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A review of Australian research into natural fibre cement composites

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Abstract

Over the last three decades considerable research has been committed to finding an alternative fibre to replace asbestos in fibre cement products. Australian research was centred on natural fibres and ultimately it was a natural fibre, wood pulp fibre, that was responsible for the greatest replacement of asbestos in the beleaguered global fibre cement industry.

This review reports some of the Australian research that was carried out to establish natural fibres as a suitable reinforcement for cement products. Much research data is locked away in the archives of companies. The preparation and properties of the fibres are discussed briefly as well as their compatibility with existing processing technology. Some explanation of the bonding and microstructural behaviour (under load) within these composite materials is presented and related to their performance in service. The spread of the Australian wood fibre cement technology and the range of applications for which the natural fibre cements are used are discussed briefly, particularly with reference to USA and Asian activities.

Keywords: Fibre cements; Natural fibres; Australian fibre cement industry; Asbestos replacement

1. Introduction

In the early 1970s a global effort was initiated to legislate for the removal of asbestos reinforcement from a wide range of products. Fibre cement was a major user of asbestos and as such new reinforcing fibres were being sought as alternatives to asbestos in this class of building material. Those countries that recognised the need to legislate against the use of asbestos, on health grounds, have proved to be the ones that have achieved the most advances with respect to asbestos substitution and have thus avoided, in most cases, a downturn in the fibre cement business.

Australia has never legislated against the use of asbestos. Since almost all of the asbestos was imported from Canada and Rhodesia (Zimbabwe). A major driver for James Hardie to get out of asbestos was a fear that supplies could be cut off by industrial action in the ports or elsewhere.

In 1982 the German government and industry agreed to reduce asbestos content by 30–50% before 1986, and in 1984 revised the agreement to state all building construction materials would be free of asbestos by 1990. Since 1988, two producers of fibre cement products in Germany, Eternit and Fulgurit, have received approval to produce large-sized pressed and air-cured asbestos free corrugated sheets. Unfortunately, in Germany the government subsidises metal roofing to the detriment of the fibre cement industry. This could have been a possible cause of Fulgurit closing down its Wunstorf plant, which had been manufacturing air-cured wood fibre reinforced cement.

Sweden, Norway and Denmark, by 1987, had prohibited the use of asbestos. In the decade since 1989 the governments of Italy, Belgium, the Netherlands, Austria and Switzerland, with the realisation of the open market in Western Europe, had introduced relevant bills prohibiting partly or completely the use of asbestos. Countries such as France and Spain were slower in changing to non-asbestos formulations, but with the advent of

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investments in new plant a transition to asbestos free products would be expected.

Eastern European countries such as the former Yugoslavia and Czechoslovakia, who have been exporting fibre cement products to Western Europe, will be attempting to retain their export markets by changing to asbestos free products.

Russia and China, with more than half of the world's production of asbestos, are obvious users of asbestos fibre in cement products and are expected to continue to be so for some time into the future. Although some research is being conducted into non-asbestos fibre cements, no strong drive is obvious towards legislation against the use of asbestos in those countries at the present time.

Australia was the first country in the world to be totally free of asbestos in fibre cement production (New Zealand adopted this technology immediately). James Hardie Industries have been manufacturing asbestos free cement sheeting since 1981 [1]; all products including moulded products and non-pressure pipes have been free of asbestos since 1987. The success of James Hardie's technology has encouraged a further two producers of natural fibre reinforced cement products to commence operations in Australia in recent times—BGC Fibre Cements and CSR Fibre Cements. James Hardie has taken their asbestos-free manufacturing technology overseas to New Zealand, Asia, and North America and recently has moved into South America.

James Hardie in association with Cape also sold the technology to Everite in South Africa, to Mexalit in Mexico (by default through its owner Saint Gobain in France) and Uralita in Spain.

The situation is fairly obvious with respect to developing countries. It is sometimes found that commercial interests from developed countries invest in older technology in developing countries without applying the stringent health controls that can make the process unprofitable in their own countries. Hence the large production of asbestos containing fibre cements, seen in such parts of the globe, will continue for some time.

