DINCEL STRUCTURAL WALLING

CONCRETE PROBLEMS & CEMENT MINIMISATION

FOREWORD

Concrete is everywhere and it is the most frequently used material in construction. The world's concrete production in the year 2002 has been estimated at 1.05 x 1010/tonnes/year. This quantity is increasing at an exponential growth rate together with the world's population. Currently 1.70 tonnes/year of concrete is produced for each person on this planet.

Concrete is friendly to the environment and it is virtually all natural and recyclable. Concrete is an energy efficient product. The only energy intensive demand is in the manufacture of Portland cement, which is typically a 15% component of concrete. This cement quantity and even more, is used conventionally to attempt to make the concrete durable in a variety of environmental conditions. If concrete is not durable, i.e. porous, the life of concrete will be significantly compromised.

It is strong in compression, inexpensive, plentiful, and versatile and offers thermal mass for the reduction of heating and cooling energy demand. On the other hand concrete is weak in tension, brittle, non-ductile, porous and requires formwork to hold the wet concrete mix until it dries.

Structural engineers aim to design the life of common concrete structures to last 40 to 50 years with the exception of post-disaster buildings with typically lives of 100 years. These life expectancies are often prematurely ended due to concrete's problems. Shorter building life means: more energy use, more CO_2 production, negative effect on health issues and reduction in standard of life.

It is not possible to replace the current concrete industry. The reasons are:

- Concrete is the most widely used construction material and is made from the most abundantly available raw materials on the planet.
- Concrete uses clinker based cement which is achieved by burning clays and shales.
- The cement manufacturing and concrete making procedure is established primarily with low-cost, naturally occurring materials which financially are not possible to replace. It is technically possible to develop superior concrete technologies, however it is unlikely they will be able to compete with the established clinker based Portland cement concrete.
- The concrete batching plants and especially Portland cement manufacturing plants are established to the level which will be financially not possible to modify or replace them.

Having understood the above reality, DCS chose a path to improve and better utilise the existing concrete technology rather than replacing it.

Therefore, it is important to understand the principles and problems of concrete and how Dincel Construction System offers a solution to each one of these problems.

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CONVENTIONAL CONCRETE'S PROBLEMS

1. Conventional concrete is POROUS which leads to DURABILITY problems.

Causes:

Durability problems lead to concrete cancer, steel corrosion and reduce the useful life of concrete.

Conventional Prevention:

Increased cement quantity, as well as special types of cements use. Increased concrete cover resulting in extra concrete use. Concrete's materials, placement, vibration, workability and pouring must be strictly controlled to reduce concrete's porosity.

Concrete can display significant problems, especially when subjected to wetting and drying, freezing and thawing, chloride/sulphate/acid attack and salt crystallisation since non-porous and non-cracking concrete does not exist irrespective of the type and quantity of cement being used.

Dincel Solution:

Being waterproof **(Download – Waterproof Walls)** the polymer encapsulation of Dincel provides the ultimate DURABILITY protection for concrete for concrete cancer and steel protection in any environment. There is no possibility for steel reinforcement corrosion **(Download – Dincel-Wall Waterproofing Warranty)**. The durability protection offered by Dincel can reduce by as much as 50% of general purpose cement use and totally eliminates the special type of cement use. It further allows the use of materials that are not normally allowed for concrete making. These are: recycled concrete, beach/sea sand, corals, shale, coal, waste products such as fly-ash, any left over products from the processing of mined material. The reader is highly recommended to read **(Download – Sustainable Concrete)**.

2. Conventional concrete is a BRITTLE and NON-DUCTILE material which is WEAK IN TENSION.

Causes:

Cracking in concrete which in turn affects its durability.

Reason:

The bond development between the concrete's ingredients is achieved by cement as a bonding agent. The bond is not strong enough to resist cracking because of tensile forces due to shrinkage, temperature, applied loads, building movements including foundation and supporting soil.

