DINCEL STRUCTURAL WALLING

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LEAKY BUILDINGS – ARE FIBRE CEMENT SHEETS SUITABLE?

PURPOSE

This document addresses the question whether fibre-cement sheet incorporating organic wood fibres is an appropriate building material if and when fibre-cement sheet are subjected to water contact conditions (including the case where fibre-cement sheets are used as permanent formwork for concrete walls (Download – Non-Compliant Products).

Consumers are protected by the Australian Worker Health and Safety Act 2011 where manufacturers are now required to clearly state the limitations of their products. The Act also stipulates "Responsibilities Are Not Transferable". This means that manufacturers, certifiers, specifiers, designers and builders are individually responsible for the product used in the construction.

If you have any doubts, ask the authorities for product safety/compliance/complaints at http://www.productsafety.gov.au/content/index.phtml/itemId/977131

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(1) PREFACE

The Leaky Building Syndrome commonly observed in New Zealand is also occurring in Australia.

"Leaky Building Syndrome" is the phenomenon where water/moisture is held within the building envelope leading to biological and chemical degradation of building materials which results in reduced building life and sick building syndrome. Refer **(Download – "Indoor Air Quality, Condensation, Mould and Mildew")**.

The problem associated with Leaking Building Syndrome is relevant to all porous building products including bricks, blocks and fibre-cement sheets. Provisions such as paints, renders and the use of water repellents are inadequate to avoid the problem. **The root of the problem associated with fibre-cement sheets is that the sheets are manufactured consisting of organic wood fibres and is porous.** When asbestos was banned in Australia/New Zealand, fibre-cement sheet manufacturers chose to use significantly cost effective fibres extracted from Pinus Radiata wood chips. The common problems associated with the use of fibre-cement sheets consisting organic fibres are:

1. Mould generation due to biological degradation of the organic fibres.
2. Chemical degradation of organic fibres within a high alkaline environment.
3. **The problem is further exacerbated when fibre-cement sheets are used as permanent concrete formwork.**

The problems associated with leaky buildings are well within New Zealand's public awareness. **A search will reveal private home owners and the New Zealand Government's legal action against some major material supply companies for their product failure. It has been argued by the cladding product manufacturers that the fault is not in the product but with the installation of the product.** The product manufacturers blame the installers/builders for faulty construction for the leaky building syndrome.

Fibre cement sheets are porous building cladding materials. **Water repellents and paints are used to minimise water/moisture transmission through the body of the sheet. As explained later in this document, these measures become ineffective, particularly when the sheets are subject to prolonged water/moisture exposure and when fibre cement sheets are used as a permanent formwork for concrete.** When cellulosic fibres are subjected to water, fungi-bacteria related biological degradation and chemical degradation within high alkaline water conditions occurs. Currently, all Australian and New Zealand fibre cement sheets are produced using wood fibres since the use of asbestos was banned. Firstly, water causes volume changes introducing internal stresses. Secondly, water promotes alkaline attack to the cellulose fibres thus reducing the toughness. Finally, water retention or dampness makes fungi growth possible. This negatively contributes to the joint performance of fibre cement sheets which is also affected by shrinkage-expansion and building related movements resulting in leaky joints, i.e. joint openings allowing water/moisture ingress into the building envelope.

(2) INSURANCE

All consultants, builders, product manufacturers and end users to be aware that building products displaying "actual, potential, alleged or threatened formation, growth, presence, release or dispersal of any fungi, moulds, spores or mycotoxins of any kind" are now excluded in the new insurance policies.

"Refer – Tasman Underwriting, Clause 2.16 – LLOYDS" http://tasmanunderwriting.com.au/assets/tasman2011miscPlwdgMay11GRN.pdf

(3) WHAT CAUSES THE PROBLEM WITH FIBRE-CEMENT SHEETS

The cause of the problem is that fibre-cement organic fibres are subjected to prolonged damp conditions which are direct water contact, freezing/thawing, contact with ground conditions, leaking pipes and allowing the fibre-cement sheets as formwork for concrete infill.

Building walls in Australia are allowed to utilise fibre-cement sheets in the following ways:

1. **Dry Wall Construction** – This system consists of fibre-cement sheets attached onto a metal or timber frame. The cavity between each face of the dry wall can be filled with foam or a wool type insulation material or can be left as a void. The joints of the sheets are set and the faces are finished with an appropriate type of paint or coating (i.e. render) system. **This type of use is described as DRY WALL construction in this document**.

   Fibre-cement sheets incorporating natural fibres used in DRY WALL construction are affected by the environmental temperature and humidity conditions (e.g. New Zealand's climate – freeze-thaw condition, high moisture). New Zealand's Dry Wall construction having a leaky building can be more related to fibre-cement sheets loss of toughness, with sheet joints allowing rain water/moisture into the building envelope. In fact, the New Zealand case is testimony that fibre-cement sheets are not suitable in providing effective weather tightness).

2. **Concrete Wall** – This system consists of fibre-cement sheets as permanent formwork to accommodate concrete infill. **This type of use is described as FC WALL construction in this document**.

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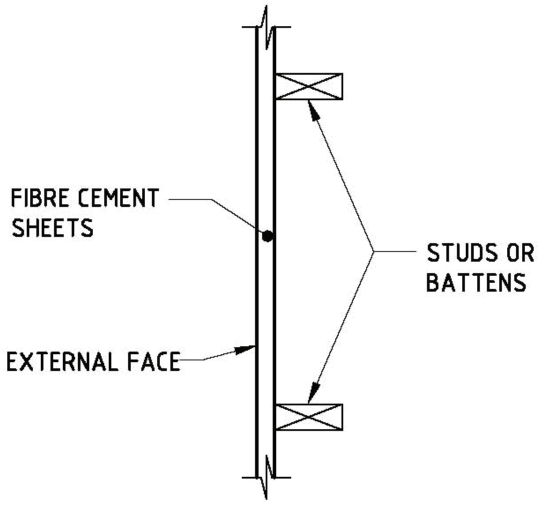

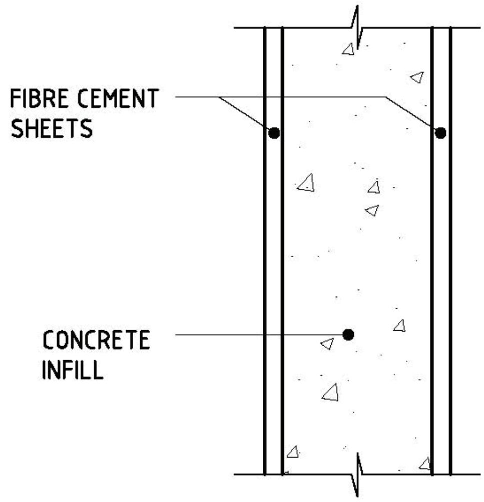

DRY WALL	CONCRETE (FC) WALL
✓	✗
Subject to fibre cement sheets are not In direct contact with water and/or prolonged damp conditions.	**Water from wet concrete results in alkaline condition of pH > 12 and causes biological and chemical degradation of fibre cement sheets.**

Organic fibres used in the production of fibre-cement sheets consist of cellulose, lignin and hemicellulose. The most widely used Pinus Radiata wood chips in Australia and New Zealand fibre production consist of 42% cellulose, 29% lignin, 7% hemicellulose plus some extracts. Lignin and hemicellulose are mainly responsible for biological degradation. **Hence the chemical process (mainly Kraft process in Australia and New Zealand) consists of a hot (about 170º) caustic soda and sodium sulphide solution which is used to separate lignin, hemicellulose and other extracts from cellulose fibres (about 50% cellulose fibres are recovered).**

The durability of fibre-cement sheets are affected in two ways:

(i) **Biological Degradation** (i.e. presence of organic matters such as lignin). The photos shown in this document are of fibre-cement sheets manufactured in Australia displaying biological degradation, i.e. mould and mildew development.