At the other end of the spectrum exist the "cottage industry" type operations. The products are usually corrugated roofing, roofing tiles and flat sheet products that depend on a cheap fibre source and labour intensive production methods [2–4]. Unfortunately, even though millions of dollars of have gone into this area of research, in the form of foreign aid, the success rate of such activities has been limited due to product failure [5]. The picture is however, not as bleak in this area as may appear at first glance. Efforts are being made to control the performance of low cost building materials for use in developing countries. Thus we find in 1987 Gambia was the first country in Africa to adopt regulations supporting the use of indigenous, low-cost building materials suited to the needs and financial capabilities of the inhabitants [6].

There remains a great need to study new cheaper methods of fibre production, low cost production processes, and the all-important question of durability. Durability is related to matrix formulations, processing methods and curing regimes and if natural fibre reinforced cement products are to be readily available for low-cost housing much research still remains to be conducted.

2. Research in Australia

2.1. James Hardie research

The real starting point for the story of wood fibre cement in Australia began long before the 1970s. James Hardie and Coy Pty Ltd. started manufacturing asbestos cement products in Australia in 1917. After establishing manufacturing plants around Australia, the company extended production to New Zealand in 1938. International expansion continued to Malaysia in 1964 with the formation in 1966 of United Asbestos Cement Berhad, a joint venture between James Hardie Industries, Turner and Newall, European Eternit companies and 51% of Malaysian ownership. In 1970 Indonesian production started with P.T. Harflex Asbes Semen. By 1977 James Hardie Industries had 29 plants in Australia, New Zealand, Indonesia and Malaysia employing 6500 people.

James Hardie and Coy Pty Ltd. took an active interest in the use of cellulose, as an economic asbestos substitute, in fibre reinforced cement in the early to mid-1940s. This work was intensified during the post-World War II years when there was a worldwide shortage of asbestos fibre. An investigation was conducted at Camellia, NSW, by Heath and Hackworthy [7] to discover whether paper pulp could be used to replace asbestos completely or partially in asbestos cement sheets. Fibres studied included bagasse, groundwood, wheat straw, cement bags and brown paper. The experimental autoclaved sheets showed brown paper (kraft) was the best of the pulp sources, giving greatest strength to the composite material. However, when asbestos supply was reinstated, this work was discontinued.

Renewed interest in wood fibres began almost inadvertently in 1960 [8,9]. In those days, the asbestos fibreboard, containing 15% asbestos, was made between steel interleaves. James Hardie was believed to be the only group in the world that at that time was steam autoclaving its sheets. To make a cheap board as an alternative interleaf, boards were made up with half the asbestos replaced by wood fibres. It was found, however, that this material was a better product than the material they were selling, being easier to nail and to cut and would conform more easily to uneven framing. This board became the first generation 'Hardiflex', and full production started in 1964. From the 1960s onwards their products have contained no more than 8% asbestos, which was about half the amount the rest of the global industry was using. However, as they also contained some 8% wood fibre (by weight) the total fibre volume was about 50% higher than the rest of the world.

Attempts to further reduce the asbestos content by adding more wood fibre were unsuccessful due to the ineffectiveness of these fibres, compared to asbestos, in trapping the cement particles during formation of the sheet on the conventional Hatschek machine. It was in the 1970s, when the use of asbestos started to be challenged on health grounds, that James Hardie made a strong commitment to the total replacement of asbestos reinforcement in their products.

2.2. CSIRO/Australian Industry research

CSIRO in the early 1970s had active research programs in studying ways to utilise wood fibres as reinforcement in a broad range of composite materials and in modification of the surface of wood pulp fibres to make them more compatible with various organic and inorganic matrices [10,11].

In 1977 James Hardie approached the then CSIRO Division of Chemical Technology (currently, CSIRO Forestry and Forest Products) about a problem with a natural fibre resource they were considering for their Indonesian operation. After several meetings the organisations entered into a collaborative project to study wood fibres in cement products. This project continued over the period 1978–1982 [1].

With over 50 years of research into the science and application of wood and paper pulp CSIRO was well equipped to study, among other things the refining of wood fibres. This was undertaken in an attempt to overcome the major problem of retaining the cement particles during the production of the wood fibre reinforced cement sheet. The project proved successful and it was later demonstrated by scanning electron microscopy (SEM) [12] that refining opened up the structure of the individual fibres resulting in a "hairy" surface [13]. During sheet production these refined fibres acted as a filter aid for retaining the matrix material, in a similar manner asbestos fibres [13]. By May 1981 the new generation of asbestos-free cement products Hardiflex II—was being manufactured commercially. This autoclaved product was asbestos-free and totally reinforced by refined kraft wood fibres [14,15].

