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DINCEL STRUCTURAL WALLING

SOLUTION FOR HYDRO CARBON FIRE

The following document is recommended to be read in conjunction with **(Download – Dincel Wall Fire Assessment)**

INTRODUCTION

Existing and new structures are built to satisfy the Building Code of Australia, and the AS3600 Concrete Structures Code is not suitable in addressing the hydro carbon fires.

The power supply authorities, gas/oil companies or even building owners carry big liabilities and their insurance will not cover them if the protection walls around the assets have been built without considering hydro carbon fire. Specifying two or four hours fire resistance level to these walls surrounding the sources for hydro carbon fire is not an appropriate solution.

The temperature during a hydro carbon fire can reach up to 1300°C. The issue with a hydro carbon fire is not the intensity of the temperature reaching 1300°C, but how rapidly the fire temperature is increasing. This is the main difference between normal building fires covered by AS3600 and the hydro carbon fire.

The temperature of a hydro carbon fire can increase to 890°C in 3 minutes and 926°C in 5 minutes. This sudden increase in temperature is called thermal shock. Thermal shock would not be important in the case of a normal building fire (cellulosic fire) if there is no fuel source similar to hydro carbons. Cellulosic fires are those that are sustained by cellulosic products (e.g. timber, fabrics, paper, etc.). A cellulosic fire will take a minimum of 22 minutes to reach a temperature level of 800°C and 925°C in 60 minutes. Fire fuels such as oil, gas or chemical based materials cause a rapid temperature increase during fires due to their hydro carbon nature.

The reference "Fire Safety Design – Concrete Spalling Review – by Professor Gabrial Alexander Khoury and Dr Yngve Anderberg – June 2000" is a highly recommended paper to review to have a good understanding about concrete spalling behaviour in conventional building fires (i.e. cellulosic fire).

http://www.fsd.se/FoU/artiklar/Spalling-Review-Final.pdf

In a fire exposure, aggregates expand while the cement paste shrinks. This causes thermal incompatibility leading to spalling in a fire. These two effects (aggregate thermal incompatibility and steam pressure) are additive hence if one or both of them are reduced/eliminated the magnitude of thermal stresses leading to spalling is reduced.

When concrete structures are constructed, the object of AS3600 (or other similar codes) is to create denser concrete, i.e. limits the porosity of concrete for durability purposes. The denser concrete intends to limit the penetration of external contaminants such as water, CO_2 or gases reaching the steel reinforcement and starting the corrosion process. The corrosion that has initiated at the steel reinforcement expands and spalls the concrete and the life of the reinforced concrete is prematurely diminished.

Fire related spalling is attributed to the build up of **pore pressure**. The main factors which influence the pore pressure spalling are the permeability of concrete, moisture level of the concrete at the time of a fire and the rate of heating (e.g. hydro carbon fire). High strength concrete is believed to be more susceptible to this pressure build up because of its low permeability, compared to that of normal strength concrete.

The extremely high vapour pressure generated during exposure to fire cannot escape because of the high density and low permeability of high strength concrete. Low permeability (i.e. higher strength) is achieved by reducing the water/cement (W/C) ratio. Any W/C ratio less than 0.4 to 0.5 or compressive strength exceeding 55 Mpa is more susceptible to spalling.

Aggregate expansion during a fire also causes spalling. The likelihood of thermal stress spalling is less for concrete containing low thermal expansion aggregates. The risk of spalling is increased in the following order: lightweight (volcanic rocks, pumice, scoria, bottom ash), limestone, basalt and siliceous aggregates. However, this applies to concrete made with dry aggregates and concrete which are not subject to high humidity conditions (the waterproof Dincel Polymer prevents absorption of moisture through the capillary action of concrete, hence the use of lightweight aggregates together with Dincel's protection represent good value).

Aggregates expand whilst cement paste shrinks during the event of a fire. The smaller size aggregates reduce thermal expansion of the overall aggregate content which in turn assists in reducing spalling.

The moisture within the concrete can remain for a very long time. Also, concrete walls without membrane type finishes absorb moisture from the environment through capillary action (significant spalling occurs when relative humidity is higher than 80%). During a fire event, the moisture that is available within the concrete starts to evaporate after 100°C. The sudden steam pressure due to thermal shock increases within the denser concrete matrix and cannot escape, resulting in concrete spalling at thousands of locations in a rather violent manner. In this way the concrete wall loses between 25mm to 100mm of the surface when subjected to hydro carbon fires. This could result with the structural failure of the concrete wall depending on the wall height and the magnitude of load carried by the wall.

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SOLUTION

The recommended solutions may incorporate the following concrete mixes within Dincel-Forms.

The risk of spalling is reduced if the moisture is low and the permeability of concrete is high.

