted by the University of Technology Sydney clearly demonstrate that significant lengths of walls are required in major earthquakes. (Download) - Building Solution for Earthquake Prone Regions. The length of lift shafts as shear walls that may be commonly used in buildings are very much less than the shear walls' length that is normally required for significant earthquake design loads. For this reason, engineers often introduce additional length of shear walls.

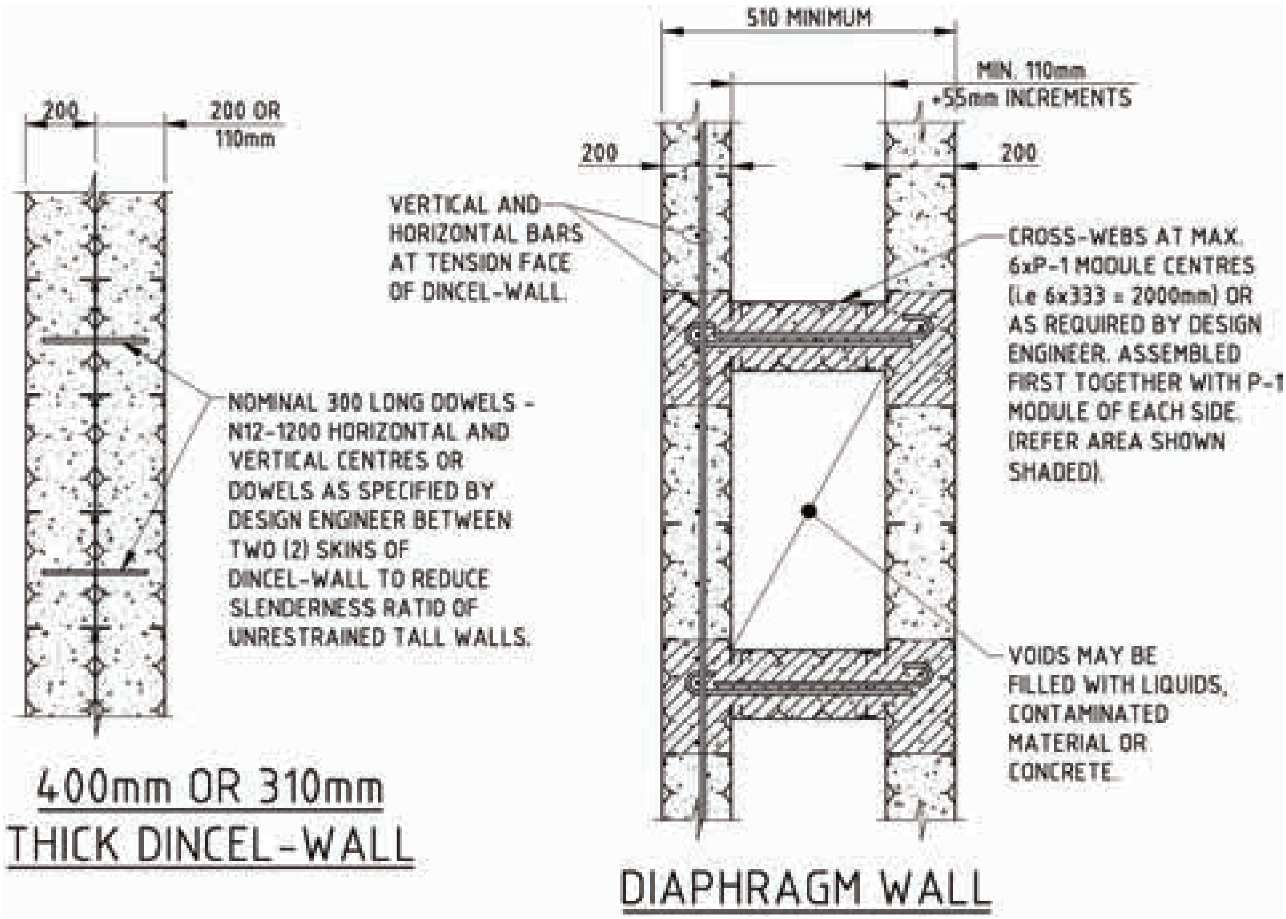
An experienced earthquake design engineer already knows that the stiffness of a shear wall is achieved by the length of the wall and not necessarily by its width. The increase of wall thickness from 200mm to 250mm or even 300mm can only make insignificant stiffness increase in comparison to the length increase.

There is no need to exceed 200mm in wall thickness for a shear wall, provided that compressive stresses are satisfied by providing adequate length of Dincel Wall.

14. WHAT IF THE DESIGN ENGINEERS NEED WALLS THICKER THAN 200MM THICK DINCEL-WALLS?

The thickness of Dincel-Wall is 200mm. The design engineer may require walls thicker than 200mm for cases such as high rise building's shear walls, very high earth or storage retaining walls, or walls with high slenderness ratios.