2.2.1. Refining of fibres

Refining or beating can be defined as the mechanical treatment of pulp carried out in the presence of water, usually by passing the suspension of pulp fibres through a relatively narrow gap between a revolving rotor and a stationary stator. The term 'beating' is usually applied to a batch treatment of pulp suspension, whereas 'refining' is used when the stock is passed continuously through one or more refiners in series [16,17].

Changes observed in fibre structure as a result of the mechanical action on the fibrous material depend on the type of refiner, the refining conditions used, the fibre type (hardwood or softwood) and the pulp (mechanical or chemical). However the main effects which are observed can be classified into four areas:

(i) Internal fibrillation or delamination.
(ii) External fibrillation of the fibre surface.
(iii) Fines formation.
(iv) Fibre shortening.

Internal fibrillation effects (i) are difficult to observe under a microscope, but they can be considered by analogy with a piece of rope. Rope is a helical wrap of strands that are themselves helical wraps of fibres. If one twists a rope in the direction of the helical wrap the rope becomes 'stiffer'; likewise, if the twist is in the opposite direction the rope unwinds (or delaminates) to open up the structure and becomes 'floppy'; such is the case with internal fibrillation. The main effect of internal fibrillation is to increase fibre flexibility and swelling. The fibres may also undergo excessive curling and twisting.

External fibrillation (ii) is easily observed by scanning electron microscopy. The fibrils or fibrillar lamellae attached to the fibre surface can vary widely in size and shape (but the process is again like unravelling a piece of rope at its surface).

The last stage (iii) of external fibrillation is the peeling off of the fibrils from the fibre surface with the formation of fines. Depending on the forces acting on the fibre during refining, more or less of the fibrils will be removed from the surface of the fibre.

Fibre shortening (iv) is the other primary effect attributed to refining and is to be avoided. An indication that fibre shortening has occurred is the change observed in particle size distribution, which is a result of the cutting action of the blades or discs in the machinery on the single fibres.

Refining plays an important role in producing a large surface area for fibre-to-fibre or fibre-to-matrix (in the case of composites [18]) bonding and, more importantly, can assist in controlling the drainage rates of processing liquids during the fabrication of products. Refining affects the hydraulic properties of the fibre effectively reducing its average diameter. In turn this affects the propensity to flocculate with itself and to trap the essentially equi-dimensional particles of cement, ground sand, etc. Small effective diameter allows good film formation on the Hatschek machine and it is this that distinguishes wood pulp fibres from the synthetic fibres. Synthetic fibres are effectively an order of magnitude greater in diameter than wood fibres and thus cannot by themselves form films and trap the particles. They are more likely to settle out in the Hatschek machine. This is one of wood fibre's main advantages compared to synthetic fibres such as glass, steel, etc., and a key factor in the success of this natural fibre in replacing asbestos while using the existing Hatschek manufacturing process [19].

2.2.2. Chemical modification of fibres

During this same period of time it was believed that modification of the fibre surfaces by chemical means might be an alternative method of bonding matrix particles to the wood fibres during manufacture. This complemented earlier studies at CSIRO on the use of coupling agents for composite products [10,11], and surface treatments of pulp for paper production. A collaborative research project with Australian Chemical Holdings was carried out during 1979–81. Although an extensive range of novel polymeric systems were studied and certain benefits were achieved; the mechanical approach of refining the fibres proved far superior with respect to performance for cost.

2.3. CSIRO Research

Much of the research conducted by CSIRO in the early 1980s was directed towards providing a cheaper natural fibre reinforcement to the relatively expensive kraft pulped softwood fibres in use by the Australian industry. At the same time there was a considerable interest in explaining the manner in which the fibres bonded to the cement matrix, and the performance behaviour of these new wood fibre reinforced materials under load and under differing climatic conditions.