To avoid mould problems when fibre-cement sheets are used, contact with water must be eliminated. Just because something gets wet, it does not mean that it will get mouldy. It needs to be wet for a period of time. Wet paper needs to be wet for a couple of days. Wet wood needs to be wet for a few weeks. Fibre-cement sheets is in between or similar to paper or wood.

Cellulose can serve as a source of energy to many organisms, including fungi and bacteria. Fungi growth reduces the aesthetic performance of fibre-cement products and increases their absorbance to solar radiation which greatly reduces the energy efficiency of the building and further contributes to urban heat islands.

(ii) **Chemical Degradation.** High alkaline conditions occur when Portland cement within the fibre-cement sheet is in contact with the water. The reaction releases calcium hydroxide to the contact water (pH ~ 13.5). The high alkalinity of water (PH>12) in the pores of cementitious matrix weakens the cellulose (which may also include lignin fibres), induces mineralisation and, consequently, yields to decay of the composite tenacity in the long term. Contact with water for a prolonged time results in volume changes of the porous cement matrix and the hydrophilic cellulose fibres cell wall. The result is disjointing of the reinforcing elements and degradation of the composite material properties. (Refer attached extract from G.H.D. Tonoli, Filho, Savastano, Belgacem, Lahr). In the fibre cement system, chemical degradation would be more significant than biological degradation due to the high alkaline environment.

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(4) QUESTIONS AND ANSWERS

(i) Does the chemical pulp (Kraft) process remove lignin and hemicellulose from cellulose fibres? Lignin and hemicellulose are mainly responsible for biological decay hence the reason for the Kraft process mainly used in Australia and New Zealand. It is not possible to remove all lignin during chemical pulping, therefore all unbleached chemical pulps (bleaching is used to get a white colour in paper manufacturing) contain some residual lignin which is brown in colour. The Kraft process for fibre cement use appears not to incorporate the bleaching process. Therefore, if lignin cannot be removed, biological degradation occurs as shown in the following photos.

(ii) What quantity of water is required to cause problems?

The relative humidity of RH 90% represents 3% of moisture content in concrete and 15% of moisture content in fibre boards as confirmed in Figure 1.1 of Straube, J – Moisture Properties of Plaster and Stucco for strawbale buildings, Canada Mortgage and Housing Corporation, Research Report 00-132, 2000, http://homegrownhome.co.uk/pdfs/Straube_Moisture_Tests.pdf Concrete can be considered fully saturated with about 5% of moisture content.

Concrete mixes typically consist of an average of 11% free water by volume (which does not combine chemically with cement) as in the case of concrete within FC WALLS with the water and cement ratio W/C of 0.5; more free water if W/C > 0.5. The question of whether this quantity of water is adequate for fungal growth is also confirmed in the document **Dampness and Mould, World Health Organisation (WHO), Guidelines For Indoor Air Quality** in Table 1, page 12 shows that 80% relative humidity which represent less than 3% moisture content is adequate in promoting fungal growth. http://www.euro.who.int/__data/assets/pdf_file/0017/43325/E92645.pdf

Lstiburek J. 2002 – Moisture Controls For Buildings - ASHRAE Journal, February 2002, page 36 states that the relative humidity of 70% results with 16% moisture content which will initiate mould growth within 72 hours for a typical softwood.

It is therefore obvious that if 3% moisture content in concrete and 16% moisture content in softwood causes fungal growth as reported by WHO and Lstiburek, 11% water by volume from the concrete mix of FC WALLS will cause (even if the effects of relative humidity are ignored) more fungal/bacterial growth since 11% water will not dissipate in a short space of time and degradation of cellulosic fibres is unavoidable.

(iii) Why chemical degradation occurs?

Dry Wall Construction:

The moisture/water, with sufficient time and quantity, in contact with the hardened Portland cement of fibre-cement sheet releases alkaline calcium hydroxide to the water. The final solution represents pH ~ 13.5 which is the reason for the chemical degradation in dry wall construction.

FC Wall (fibre-cement sheet as formwork) Construction:

Free (or excess) water (11% by volume for W/C = 0.5; noting that the concrete industry commonly use W/C = 0.55 ~ 0.7) does not combine chemically with cement which is referred to as "bleed water" and is highly alkaline (pH ~ 13.5) due to free potassium and sodium hydroxide in the solution. The bleed water will be absorbed by the capillary action of porous fibre-cement sheets used as a formwork for concrete mix.

When bleed water from the concrete mix (already high alkalinity) is in contact with the hardened Portland cement of the fibre-cement sheet it further releases calcium hydroxide, thus exacerbating the chemical degradation of fibre cement.

Therefore, the above provides an alkaline environment of pH > 12 and the water from the concrete mix alone, without the moisture contribution of an ambient environment is more than enough to conclude that FIBRE-CEMENT SHEETS ARE NOT SUITABLE FOR PERMANENT CONCRETE FORMWORK PURPOSES.

(iv) Would Water Repellents be sufficient to prevent water/moisture penetrating into fibre-cement sheets?

The problems of using fibre-cement sheets in dry wall construction, such as cladding are minimised with the application of water repellent treatment to the face exposed to a moisture source, i.e. rainwater, moisture ambient conditions. The water repellents improve the hydrophobicity of the fibre-cement sheets against normal atmospheric conditions at façade walls.

All technical recommendations about fibre-cement sheets state that the product must be used away from moisture sources (e.g. liquid water, clearance from ground condition is required where water can be absorbed by the capillary action).

Water repellents on fibre-cement sheets are introduced to minimise the ingress of moisture originating from ambient conditions. The important issue to understand is that water repellents are not a replacement for waterproof membranes to protect fibre-cement sheets against direct contact with water (e.g. being in contact with the ground or fibre-cement sheet used in direct contact with wet concrete mix).

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Water repellents can be applied to fibre-cement sheets as additives (i.e. embedded into fibre-cement sheet material) or applied via post-treatment. Water repellents work by repelling water while still allowing the sheet to breathe. Water repellent means that it is hindering the penetration of water – it does not mean that it is entirely waterproof. Water repellents as additives into the core of the fibre-cement sheet would be preferred. However, even the best form of water repellents performance depends on the period and quantity of the contact water. **The following extract from B.R. Babic (refer attachments at the end of this document) consists of statements that water repellents' effectiveness depends on water contact to the cellulosic fibres being prevented**.