The following forms can be used:



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15. WHY SPECIFY DOUBLE FACE REINFORCEMENT WHERE THE WALL THICKNESS IS MORE THAN 200MM?

Concrete walls which are not subject to out of plane flexural actions can be reinforced centrally. Shear walls or walls under compression stresses can be reinforced centrally both in vertical and horizontal directions in conventional concrete walls.

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

16. IS IT NECESSARY TO PROVIDE A DOUBLE FACE REINFORCED SHEAR WALLS FOR A LIFT SHAFT DESIGNED FOR EARTHQUAKE/WIND RESISTING STRUCTURE?

Not necessarily. A lift shaft when designed as a shear wall consists of four (4) walls. Each opposite wall depending on the direction of earthquake/wind loading will be in tension or compression.

Concrete is weak in tension and this is why both vertical and horizontal reinforcement is required to cater for the flexural and shear actions of a shear wall.

The lever arm between the tension and compression walls is the width of the lift shaft. The in-plane wall connecting tension and compression wall is the wall which resists shear forces. Therefore, whether each wall has central or double face reinforcement, as long as the quantity of the reinforcement satisfies that which is required by design, the end result for shear-wall load carrying capacity in bending or shear will not change.

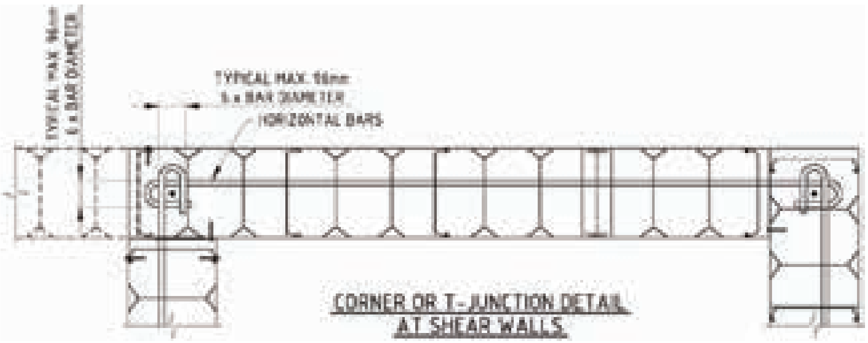
The Australian Standard AS3600 – Concrete Structures Code requires double face reinforcement for crack control purposes only when the thickness exceeds 200mm [AS3600 – Clause 11.7.3 (a)]. It is always difficult to place double faced reinforcement (i.e. double the labour). Dincel-Walls consist of circular web holes between the adjoining modules. The placement of double faced vertical reinforcement is easy, however the placement of double faced horizontal reinforcement will not be impossible but time consuming. The question of why use double faced reinforcement is clearly stated in AS3600 as stated above. A single layer of reinforcement achieves much better concrete compaction and less chance of having honeycombing problems which is a real problem in the case of conventional formwork, especially at corners where reinforcement is congested. Therefore it is detrimental and there is no valid reason why an engineer should consider double face reinforcement for walls up to 200mm thick.

17. WHY HOOK ENDED BARS ARE USED IN CORNERS OF DINCEL-SHEAR WALLS?

It is very difficult to utilise 'L' bars at wall corners as Dincel-Wall is a pre-formed and modular system. The strong earthquake/wind events can cause cracking in the concrete along the length of the corner "L" bars. The bond failure, hence slippage of 'L' bars is a big possibility under significant tensile forces. However, when the hook end horizontal bars (i.e. shear reinforcement) of each direction overlap each other with the inclusion of a vertical bar at the intersection, it provides a mechanical means of reinforcement splice rather than relying on the bond strength between concrete and 'L' bars. Concrete, being brittle, cracks easily especially in the case of shock loading such as an earthquake.

Dincel-Walls have 115mm diameter web holes which are rather suitable to 6 bar diameter hook bars. The overall width of the hook becomes 72mm for 12Ø or 96mm 16Ø bars which will fit within 115Ø web holes.

If horizontal bars (i.e. shear reinforcement) are to be spliced with hook end bars or spliced at the middle of the walls, the full tension lap is 375mm for N12Ø and 500mm for N16Ø bars.



CORNER OR T-JUNCTION DETAIL AT SHEAR WALLS

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18. CAN STAIR MID-LANDING LEVEL BE DOWELLED TO DINCEL-WALLS?

For simplicity and expediency purposes, builders prefer to build load bearing walls between each adjacent floor level and connect stair mid-landing level to walls.