Conventional Prevention:

The only way of controlling cracking is to accommodate the joints at close centres. Joints are expensive to build and can also lead to further problems. This is why wall joints are placed between 6 m and 8 m centres. The concrete in between the joints are reinforced to minimise the crack widths. 90% of concrete cracks occur whilst the concrete is still wet, and the steel reinforcements cannot provide assistance as there is no bond between wet concrete and steel reinforcements. Steel reinforcements are mainly required to compensate the weakness of dried concrete in tension and assist its ductility. However, even reinforced concrete cracks. For a number of reasons the cracking makes concrete vulnerable.

Dincel Solution:

Dincel consists of closely spaced in-built crack inducers which eliminates the need for wall joints and majority of steel reinforcement. The steel reinforcement required in hardened concrete work as crack control, as well as flexural purposes. The following steel reinforcement uses are not required with Dincel-Wall.

- **Crack control steel not required.** **(Download – Why Engineers Can Omit Crack Control Steel in Dincel Wall)**.
- **Vertical steel reinforcement can be omitted** where walls are subjected to axial compression load only. **(Download – Common Engineering Questions and read Items 10 & 12)**.

The cracked concrete within Dincel Polymer forms is completely concealed and no cracks are visible at the face of the wall.

Durability is not a concern as Dincel-Wall, including its joints, is waterproof. The polymer encapsulation also offers additional ductility to the concrete infill which has been proved by the earthquake and flexural beam tests conducted by the University of Technology Sydney. **(Download – Building Solution for Earthquake Prone Regions)**

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3. Conventional concrete requires FORMWORK to hold wet concrete until it dries.

Conventional Formwork:

Conventional formwork requires significant safety issues during installation, removal and storage which can only be handled by skilled labour, additional lifting equipment to assist installation, time consuming and expensive to deal with. The conventional formworks are porous in nature which causes friction due to the capillary action between the wet concrete mix and porous formwork surface. This leads to honeycombing in the concrete infill. To address this problem, increased flowability of the concrete mix is required. This often results in cost increase, reduction in strength and does not necessarily avoid honeycombing, i.e. voids. The overall conventional concreting and formworking becomes unnecessarily expensive, time consuming and represents workplace safety hazards.

Dincel Formwork:

Dincel provides a lightweight, permanent formworking system and is extremely fast to install, even by the lower skilled labour force. It eliminates nearly all safety and time concerns associated with conventional formwork. It also eliminates honeycombing, air pockets, segregation, requirements for vibration and curing associated with construction site concrete handling issues. The permanent curing offered by Dincel achieves a significant decrease in porosity which results with significantly higher concrete strength and tensile capacity which steadily improves with the age of the concrete.

Dincel consists of a polymer-based material that is VOC free, suitable for potable water/food grade use, superior fire properties for the spread of fire and smoke issues **(Download – Building Code of Australia (BCA) Certification)**, and is environmentally indestructible from anything in nature, including pollutants, acids, chemicals, sea water, pests, bacteria and biological activity.

When filled with concrete the product is waterproof and air-proof and thus becomes the solution for sick building syndrome, contributes to a healthy air atmosphere within buildings, and reduces mould/mildew condensation.

The special design of the product eliminates the need for the majority of steel reinforcement in the Dincel-Wall as explained Item No: 2.

(Download – Dincel Solution for Construction Safety)

(Download – Why Dincel Is Safer)

CEMENT MINIMISATION AND ELIMINATION OF SPECIAL CEMENT USE WITH DINCEL

Achievement of many of the desirable hardened-state characteristics of concrete, particularly its strength and durability, depends to a great extent on the development of physical and chemical bonds within the cement paste as it hydrates, i.e. reacts chemically with water and between the cement paste and the aggregate particles as the concrete hardens.

Generally, for a given mixture, maximum bond development will occur when the water content of the cement paste is at a minimum and all air is expelled from the system.