Alternative Type 1 Concrete Mix

The most effective way of avoiding this problem is to have a concrete mix with no-fine aggregate. Concrete without conventional sand, but with aggregates (e.g. bottom ash, volcanic pumice or scoria, i.e. very high heat resistant aggregates) of about 5mm in size achieves porous lightweight concrete. The porous and lightweight aggregates absorb the moisture and assist with the hydration process, and the excess water during the curing period dissipates easily because of the porosity of the concrete. The same porosity, i.e. openings between the aggregates allows steam pressure to escape easily during the thermal shock. This way, structural adequacy of the concrete wall in the absence of spalling is significantly increased. The concern for durability of this type of concrete would not be an issue as Dincel provides waterproof encapsulation to the concrete infill.

In the absence of fine aggregates the above described Type 1 concrete mix may not be pumpable. A concrete mix with no-fines would have been an adequate solution for hydro carbon fires if there was no necessity in using pumped concrete (i.e. construction in urban centres with cranes utilising gravity feed concrete supply). This represents problems for construction sites without cranes. Pumpability can be achieved by adding mixed fine aggregates to the concrete and polypropylene fibres. The above described concrete mix would represent the best possible solution, if only the availability of the abovementioned aggregates do not represent a problem. This depends on the location of the project and the position of the concrete supply.

Alternative Type 2 Concrete Mix

The alternative solution without the supply of fine lightweight aggregates and without a pumpability problem is to have a concrete mix made out of conventional sand + maximum quantity of fly ash + minimum quantity of cement + polypropylene fibres. Depending on the cement content, this concrete mix would normally have a low compressive strength, in the order of 6Mpa to 10Mpa. It is also possible to have fly ash concrete with 20Mpa to 25Mpa compressive strength. **(Download – Dincel Fly Ash Cement Concrete)**. Or alternatively air-entraining agents with polypropylene fibres and cement (with or without fly ash) + conventional sand can also be used as lightweight concrete. Therefore, alternative Type 2 concrete mix would be suitable to address the issue of thermal shock. Wall 'B' of the following Figure 1 or Figure 2 would be filled with this type of concrete mix. Wall 'A' would be filled with normal density/high strength concrete (or could be an existing wall) to resist blast loading.

Alternative Type 3 Concrete Mix

This alternative solution utilises concrete with conventional sand plus smaller size (5mm to 7mm) limestone, basalt type aggregates readily available by all major concrete suppliers in all locations. The concrete mix for both Walls 'A' and 'B' would consist of polypropylene fibres, with minimum W/C ratio = 0.40 and can achieve reasonably high compressive strengths. The alternative Type 3 concrete mix can be designed, similar to the Channel Tunnel Rail Link lining used between England and Europe to resist a hydro carbon fire. Refer "Fire Protection of Concrete Tunnel Linings" – Peter Shuttleworth, Rail Link Engineering, UK. This technology has also been used in Australia.

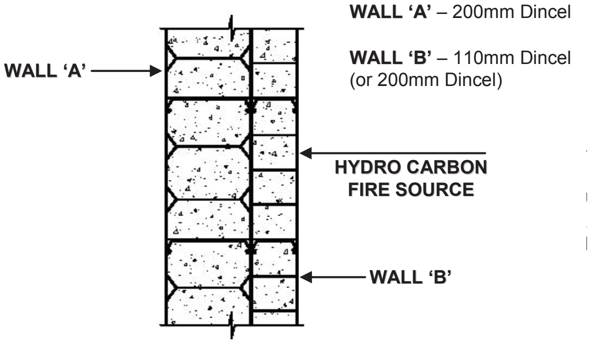

FIGURE 1 – DINCEL WALL PLAN

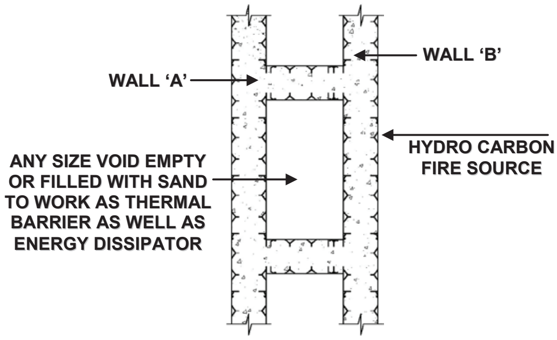

FIGURE 2 – DINCEL DIAPHRAGM WALL PLAN

WALL 'B' is a sacrificial wall against a hydro carbon fire. If extensive damage occurs, WALL 'B' can be replaced in any fire event without affecting WALL 'A'.

WALL 'A' + WALL 'B' resist blast loading.

The principle of steam pressure relief is based on the concrete mix incorporating polypropylene fibres. The fibres melt at 160°C and start to burn at their flash point temperature of > 360°C. The evaporation of fibres provides thousands of vents between the concrete body and outside environment within the first minute of a hydro carbon fire. In this way, the built up steam pressure as explained previously can be avoided. This is a proven technology and supply is available by major Australian concrete suppliers (refer DCS for contact details).

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The advantage of Dincel can be further appreciated for the subject topic in the following ways:

1. There is no durability problem that exists with Dincel as the product is already certified by CSIRO-Australia as waterproof. Dincel's life expectancy is minimum 100 years.

(Download – Waterproof Walls)

(Download – FAQ Sustainability Answer No: 6)

2. Dincel has an impervious permanent polymer formwork and as a result achieves no capillary action between the water of the concrete mix and the formwork. This means significantly reduced friction resulting in improved flowability characteristic; hence totally eliminating the possibility of honeycombing which is a major problem for durability and fire resistance.