The simplest connection for stair landings consists of epoxy grouted or chemically anchored dowels or simple 'L' bars. The capacity of any of these dowels/bars can be designed well above any load that can possibly be experienced by any stair. However, the last thing that a builder wants to do is to stop and re-start the walls at mid-landing levels of stairs. Alternatively much more elaborate but rather unnecessary details having rebates can also be engaged as well. This way, stair flights and mid-landings between each floor can be poured together with the relevant floor slab, thus eliminating additional concrete pouring for stairs alone.

19. IS DINCEL CONSTRUCTION SYSTEM FASTER THAN OTHER WALL SYSTEMS?

Yes. Please **(Download) – Why Dincel is Faster to Build** for the answer.

20. IS DINCEL CONSTRUCTION SYSTEM PREFERRED BY THE FORMWORKING TRADES?

Yes. Lightweight, reduced cranage need, less chance of having accidents, significantly faster, flexible, easy to handle, requires less number of labour, and cash flow improved business are the clear advantages that DCS offers to the construction teams. Please read **(Download) – Formworkers Benefit**

21. WHAT IS THE ADVANTAGE OF LOAD BEARING DINCEL-WALLS OVER THE FRAME SYSTEM CONSISTING COLUMNS AND SLABS?

The simplest answer is the cost. The frame structure may consist of party, façade or partition walls of many different types carried by the floor slabs. The floor slabs on columns rather than load bearing Dincel-Walls will always require additional thickness and reinforcements. **(Download) – FAQ, Answer No: 21 – System Advantage/Construction**.

22. WHY A DESIGN ENGINEER HAVE TO BE VERY CAREFUL IF BRICK INFILL WALLS, INCLUDING PARTY WALLS ARE USED IN BETWEEN THE COLUMNS OF THE FRAME STRUCTURE?

AS1170.4 – Earthquake Code is the revised 2007 version, is now mandatory. The use of load bearing brick wall is strictly limited. The brick wall (or any other type of wall), when used as an infill wall between columns, must be restrained by the floors. The restraining detail at party walls must accommodate structural, fire and acoustic provisions simultaneously. Please refer to **(Download) – Earthquake Hazard Risk Prevention for Developers and Building Professionals** which is available in our website.

23. IS REINFORCED 140MM BLOCK WALL STRUCTURALLY ADEQUATE?

Many structural engineers consider the masonry block wall's core size for concreting is too small especially after the placement of both vertical and horizontal reinforcements. It is a common problem that 140mm block walls end up with significant sized air pockets in the concrete filling because of the porosity of the block wall's surface and the presence of both horizontal and vertical bars which do not leave much space for concrete flow even with excessive slump and 10mm aggregate sizes. This is most common and may lead to honey-combing problems together with settlement cracks of the plastic concrete along the horizontal bars. This problem will cause structural, fire and acoustic problems depending on the function of the wall.

24. DOES A 150MM THICK CONCRETE WALL AND A 200MM THICK BLOCK WALL COMPLY WITH THE RW + CTR > 50DB ACOUSTIC BCA REQUIREMENT?

No. A 150mm in-situ concrete wall without the presence of any service conduits or pipes provide Rw + Ctr = 47 dB. A 180mm thick concrete wall provides Rw + Ctr = 50 dB.

The non-compliance of 200mm thick block walls is clearly noted in the current Building Code of Australia.

25. DO FINISHES OF A 150MM THICK CONCRETE WALL MAKE AN EFFECT ON THE A ACOUSTIC CAPACITY?

- A 150mm concrete wall plus 13mm cement render on both sides improves acoustic performance.
- A 150mm concrete wall with direct stick plasterboard and plasterboard with furring channels significantly reduces the acoustic performance capacity. (Refer BCA Deemed To Satisfy Conditions).

26. IS IT POSSIBLE TO USE MESH REINFORCEMENT FOR ONE-WAY SLABS UTILISING DCS WALLING SYSTEM AS LOAD BEARING WALLS WITHIN THE PROVISION OF THE LATEST VERSION OF AS3600 – 2009?

Yes.

If we refer to AS3600 – 2009 we will find the following:

Clause 1.1.2 (c) – Class 'L' Reinforcement (which includes mesh)

(i) May be used as main or secondary reinforcement.

(ii) Not to be used in a situation where large plastic deformation is expected under strength limit state.

Table 2.2.2

Bending without axial forces

$ØN = 0.6 \leq (1.19 – 13/12\ kuo) \leq 0.8$ N Class

$ØL = 0.6 \leq (1.19 – 13/12\ kuo) \leq 0.64$ L Class

Clause 3.2 – Properties of Reinforcement

All reinforcement N and L Class shall comply with AS4671.

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Clause 6.2.7 – Moment Re-distribution

6.2.7.2 – Deemed To Comply For N Class Only

Therefore, no moment re-distribution allowed for 'L' Class reinforcement.