The action of water increases the workability of the concrete, but it also dilutes and weakens the cement paste. However, if the chemical reaction between cement and water (hydration) is allowed to take effect over a longer period of time as in the case of Dincel, i.e. the concrete is kept moist allowing the process of curing to take effect; the concrete will achieve its maximum potential strength and durability.

Dincel achieves cement minimisation in the following way.

Dincel's permanent polymer encapsulation provides an environment for which the concrete can achieve a significant increase in its normal compressive and tensile strength when compared with any other environmental condition. **(Download – Common Engineering Questions - Refer Item 1 The Effect of Impervious Membrane on Curing and Strength)**. Being waterproof, the same impervious polymer encapsulation **(Download – Waterproof Walls)** totally protects the concrete infill. This eliminates the need for having an excess quantity of cement to satisfy the durability requirements of the concrete mix design. For example, the Australian Concrete Structures Code AS3600 requires a concrete mix to have 20Mpa concrete for durability reasons which represents a minimum of 280kg cement for each cubic metre of concrete. There is no reason why this quantity cannot be reduced to 140kg (i.e. 50% reduction) for the majority of uses as the resultant concrete's compressive strength would be adequate for most cases. It is important to understand that 10Mpa or 12 Mpa concrete would be adequate for a wall under squash loading of up to approximately 10 storeys high.

The 50% reduction of the cement volume can be replaced by sand or coarse aggregate or alternatively by untreated fly-ash, corals, volcanic rocks, etc. For more information refer to **(Download – Dincel-Sustainable Concrete)**

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CEMENT TYPES AND THEIR USE WITH DINCEL

General Purpose (GP)

Intended for use in most forms of concrete.

The use of Dincel would only require the use of GP cement.

General Purpose Blended Cement (GB)

This is similar to the GP cement, however varying the percentage of fly-ash, slag and silica fume permits a fairly broad range of characteristics. The minimum strengths are lower than those of GP cements with typical curing rates, however, providing moisture or sustaining longer periods of curing can increase ultimate strengths to equal or exceed those of GP cement.

The use of Dincel would not require the use of GB cement.

High Early Strength Cement (HE)

This cement develops strength more rapidly than the GP and GB cements. High early strength cement lends itself to applications where rapid strength development is required, for example where formwork has to be removed as soon as possible or where early strength is required so that further construction can proceed.

The use of Dincel would complement the use of HE cement as the Dincel-Polymer would not require to be stripped.

Low Heat Cement (LH)

This type of cement is used where the temperature rise in concrete during curing of massive structures or thick structural elements results in unacceptable thermal stresses. Low heat characteristics are achieved by reducing the content of the more rapidly hydrating compounds in cement, which tends to produce a lower rate of strength development.

The use of Dincel would complement the use of LH cement with the adoption of cellular construction.

Shrinkage Limited Cement (SL)

This type of cement is intended for use to limit shrinkage and cracking such as on road pavements and bridge structures.

The use of Dincel would not normally be used for road works however, for other systems such as beams carrying large mass, the use of SL cement would not be required with the use of Dincel.

Sulphate Resistant Cement (SR)

This type of cement is intended for use where resistance to ground water containing sulphates in solution is required.

The use of Dincel would not require the use of SR cement as the Dincel-Polymer would protect the concrete from contamination.

(Download – Acid Sulphate Soil Damages)

REACTION OF WATER IN PORTLAND CEMENT

When Portland cement is mixed with water, a series of chemical reactions take place which result in the formation of new compounds and the progressive hardening (compressive and tensile strength) of the cement paste.

Water added to Portland cement results in hydration of the tricalcium aluminate (C3A) which is affected by the gypsum included in the cement to control its setting or otherwise known as curing as this controls the loss of moisture from concrete after it has been placed in position. The hydration involves an increase in the volume of the solids, bringing about stiffening of the cement paste.