3. Dincel polymer is a resilient polymer which adds significant ductility and impact strength to concrete during blast loading.

4. After 70°C Dincel's material will soften and the snapped joints will let out steam build-up within the Dincel enclosure. Dincel polymer will burn at about the flash point temperature of the polypropylene fibres which allows the venting of the built-up steam pressure as explained above.

5. Dincel's 200mm version has 4 hours fire resistance level (FRL) as tested by CSIRO in compliance with AS1530.4 Australian Standard. This FRL of 4 hours would not change if the above described concrete mixes are used with Dincel-Wall for the purposes of hydro carbon fires.

6. The fire characteristics of Dincel polymer's formulation are significantly superior to common thermoplastics. The material cannot initiate or continue to burn in the absence of a fire source. The Dincel polymer surface will char rather than melt and drip, hence eliminating the necessary oxygen source for it to continue to burn. The material therefore does not drip or melt. The material is identified as the equivalent of the BCA's deemed non-combustible materials. Refer **(Download – Dincel Wall Fire Assessment)**.

7. Dincel-Wall can be used in the following forms to achieve a significantly higher capacity in the case of hydro carbon fire + blast loading. Refer to appropriately qualified structural engineers or DCS (who are practicing structural engineers as well) for the use of the following options:

   (i) 110mm (or 200mm) + 200mm attached wall (refer Figure 1).

   (ii) Any combination of 110mm and 200mm Dincel Walls with cavities of any size between two skins of the wall, i.e. diaphragm wall construction (cavities between Dincel-Walls can be filled with energy dissipating materials such as sand) for walls of significant structural spans (refer Figure 2).

THE COMPLIANCE OF HYDRO CARBON FIRES WITH BCA

The Building Code of Australia refers to AS3600 Concrete Structures Code for "deemed to satisfy" conditions which apply to ordinary concrete with a thickness in excess of 170mm providing 4 hours FRL. This is misleading as AS3600 compliant concrete mix designs are not necessarily suitable for a rapid excessive temperature rise occurring during hydro carbon fires. The testing methodology of AS1530.4 is not a test for hydro carbon fires; it is a test for cellulosic type fire conditions since the temperature increase by the gas burners of the testing facility simulates the temperature characteristics of cellulosic fires. Concrete spalling associated with rapid temperature increase can be reduced to an acceptable level (i.e. similar to cellulosic fires) if the built-up steam pressure is vented out from the concrete matrix. Conventional concrete does not have this capability in the event of hydro carbon fires. **Therefore, new or existing buildings consisting of ordinary concrete without a venting facility are not adequate in resisting hydro carbon fires, depending on their moisture content at the time of the fire** (i.e. high moisture content may exist even for 20 year old concrete since it will absorb moisture due to capillary action if exposed to relatively high humidity weather conditions).

Hydro carbon fires are not only limited to tunnels or oil platforms. The following buildings or their components are subject to the Building Code of Australia requirements which are strictly subject to cellulosic fires, not hydro carbon fires. It is therefore important to define the fire source and use the above recommended solution.

- Sub-stations, particularly around the transformers.
- Petrol/diesel use or storage facilities, i.e. service stations, refineries and equipments utilising petrol/gas use, e.g. central heating equipments, boilers, etc. (plant rooms of buildings).
- Paint, flammable chemical and explosive goods storage facilities.
- Gas and oil pipe supply breakdown in building structures after natural disasters such as earthquakes.

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SUMMARY CONCLUSION

The issue of hydro carbon fire damage is somewhat overlooked and there is no provision in AS3600 or the BCA to warn designers.

The very rapid temperature rise of hydro carbon fires generates internal pressures significantly above the tensile strength of concrete. This pressure build-up must be relieved to prevent structural damage. This can only be achieved by venting out the steam pressure built-up. The following factors will contribute to venting:

- Use of polypropylene fibres.
- Porous concrete (Dincel eliminates durability concerns and allows lower W/C ratio and porous lightweight aggregates).
- Moisture content of the concrete at the time of fire (ambient moisture absorption by the structure is prevented by Dincel).

The above explanation is intended to warn the construction industry that normal or high density concrete as required by AS3600 should not be used without a venting facility where rapid temperature rise could happen as in the case of hydro carbon fires. It is equally important that the concrete, irrespective of its mix design, should be protected against moisture ingress. The structures exposed to high relative humidity, particularly in coastal regions, will be vulnerable to significant hydro carbon fire damage if they are not protected against moisture ingress during the life of the structure.

Existing structures with conventional concrete or block walls can be upgraded by attaching the appropriate thickness of Dincel-Wall (110mm or 200mm) with the above described concrete mixes (Alternatives 2 or 3) to achieve the required resistance for hydro carbon fires.

Building designers and building owners may therefore possibly be subjected to potential liability if the structures they get involved with are subjected to hydro carbon fires and the concrete of their fire walls do not consist of the abovementioned or similar provisions.

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