Clause 6.9.5.1 – Idealised Frame Method For 2 Way Slabs (column supported)

Class N only.

Therefore, cannot use 'L' class reinforcement (i.e. mesh for two way slabs) for the main flexural reinforcement.

Clause 6.10.2.2 – Simplified Method

Negative design moment.

Factors 'N' Class ≤ Factors 'L' Class

Clause 6.10.2.3 – Positive Design Moment

Factors 'N' Class ≤ Factors 'L' Class

Clause 6.10.3 – Simplified Method For 2 Way Slab Supported on 4 Sides

'L' Class reinforcement can be used if supported on 4 sides. Bending Moment co-efficients shall be determined in accordance with Table 6.10.3.2 (13).

In summary, it is therefore possible to design one way slabs utilising DCS walling system as load bearing walls with the structural floor slabs utilising Class 'L' mesh reinforcement.

27. THE USE OF AS3600 – 2009/EUROCODE FOR DINCEL WALLS (Download)

28. DOES DINCEL WALL SATISFY THE STRUCTURAL DUCTILITY REQUIREMENTS OF AS3600 TO BE CLASSIFIED AS A DUCTILE SHEAR WALL?

YES. Dincel Wall has been subjected to an extensive earthquake testing program carried out at the University of Technology. This testing program included in-plane shake table testing of shear walls, pushover testing of shear walls and out of plane shake table testing. The testing program and results are outlined in the documents titled **(Download) Building Solution for Earthquake Prone Regions** and **(Download) Earthquake Testing Report**.

Ductility is the ability of a structure to sustain its load carrying capacity and dissipate energy when responding to cyclic displacements in the in-elastic range during an earthquake event.

The testing clearly revealed that Dincel Wall was capable of sustaining extremely large deformations when subjected to cyclic loading. Typically, lateral deformations in excess of 2.5% are considered unsafe and a potential collapse state. The Dincel Wall was able to sustain deformations of 4.4%, far in excess of conventional ductile walls.

The conclusion of the testing program revealed that the Dincel Wall is capable of sustaining large displacements beyond that of a conventional concrete wall whilst maintaining stiffness equivalent to a comparable conventional concrete wall.

When designed in accordance with the requirements of Appendix 'C' of AS3600, Dincel satisfies the requirements of AS3600 to be classified as a ductile shear wall.

29. DOES 110MM DINCEL WALL PROVIDE 90/90/90 FRL?

YES. 90/90/90 FRL can be achieved for loadbearing walls not exceeding 3,000mm in height. If required, 90 min. FRL can be increased by adding insulation materials (e.g. fire rated plasterboard) in accordance with AS3600 – 2009 Clause 5.8.

Common misunderstandings by the majority of certifiers and some engineers are as follows:

FRL means structural adequacy/integrity/insulation Fire Resistance Level during a fire event. For example, for a structural concrete wall, FRL of 90/90/90 is required for a Type "A" Class 2 Building. The fire resistance levels for the walls compliant with the "Deemed to Satisfy" definition are determined in accordance with AS3600 – 2009, Concrete Structures Code.

Dincel is a permanent formwork. The concrete infill is used for structural and fire purposes. Refer **(Download) Dincel Structural Engineering Certificate** to understand that Dincel Wall complies with the "Deemed to Satisfy" definition of AS3600. Therefore, the following is relevant for Dincel Wall:

Insulation: AS3600 – Table 5.7.1 – FRL = 90 minutes; minimum concrete thickness of 100mm is required (110mm Dincel has net concrete thickness of 105mm).

Integrity: If both insulation and structural adequacy is satisfied, AS 3600 state that this condition is satisfied as well.

Structural Adequacy: This FRL level is NO LONGER determined by the concrete thickness alone. Engineers can no longer determine the FRL for structural adequacy based on the concrete thickness alone. This approach of AS1480 and AS3600 – 2001 version has now been replaced by the following requirements of AS3600 – 2009.

The FRL for structural adequacy must be calculated by design engineers, including the wall thickness, wall height, load on the wall, loading eccentricity on the wall and concrete grade. AS3600 – 2009 has adopted a less sophisticated EuroCode method in Table 5.7.2 – AS3600 – 2009. Table 5.7.2 of AS3600 can be misleading for high slenderness and some load conditions, and as a result AS3600, Clause 5.3 allows engineers to use a sophisticated EuroCode methodology called the Zone Method to be used for the "Deemed to Satisfy" conditions. Refer **(Download) The Use of AS3600 – 2009/EuroCode for Dincel Walls, Item No: (1)** for detailed explanation.

The Zone Method of the EuroCode is adopted by Dincel Wall. The DINCEL DESIGN TOOL is available to all structural engineers.

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