The immediate reaction between the C3A and gypsum produces needle like crystals known as 'ettringite'. This layer of ettringite on the surface of the C3A grains retards the hydration process resulting in a dormant period in which the concrete remains plastic. This dormant period is defined as the ***initial period*** where the concrete is workable.

The ***initial set*** for concrete is the point at which the paste reaches a certain degree of stiffness.

Further hydration decreases the porosity of the set paste, thereby increasing its strength. Final set in cement is the point at which the paste may be regarded as a rigid solid and begins to develop measurable strength.

With respect to Dincel, the rate of water evaporation in the concrete is minimised as the concrete structure is enveloped in a layer of Dincel-Polymer, this allows the hydration of the C3A ettringite to be converted into monosulphate and a hexagonal solid plate solution (C4AH13) over a longer period of time, the process for which concrete develops the maximum compressive and tensile strength, i.e. greater than for other conventional methods.

The effect of temperature can also have a marked effect on the rate at which concrete hydrates, and the nature of the new compounds that are formed, which would have a permanent effect on the long term strength and durability of the concrete.

In short, lower temperatures reduce the rate at which hydration occurs. At high temperatures the rate of hydration increases but reduces the potential strength of the concrete at later ages. Generally though, for practical purposes, no significant harm will result to the strength of the concrete for concrete temperatures up to 35°C.

In summary, concrete strength is affected by a number of factors:

- The length of time for which it is kept moist;
- Kept moist for a period of time and allowed to dry out;
- Allowed to dry out from the time it was first made.

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For example:

- Concrete allowed to dry out immediately achieves 40% of the strength of the same concrete allowed to cure over 180 days.
- Concrete allowed to cure over three days will achieve 60% of the strength of the same concrete allowed to cure over 180 days.
- Concrete allowed to cure over 28 days will achieve 95% of the strength of the same concrete allowed to cure over 180 days.

Keeping concrete moist is therefore the most effective way of increasing its ultimate strength. Concrete enveloped in Dincel-Polymer such as in the case when Dincel is used, will maximise the rate of curing without requiring special environmental conditions or human intervention.

Furthermore, as the thermal conductivity of Dincel-Polymer is low, this would tend to allow the temperature of the curing concrete to be slightly higher. This would have the effect of accelerating the rate of curing and therefore accelerate the rate at which concrete gains strength.

The above methods of hydration and accelerated curing of concrete would be achieved in conjunction with proper placement of concrete within Dincel, liquefaction of the concrete which allows it to slump and fill the form (Stage 1, vibrated with an immersion vibrator) and expulsion of entrapped air (Stage 2, vibrated with an immersion vibrator). The period of vibration varies for different volumes of concrete and is documented in most National Standards.

As an example, concrete containing 10% entrapped air may reduce the strength of concrete to 50% that of concrete when fully compacted.

The curing of concrete would therefore be an important consideration in relation to its method of construction, its physical appearance, strength, future maintenance, all of which factor into time and cost.

Refer **(Download – Common Engineering Questions)** – Item No: 1 – The Effect of Impervious Membrane On Concrete and Strength.

Dincel retains the moisture that is required in the concrete for curing and thus can achieve maximum concrete strength over extended curing periods with minimal human intervention. The minimal human intervention relates to a cost saving benefit. Further, the volume of cement required for achieving a nominated compressive strength is reduced. This relates to a cost saving benefit. As a consequence, the thickness of the walls is reduced which translates to an increase in floor area available which permits a higher real estate price to be achieved, which ultimately relates to a cost benefit.

Refer to the following for further Dincel cost savings.

(Download – Cost Saving Summary and Wall Comparisons)

(Download – Costing Analysis)

Other concrete related documents are available as follows:

(Download – Common Engineering Questions)

(Download – Dincel-Sustainable Concrete)

(Download – Dincel Fly-Ash Concrete)

(Download – Acid Sulphate Soil Damages)