The following Photo No: 2 of a Sydney-Homebush Bay Region Apartment are from a project consisting of FC WALLS incorporating water repellents (embedded into the core of the fibre-cement sheet) showing significant fungi development. **(The question is what magnitude of corrosion is taking place in the metal studs behind the fibre-cement sheet showing this degree of fungal development that is open to the exterior environment)**. Therefore, it should be clear that cellulosic fibres should not be allowed to be in contact with water for prolonged periods as in the case of FC WALLS. It is also clear that even membrane types of paint on fibre-cement consisting of water repellents, in the case of FC WALLS, will not help in avoiding this problem since the problem comes from the presence of 11% free water of the infill concrete mix. External paints can only slow the penetration of the external moisture into fibre-cement sheets subject to ongoing paint maintenance.

Fibre-cement sheets with water repellents and coating systems can be effective in the case where the Dry Wall is not in direct contact with water. As stated before, when the fibre-cement sheet joints open (structural, shrinkage/temperature, biological – chemical degradation related volume changes, hence loss of sheet toughness) allowing water/moisture directly into the building envelope through the joints of Dry Wall construction and the water repellents are therefore useless in the case of FC Walls as explained above.

(v) Would Paint/Render be sufficient to prevent water/ moisture penetrating into fibre-cement sheets?

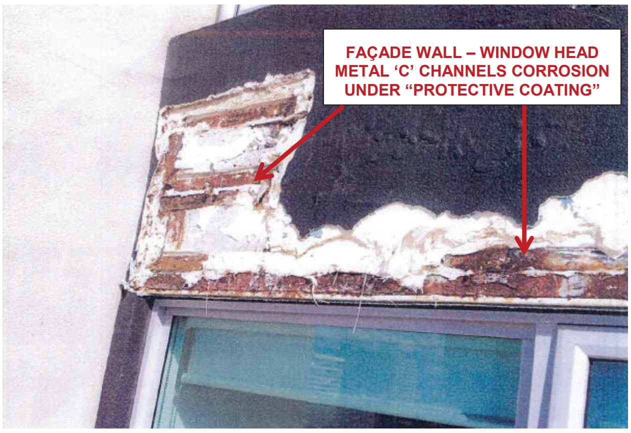
Not all commercial paints (except membranes) and renders are breathable. Rrefer **(Download – FAQ, Sustainability Questions, Q11)**. When paint/renders utilise silicone based membrane paint with adequate dry film thickness and appropriate workmanship skill (which is hard to find) as top coats, the ambient vapour transmission into the fibre-cement sheet is limited subject to ongoing paint maintenance. Otherwise the majority of ambient moisture penetrates through the breathable paint and the porous fibre-cement sheets of a DRY WALL Construction and dissipates during the drying phase. This behaviour does not normally represent a problem in a DRY WALL Construction unless prolonged damp conditions prevent the drying of the fibre-cement sheets and the cavity of the dry wall is well ventilated. However, if the same external wall consists of a FC WALL, water from the wet concrete mix will be absorbed by the fibre-cements of a FC WALL.

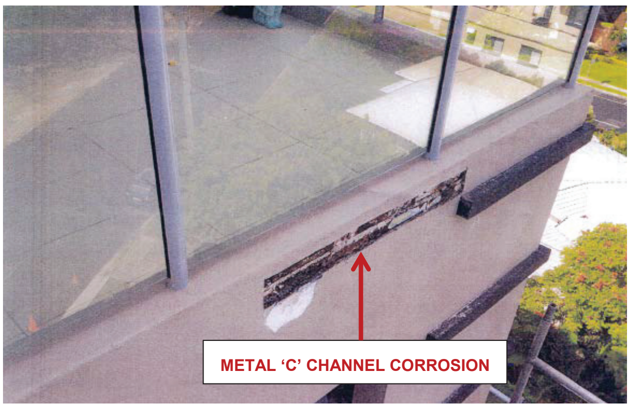
Building codes require vapour barriers on the warmer face of the façade wall which can be the interior or exterior of the wall, depending on the climatic conditions. Building codes do not recognise paints as a VAPOUR BARRIER.

Any doubt, ask the paint render suppliers for a guarantee stating that their product as installed condition will provide total imperviousness for air transmission. Refer following Photo No: 1.

PHOTO NO: 1

"PROTECTIVE COATINGS" (i.e. renders are porous and cannot provide protection to the underlying FC Wall)





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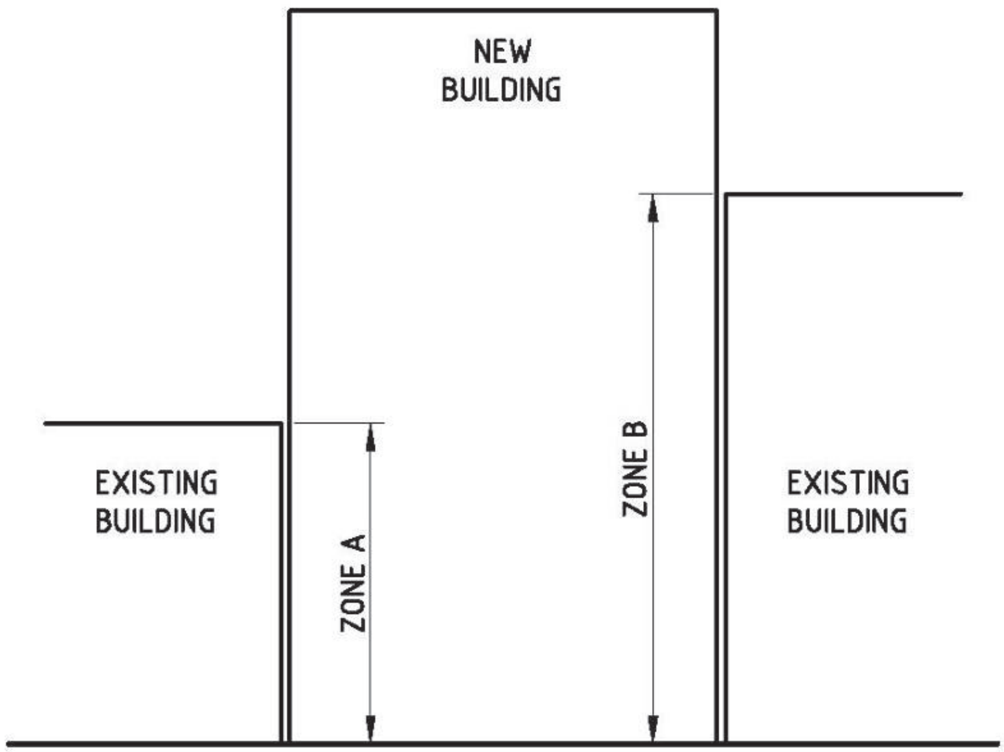
Walls of a new building as shown in the diagram below, having concrete façade FC walls incorporating fibre-cement sheets as permanent formwork, will have no protection offered by external coating systems, particularly when Zones A and B of the below diagram have no adequate access.



CONSTRUCTION AGAINST EXISTING BUILDINGS

(5) ARE FIBRE-CEMENT SHEETS SUITABLE FOR PERMANENT CONCRETE FORMWORK PURPOSES?

NO. Fibre-cement sheets are developed for the cladding of dry wall construction and NOT suitable for prolonged damp conditions such as permanent formwork.