2.3.1. Fibre research

The choice of wood pulp fibre as the preferred replacement for asbestos in fibre cement was not a forgone conclusion. It must be remembered that during the 1970s glass fibre reinforced cement was being acclaimed as the prime alternative to asbestos reinforced cement [20]. Also steel fibres, a wide range of synthetic polymeric fibres as well as other natural fibres were actively under research in various countries around the world [21]. Although kraft wood pulp fibres were found to be suitable they were reasonably expensive. Considerable research was conducted into alternative methods of producing wood pulp fibres, as well as extending the range of natural fibres suitable for reinforcing cement products [22,23].

The search for a replacement of asbestos fibres resulted in many natural fibres being examined in numerous laboratories around the globe as well as by Australian researchers. Obviously the fibre cement industry has considerable in-house data, the results of which has not been made available to the general scientific community. At CSIRO a wide range of natural fibres (wood, bamboo, banana, flax, etc.), prepared by different pulping methods (chemical, mechanical and various combinations) was studied in various matrix systems (cements, mortars, etc.) [34–41]. Some representative published results are summarised in Table 1.

The range of CSIRO research interests was wide taking in studies of "fibre curl" [42], fibre compatibility to cement [43,44], relationships between fibre properties and composite performance [45], pressure effects during manufacture [46] and testing of the commercial product [47].

Research at CSIRO on fibre selection was in part carried out in collaboration with universities both in Australia and overseas [30–32,37,40,41]. The overseas scientists were endeavouring to evaluate the potential of various abundant natural resources available in their country of origin. More detail of some of this collaborative work is reported within this special issue of the journal (Savastano Jr. et al. paper).

2.3.2. Microstructure and bonding

It is appropriate to mention here that the hydroxyl groups available on the surface of the cellulose are the

Table 1
Some natural fibres systems studied at CSIRO

Fibre	Pulping[a]	Refining[b]	Matrix[c]	Cure[d]	Reference
P. radiata (softwood)	K, TMP, CTMP	R/NR	C, M	A, AC	[14,22–26]
E. regnans, *E. grandis*, *E. saligna*, *E. pellita* (hardwoods)	K, CTMP	R/NR	C, M, GFS	A, AC	[27–31]
A. Mangium	K, CTMP	NR	C, M	A, AC	[31,32]
Waste paper	–	NR	M	AC	[33]
New Zealand flax	NaAQ	R/NR	M	A	[34]
Abaca	K	R	C	AC	[35]
Banana	K	NR	C	AC	[30,36,37],
Sisal	K, S	NR	C, GFS	AC	[30,38,39]
Bamboo	K	R	C, M	A, AC	[40,41]

[a] K = kraft pulp, TMP = thermomechanical pulp, CTMP = chemi-thermomechanical pulp, S = soda pulp, NaAQ = soda anthraquinone pulp.
[b] R = refined, NR = not refined.
[c] C = cement, M = cement and sand/silica mix, GFS = ground furnace slag matrix.
[d] A = autoclaved, AC = air-cured.

prime means by which fibres and cement bond together [18]. The main reason that unrefined fibres do not bind well to the cement is due to the stiffness that prevents it from making intimate contact over an extended area between the fibre and the rigid particles. Refining softens the fibre allowing it to wrap around the cement and other minerals and make intimate contact thus binding them tightly together [13,14,23]. Improving the fibre/matrix bond too much will lead to the composite becoming too brittle and susceptible to movement cracking in service. Thus there are technical reasons for not wishing to increase the bond too much even though the cost of chemical improvement was a deterrent in the first instance. It has also been realised that a simple way to improve the fibre/matrix bond is to use bleached pulp that contains less lignin and other chemicals that tend to interfere with the bond particularly in autoclaved product.

Although wood fibres were well suited for use with the Hatschek technology (the process universally used for fibre cement production [19,21]) the understanding of what was taking place at a microscopic level during loading to failure, and under different atmospheric conditions needed to be understood.

Mechanical testing of individual fibre strands embedded in cement was undertaken [38] and the behaviour correlated with SEM studies of fracture surfaces of wood fibre reinforced cement [13,48]. The hypothesis that was proposed for the bonding taking place at a molecular level [18] has been generally accepted [49] although it was in conflict with views held both within Australia and overseas in the early 1980s.