Item No: (3) (iii) – QUESTIONS AND ANSWERS shows that the FC Walls are subjected to more than enough water to cause biological and chemical degradation of fibre-cement sheets.

Refer to the following Photo No: 2 showing an external façade FC WALL of an apartment complex with extensive mould infestation in only a short period of time after its completion. These photos demonstrate the effect of wet concrete as a water source (Sydney – Homebush Bay Region – period between October 2011 and February 2012). The extensive fungal activity is obvious at the external wall's face of the property where the wall is exposed to open air. A property subjected to this type of fungal infestation would cause sick building syndrome

(Download – Indoor Air Quality, Condensation, Mould and Mildew)

Fibre-cement sheet usage as a building façade cladding is not allowed by fibre-cement sheet manufacturers if the product is subjected to FREEZING – THAWING which causes a water source for mould, mildew and reduction in the materials' mechanical properties. The use of fibre-cement sheets is not allowed for temperatures below 0°C by many fibre-cement sheet manufacturers. **Australian regions such as Canberra where the average daily temperature drops below 0°C should therefore not use fibre-cement sheets, particularly for permanent concrete formwork purposes.** (Refer fibre-cement sheets' manufacturer's warranty at the end of this document).

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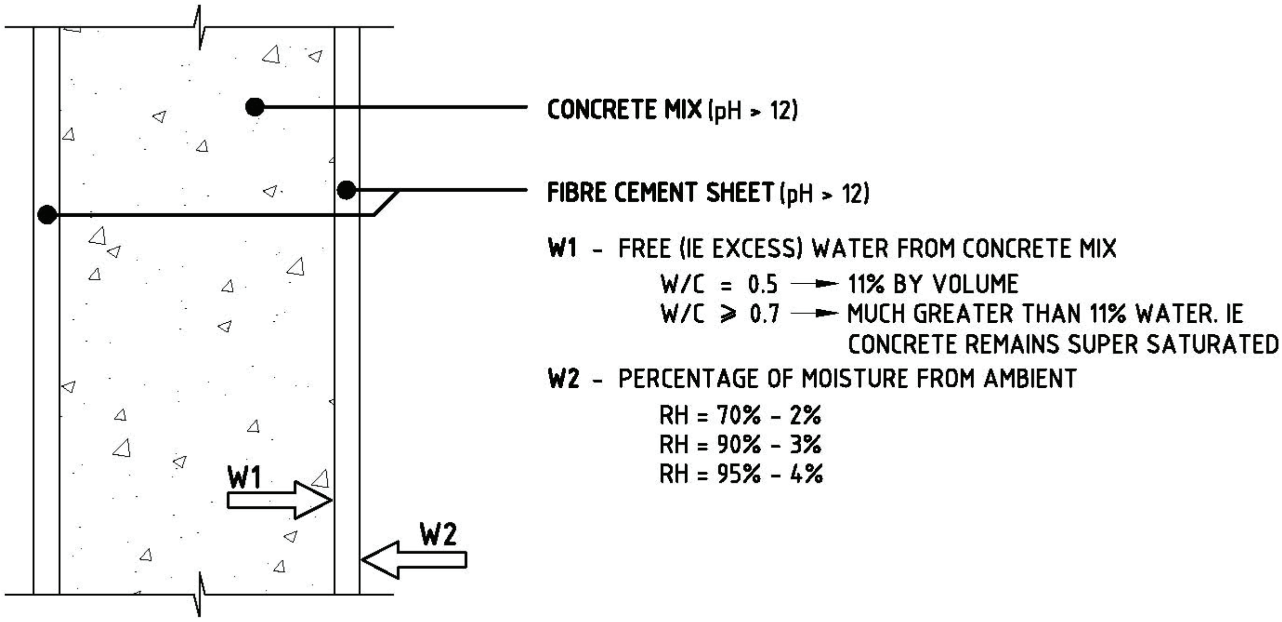
Water absorption is an important degradation factor with fibre-cement products, especially the ones using hydrophilic fibres like cellulose as confirmed by the fibre-cement sheet manufacturers. Refer to the following abstracts as reference. These conditions are possible when fibre-cement sheets are used as permanent concrete formwork because water from the concrete mix provides sufficient water source.



FC WALL

CONCRETE WITHIN THE PERMANENT FIBRE-CEMENT SHEET AS FORMWORK

When concrete is permanently encapsulated with fibre-cement sheets containing organic fibres, there is adequate water for a very long period of time to cause biological and chemical degradation. **Refer previous Item 4 (ii) – What quantity of water is required to cause problems?**

Externally applied water repellents, paints, renders, vapour barrier-silicone paints may significantly reduce the intake of water (W2 of the above diagram) CO_2 and chlorides in the body of the fibre-cement sheet after their application, but also prevents W1 from escaping from the FC Wall as well. In any case, W1 of the above diagram only needs a couple of weeks to start the degradation process.

The FC Wall illustrated in the diagram below can exacerbate the MOULD/FUNGUS problem due to the reasons explained below.

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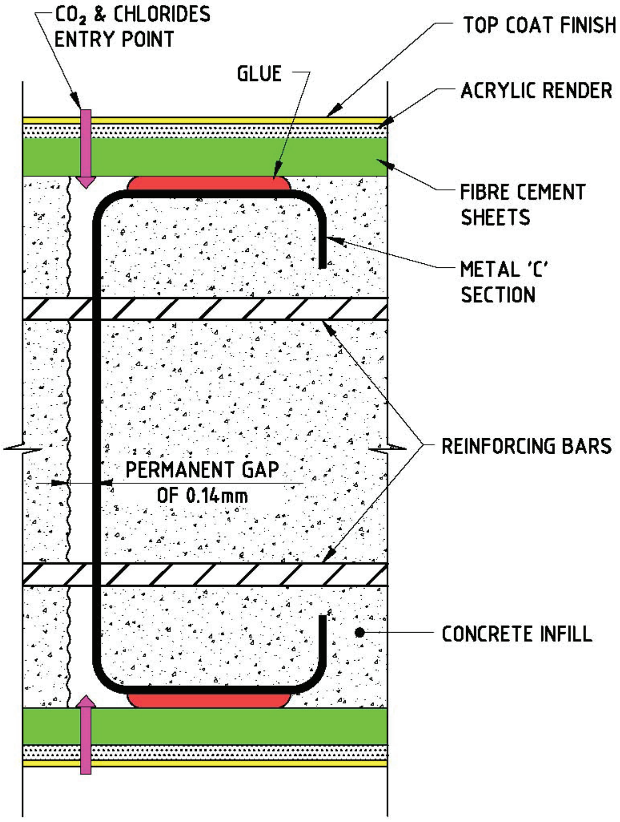

FC WALL – TYPICAL SECTION

- Metal is a thermal conductor; hence the metal 'C' sections shown will act as a thermal bridge.
- It is common knowledge that where a thermal bridge exists, condensation, mould and mildew will occur.
- Honeycombing (i.e. Air Voids) associated with FC Walls are shown in the following Photo No: 3. This is a common problem associated with porous materials. The masonry block industry wet the blocks prior to concrete pouring. The saturated blocks do not suck much water from the wet concrete mix and the high slump of concrete in the vicinity of 200mm and good vibration assist to somewhat reduce (problem is not eliminated) the air voids/honeycombing problem in the masonry block wall. FC Walls are delivered to the site with plastic wrapping (represents dry condition at the time of installation). If the dry fibre-cement sheets, without prior wetting, receive concrete mix, particularly slumps of less than 200mm, irrespective of the vibration, the hydrophobicity nature of fibre-cement will suck the water from the concrete mix and the resultant effect is unavoidable honeycombing. Photo No: 3 is from a North Sydney, NSW property – Tier 1 builder, installation by an experienced installer of FC Walls which demonstrates that the problem is not workmanship but material related. **This raises the question of whether fibre-cement sheets, particularly in the case of FC Walls (i.e. system consisting of metal 'C' sections) is a suitable material for concrete formworking. The available technical literature also suggests that fibre-cement sheets are developed for dry wall conditions, and not for concrete formwork purposes.**

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(6) SOLUTION

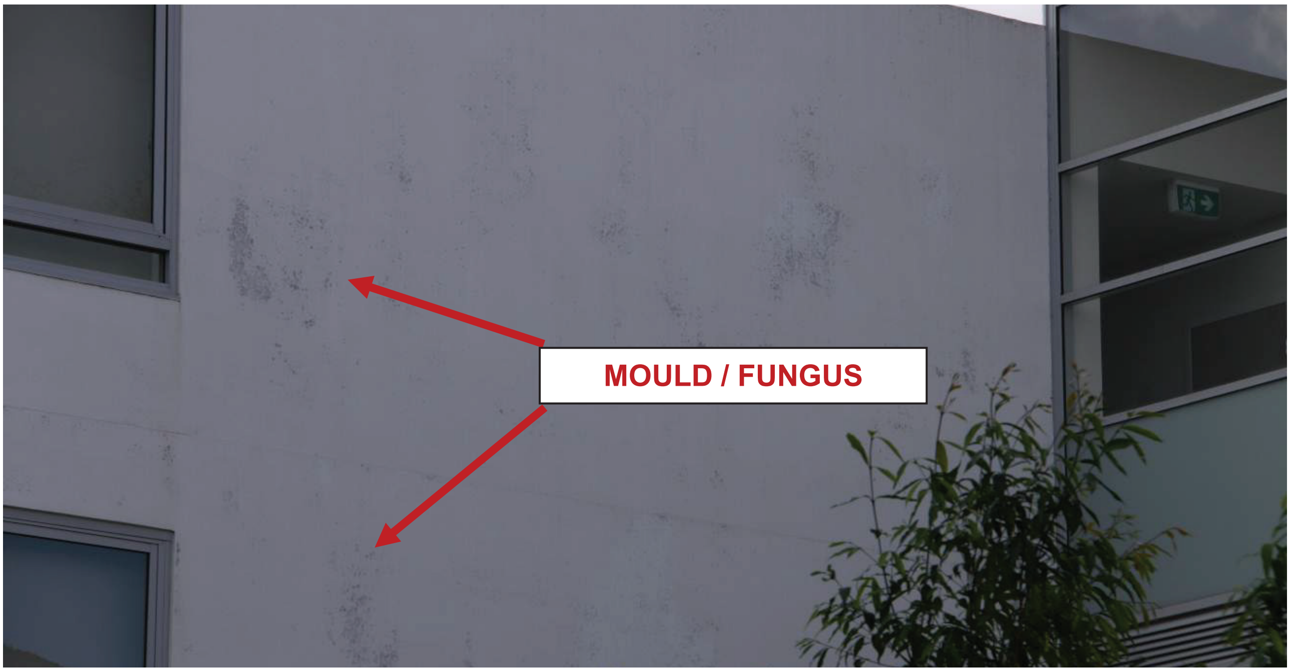
The solution is in the detailing and appropriate material selection. Look for alternatives and new technologies.
The following offers a solution to not only Leaky Buildings but to condensation, finishes and skilled labour as well.

(Download – Finishes)

(Download – Indoor Air Quality, Condensation, Mould and Mildew)

PHOTO NO: 2

RENDER PROTECTION CANNOT ELIMINATE MOULD/FUNGUS DEVELOPMENT ON FC WALLS



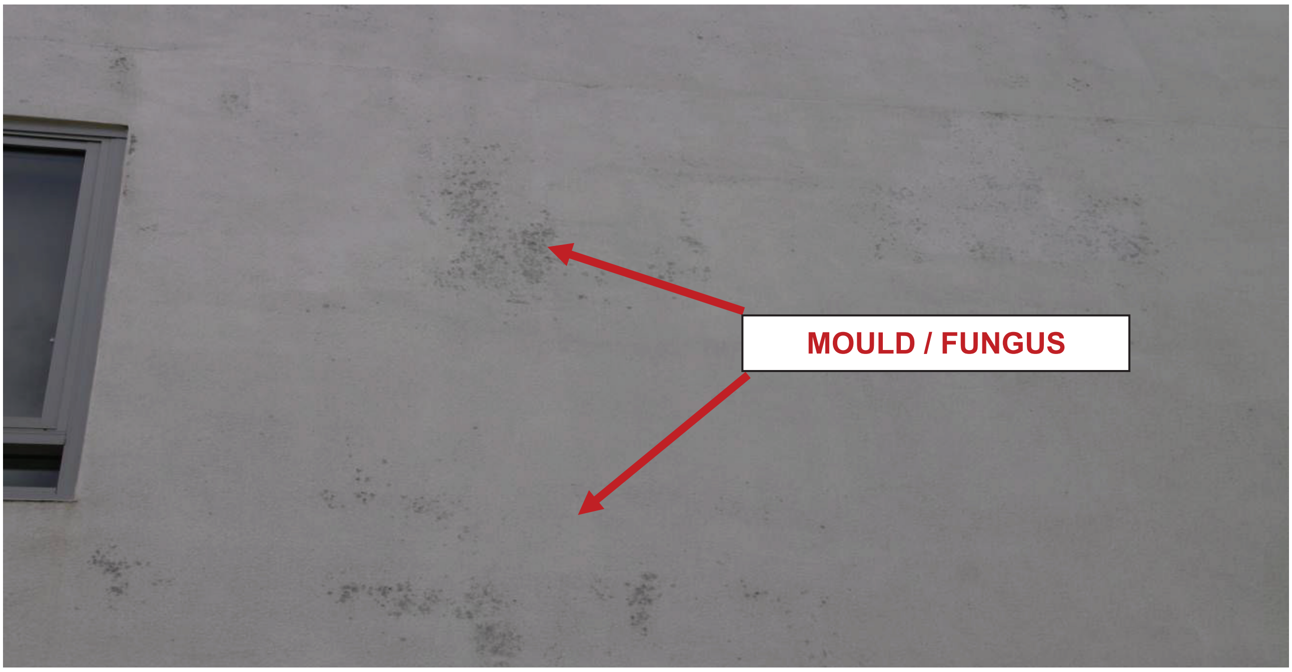


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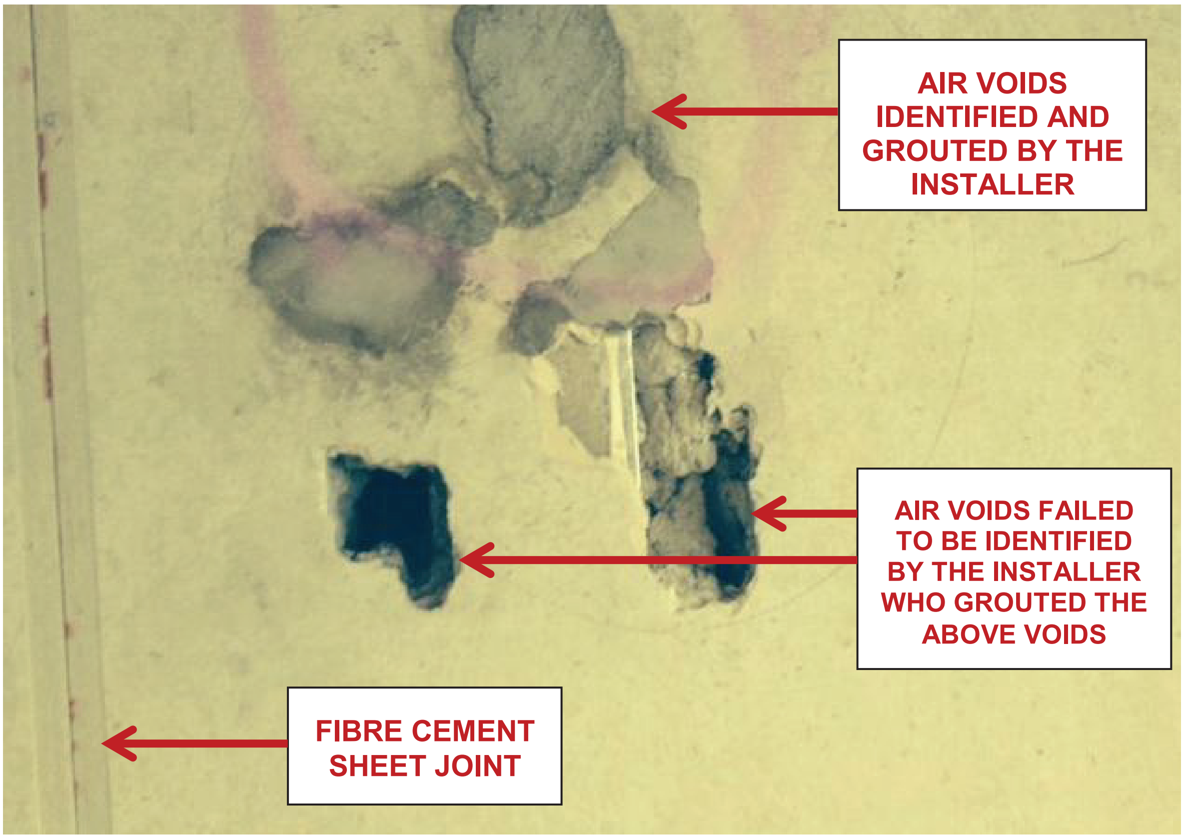
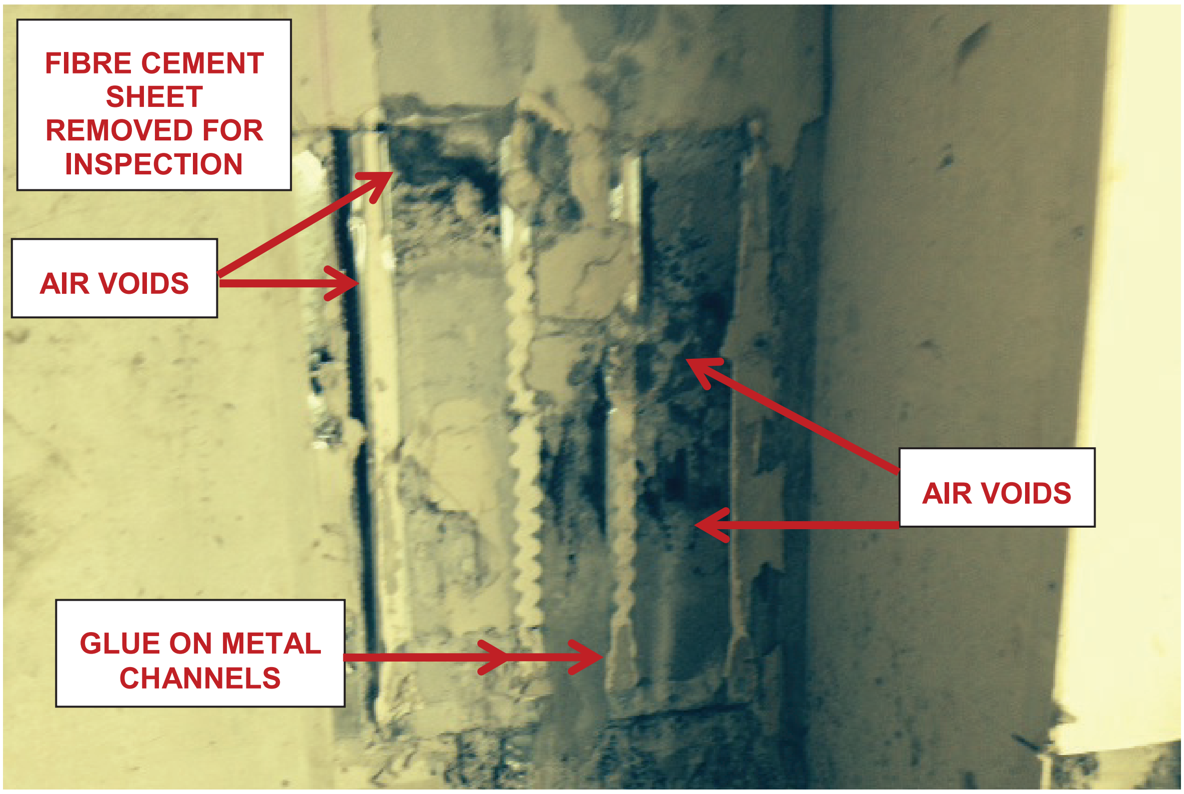
PHOTO NO: 3

AIR VOIDS CAUSE CORROSION
(PHOTOS FROM A BUILDER OF A SYDNEY PROJECT THAT HAS USED FC WALLS)





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Cellulose modified fibres in cement based composites

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ABSTRACT

The objective of the present work is to evaluate the effect of surface modification of cellulose pulp fibres on the mechanical and microstructure of fibre–cement composites. Surface modification of the cellulose pulps was performed with Methacryloxypropyltri-methoxysilane (MPTS) and Aminopropyltri-ethoxysilane (APTS) in an attempt to improve their durability into fibre–cement composites. The surface modification showed significant influence on the microstructure of the composites on the fibre–matrix interface and in the mineralization of the fibre lumen as seen by scanning electron microscopy (SEM) with back-scattered electron (BSE) detector. Accelerated ageing cycles decreased modulus of rupture (MOR) and toughness (TE) of the composites. Composites reinforced with MPTS-modified fibres presented fibres free from cement hydration products, while APTS-modified fibres presented accelerated mineralization. Higher mineralization of the fibres led to higher embrittlement of the composite after accelerated ageing cycles. These observations are therefore very useful for understanding the mechanisms of degradation of fibre–cement composites.

1. Introduction

Cellulose fibres are widely available in most developing countries from wood or annual plants. They present several interesting advantages particularly their low density, their bio-renewable character and their availability everywhere at modest cost and in a variety of morphologies and aspect ratios. All these properties make them convenient materials for matrix reinforcement, such as polymer composites or fibre–cement applications, as witnesses the significant number of recent reviews and special issue publications [1–4]. The main drawback associated with cellulose fibres in cement application is their durability in the cementitious matrix and also the compatibility between both phases [5]. In fact, the high alkalinity of water in the pore of the cementitious matrix weakens the cellulose fibres, induces their mineralization [6,7] and, consequently, yields to the decay of the composite tenacity in the long term. Moreover, the severe weathering conditions to which the composite is exposed induce water uptake and release of the composite, which results in continuous volume changes of the porous cement matrix and the hydrophilic cellulose fibres cell wall. It has been observed, as a consequence of these cycles of water uptake and release, a loss of adhesion at the fibre and cement interface, resulting on disjointing of reinforcing elements and degradation of composite mechanical properties [8].

Several approaches were reported on the use of chemical surface treatment on cellulose fibres to reduce their hydrophilic character and improve their adhesion on the matrix [9]. They were all based on exploiting the reactive hydroxyl functions of the fibre's surface through different chemical procedures, such as esterification, etherification, and urethane formation, among many others. The blocking through chemical pathways reduces the number of reactive hydroxyl groups concomitant with the formation of bonds between the cellulose fibres and the cementitious matrix, resulting in the diminution of the water absorption and in improvements of the mechanical properties of the composite.

The use of silane coupling agents is a very well-known practice in glass-fibre based composites and silica-filled polymeric matrices [10]. These chemicals were applied to cellulose fibre-reinforced polymeric composites [11] and carbon fibre-reinforced cement paste [12], as well as in wood fibre–cement materials [13,14]. Although the innovative character of these reports, there is still a relevant lack of information. For instance, the most appropriate silane and the best grafting conditions which ensure a good adhesion between the fibre and the cement matrix and a significant reduction of the fibre's hydrophilic character. Moreover, the stability of the fibre's modification can be questioned under the composites processing conditions, namely, during the de-watering and

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SILICONE WATER REPELLENTS FOR (FRC) FIBER-CEMENT BOARDS

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ABSTRACT
Fiber Reinforced (FRC) Composites, commonly referred to as Fiber-Cement boards and panels, are finding increased usage globally for applications in siding, roofing and other exterior applications because of their ability to provide a cost-effective, durable and substantial covering. Water absorption is an important degradation factor with fiber-cement products, especially the ones using hydrophilic fibers like cellulose or wood particles. First of all, water causes volume changes, introducing internal stresses. Secondly, water promotes alkaline attack to cellulose fibers, reducing the toughness. Finally, water retention or dampness makes mould growth possible. Mould growth reduces the aesthetic performance of the fiber-cement products and increases their absorbance to solar radiation, which greatly reduces the energy efficiency of the building and further contributes to urban heat islands. Silicone based water repellents are well established in the industry, and have been successfully used to improve the hydrophobicity and durability of gypsum boards. The ability of silicones to efficiently hydrophobe surfaces, and their excellent durability against UV, heat and other environmental conditions makes them a natural fit for use on fiber-cement products. To date, however, silicone-based products have not been widely used in finer-cement applications, and they are mostly employed as additives or primers. This paper presents results of a joint project between Dow Corning Corporation and the University of Sao Paulo to evaluate hydrophobic properties of fiber-cement products treated with silicones. Results are presented for a variety of silicone based materials such as silanes, polysiloxanes and their combinations. The silicones are either used as admixtures or applied via a pos-treatment.

THE USE OF CEMENT FIBRE COMPOSITES IN PROLONGED WET ENVIRONMENTS

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Abstract
Over the last twenty five years or so, studies have been conducted on a number of issues relating to cement bonded aggregate and fibre additives. Experiments with various additives to mortars made possible the incorporation of cellulose into mortars and concrete mixes and milled straw and aggregate building blocks were manufactured. The StrawCrete blocks were positioned in a shaded section of the site where the material once soaked took time to dry so that the materials remained wet for prolonged periods. The study continued for over ten years during which it become obvious that the superficial cellulose particles become degraded and supported fungal growths.

Experiments with other cement bonded fibre composites demonstrated a similar fall out of fibers into the environment due to the degrading cement matrix so that fibre contamination occurs across the product range in wet environments. Where the fibers such as asbestos, known to have health concerns are involved, important legal obligations arise that reflect on the manufacturers responsibilities.

Follow up experiments were conducted to reduce the rate of matrix degradation and a series of tests using mortars with increasing porosity and an integral water repellent additive which prevented prolonged wetting was assessed. The addition of the experimental additive did not interfere with the cementing properties of the portland cement used and the crushing strength of the resulting mortar reflected the properties of conventional mortar control. None critical structures were built to test the experimental mortar over a 25 year period.

Page 270

Water repellent additives
There are very many additives that the construction industry uses but for the sake of simplicity the available preparations are summarised into basic groups. Water repellents act by a variety of means but all are directed at reducing the water ingress into the substance of the material. When mixed with cement fibre composites, mortars, concretes and the like, the admix is spread throughout the matrix of the material to achieve its effect at each site the additive is precipitated. Once cured the water repellent additives are effective for the duration of the given additive's lifespan.

Page 271

We greatly look forward to long term results with water repellent additives admixed with high alumina cement. Samples of high alumina cement and more specifically Lafarge Cement Fondu, demonstrate that provided the finished product is not exposed to water, that the product retains its properties and that there is no degradation of the cement matrix during the experimental time scale. It seems to us that adding selected integral water repellents during production, will reduce water ingress to extend the life of such composites. The crystal structure of high alumina cement remains stable provided water is prevented from contaminating the finished product. The range of uses for such cements could be extended provided water ingress is prevented.

Discussion
The addition of straw fibre to building blocks requires the use of accelerated high alumina cement to overcome the retardation problem hydroxyl groups exercise in a slurries. It is the hydroxyl groups attached to the molecular skeletons of the many compounds found in plant life

Follow up studies exposing StawCrete to the elements continued for the straw based composites and in particular the effect prolonged wetting had on the building blocks. Concrete blocks, 440x215x100mm in size, were manufactured with 30% by volume of wheat straw and 70% sand/cement mixture using accelerated high alumina cement. Samples were then positioned in a shaded site and left exposed. The intention was to examine the effect the wet environment had on the organic and inorganic mixture in this slow drying situation.

Wood Cement composite building block also grew fungal growth. Fungal growths (Peziza Genus)

Fig 4

StrawCrete composite building block Fungal growths (Peziza Genus)

Fig 5

It was of no surprise to see flora growth on these blocks. The blocks become wet and over the winter months generally remained wet for months on end, with short drying out periods, before the material was again saturated. Several plant forms were observed and of particular interest was the growth of a fungus. This was totally unexpected because although the exposed surface cellulose particulates (being specified at 5mm-0mm) would no doubt attract wood feeding entities, it was expected that these would be of a diminutive size. The appearance of a complex large fungus[8] on the shaded sites of the block, induced an anxiety that certain life forms might have enzyme systems that could actually damage the concrete mixture These fungal growths remained well contained and short lived and appeared in all cellulose cement bonded composites. The same fungus was seen growing on the wood block but the surprised was the size of the fungus. On closer examination it appeared that the cement, wood, aggregate block used as a control, contained large particles of wood that were 30mm long and up to 5mm thick. The fungus died having consumed the nutrients on which it was growing.

It appeared clear, that the growth of fungus in cement bonded cellulose composites was dependant on the availability of exposed cellulose, in damp conditions. In all cases, all fungal growth died, as the blocks dried out. Control blocks kept in the dry environment, did not develop or sustain any kind of visible organic life forms during the same time span, nor, did they lose the golden color of wheat straw.

The availability of water was concluded to be a prime factor in sustaining life forms on cement bonded cellulose composites.

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Maintenance

Building Owners are responsible for the maintenance of claddings.

Annual Inspections must be made to ensure that all aspects of the cladding systems, including flashings remain in a waterproof condition. Any damaged areas or areas showing signs of deterioration which would allow water ingress, must be repaired immediately. Sealant, paint coatings, flashings or the Durasheet must be repaired in accordance with the relevant manufacturers' instructions.

Regular cleaning (at least annually) of the paint finish with water and a mild detergent is recommended to remove grime, dirt and organic growth, to maximise the life and appearance of the cladding.

Recoating of the paint finish will be necessary throughout the life of the cladding system. Repaint every 5-10 years in accordance with the paint manufacturer's instructions. When re-painting, care must be taken to ensure bottom edges are well covered with paint.

Flashings and sealants must continue to preform their design function.

Preparation and Painting

Painting of Durasheet™ is required to meet the durability and external moisture requirements of the NZBC.

Durasheet™ must be painted within 3 months of installation. When using uPVC flashings, the light reflective value of the the colour used must be more than 40% as required under E2/AS1. Darker colours can cause excessive movement and reduce the cladding performance.

It is recommended that only quality sealants that comply with the New Zealand Building Code be used – preferable BRANZ appraised products. The sealants manufacturers' instructions must be followed.

Quality Paints that comply with AS3730 should be used and manufacturers' specifications must be followed. All surfaces should be free from dust and contaminants prior to painting.

BGC Fibre Cement manufactures and grades the Durasheet™ to strict quality control measures. The installer is responsible to ensure it will meet the required finish prior to installation. BGC will not be responsible to correct self-evident surface issues after installation

Freeze Thaw

Durasheet™ should not be used in situations where it will be in direct contact with snow or ice for prolonged periods.

Warranty

BGC Fibre Cement (NZ) warrants its products to be free from defects caused by defective materials or workmanship (manufacturer) for a period of 15 years or 50 years for bracing sheets from the date of purchase, subject to the conditions set out below. Further, BGC Fibre Cement (NZ) warrants its products to be resistant from rotting, fire and cracking so long as the installation is carried out in accordance with BGC Fibre Cement literature available at the time of purchase.

Conditions

i) This warranty is non transferable
ii) The product must be installed and maintained in accordance with the relevant BGC Fibre Cement (NZ) literature current and available at the time of purchase. All additional products including accessories, jointing systems and coatings used in conjunction with the BGC Fibre Cement product(s) must be applied or installed according to the appropriate manufacturer's instructions.
iii)BGC Fibre Cement (NZ) is not liable for any breach of warranty unless the claimant provides proof of purchase and a claim is submitted in writing within 30 days of the defect becoming evident. If the defect is detected prior to installation, the claim must be submitted before installation occurs.
iv)If BGC Fibre Cement (NZ) products are found to be defective, BGC Fibre Cement will at its option, repair or replace the product, supply equivalent replacement products or reimburse the purchase price of the product.
v) BGC Fibre Cement (NZ) shall not be liable for any damage or losses (direct or indirect) including property damage or personal injury, economic loss or loss of profits, consequential loss arising in contract or negligence or howsoever arising. BGC Fibre Cement (NZ) shall not be liable for any claims, damages or defects arising from or attributed to poor workmanship, poor design or detailing, settlement or structural movement or movement of materials to which the product is attached, incorrect design of the structure, acts of God, including but not limited to floods, cyclones, earthquakes or severe weather or unusual climate conditions, performance of coatings or paints applied to the product, normal wear and tear, growth of mould, mildew, fungi, bacteria or any other organism on the products surface (exposed or unexposed).
vi)The project must be designed and constructed in accordance with all relevant requirements of the current New Zealand Building Code regulations and standards.
vii)If satisfying a claim under this warranty which involves recoating or painting of BGC Fibre Cement (NZ) products, there may be slight colour differences between the replacement product and the original products due to the effect weathering and variations in materials over time.
viii) All warranties, conditions, liabilities and obligations other than those specified in this warranty are excluded to the fullest extend allowed by the law.

Disclaimer

The successful performance of the relevant product depends on a number of factors outside the control of BGC Fibre Cement (NZ). As such, BGC Fibre Cement (NZ) shall not be liable for the recommendations made in its literature and the performance of the products/systems including its suitability for any purpose or ability to comply with the relevant conditions set out in the New Zealand Building Code. It is the responsibility of the building designer to ensure that the details and recommendations provided in the relevant BGC Fibre Cement (NZ) installation guide are suitable for the intended project and that specific design is conducted where appropriate.

The instructions and recommendations in BGC Fibre Cement (NZ) literature are based on good building practice, but are in no way an exhaustive statement of all relevant information and are subject to conditions above. BGC Fibre Cement has tested the performance of its products when installed in accordance with the products technical specification, in accordance with the standards required by the New Zealand Building Code. Those test results demonstrate the products compliance with the performance criteria set out by the New Zealand Building Code.

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DINCEL STRUCTURAL WALLING

BRANZ

level

THE AUTHORITY ON SUSTAINABLE BUILDING

Health and Safety

Taking care with materials, equipment and work procedures and dealing with hazards.

Mould

Moulds are a type of fungi that require moisture and a food source to grow. They reproduce by releasing vast numbers of tiny spores into the air which can be inhaled.

If inhaled in large quantities, some mould spores can cause health problems such as allergic reactions similar to hay fever, breathing difficulties, eye irritation, skin rashes and occasionally, more serious symptoms.

On this page:

- mould and leaking buildings
- Stachybotrys chartarum (SC)
- testing for Stachybotrys.
- removing and cleaning up procedures for moulds.

Mould and leaking buildings

Leaking buildings are likely to have mould in wall cavities as the conditions are well suited for fungal growth.

Mould growth can often be seen as surface discolouration on ceilings, walls and furniture. There may also be a musty smell. If there is any evidence of water damage, there is likely to be mould growth.

Stachybotrys chartarum

Some types of moulds produce toxic compounds. *Stachybotrys chartarum* is a toxic mould that is associated with leaking buildings in New Zealand in recent years. The mould is caused by leaks that originate outside the building and from leaks within wet areas in buildings.

Stachybotrys is a greenish-black mould that grows on materials that contain cellulose such as wood fibreboard, fibre-cement, the paper lining of gypsum board, kraft paper wall and roof underlays, wallpaper and timber, when the material is subject to wetting.

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