2.4. Australian university research

Macquarie University and Sydney University were also involved with James Hardie Industries in the late 1970s. Professor "Snow" Barlow, at Macquarie University, was investigating the efficacy of other types of non-wood fibres cement sheeting. This work was not published in the general scientific literature.

Mai and co-workers at Sydney University worked on various hybrid fibre mixtures including wood fibres with polypropylene and kevlar [50]. They also carried out extensive testing of laboratory and commercial wood fibre reinforced sheeting to establish the products performance under slow crack growth [51,52] and the generation of fracture toughness [53,54]. Some attempts were made to simulate on a computer the fracture behaviour of wood fibre reinforced cement [55] but the numerous assumptions needed led to relatively poor correlation between theory and practice.

The University of Technology, Sydney investigated the effects of various autoclave conditions on wood pulp to determine the degree of damage to the fibres during manufacture. They employed the technique of differential thermal analysis to establish changes in the structure of cellulose [56].

Research by Victoria University of Technology was carried out in collaboration with CSIRO at the Division of Forestry and Forest Products and was centred on the use of non-wood pulp fibres such as banana [37] and bamboo [40,41,45].

The Australian National University has become involved with wood/cement products in more recent times and some of this work has involved wood fibre cement materials [31,32,44].

3. Other manufacturers within Australia

After the initial success of James Hardie Industries, other Australian companies became interested in wood fibre cement products. Pulp manufacturers, from both Australia and New Zealand, had considerable confidential research carried out by CSIRO on the suitability of their pulps as replacement for asbestos. Cement based companies also looked at alternative opportunities using combinations of natural fibres and cement. However, the main thrust of the research was to remain with autoclaved wood-fibre cement panel-products.

Early in 1991 Atlas-Chemtech (now BGC Fibre Cement) approached CSIRO concerning wood fibre reinforced cement production. They had acquired a second hand Hatschek machine, from Toschi in West Germany, and wished to initiate some collaborative research based on formulations. This innovative company, with no prior experience in fibre cement production, commenced construction by 1993. The location selected was adjacent to the AAC plant (Autoclaved Aerated Cement) to take advantage of the silica ball mill and the gas-fired boiler for the autoclaves. This commitment enabled the parent company to become free of the problem of supply to their extensive building empire in Western Australia. At the same time due to the availability of considerable "back-load" transport (from West to East) they could compete with their excess capacity on the Australian East-coast market. It is believed they have about 5% of the local market.

The original mix design was based on that of Supradur (Canada) which was of high cement content and with 10% bleached cellulose fibre. This mix design produced a high strength sheet that did not suit the applications for Australian conditions, as it lacked flexibility and nailability with excessive sheet movement. After much research and development, BGC perfected a mix design, using New Zealand fibre cement grade cellulose pulp. This produced a product that is fit for the purpose as a building material in various applications. The quality and production efficiency of BGC was recognised by USA building products manufacturer, Temple-Inland, who wished to enter the US fibre cement siding market. In 1996, Temple-Inland signed an agreement with BGC for its technology and assistance in constructing a fibre cement plant in Texas USA.

The company is currently operating two lines with a capacity in excess of 5 million standard metres with plans to expand this volume. Sales and warehouse facilities exist in Perth, Adelaide, Melbourne, Sydney, Brisbane and in Auckland. The company exports to Singapore and New Caledonia, as well as selling in the Australian and New Zealand markets.

CSR also approached CSIRO in 1994 with a desire to get into fibre cement production. At that time CSR was one of the world's largest building and construction materials companies, with operations in Australia, New Zealand, USA and Asia. They then employed about 20,000 people in nine countries with sales over A$6 billion per annum. Their path was a little less demanding in that they had built a 'turnkey operation'' for about A$56 million. The big advantage for this company was that they already had large distribution centres in Australia that could guarantee them entry into the market; a feature lacking in the case of James Hardie Industries, who in many cases had been suppliers to CSR-owned outlets! In 2000 CSR had about 25% of the domestic market with distribution outlets in all states and in New Zealand. Their product was also exported to several Asian/Pacific countries.

In 1998, Applied Technology and Planning Pty Ltd. (ATP) developed a patented manufacturing process called Micro Internal Compaction. This injection moulding style process allows the rapid production of two- and three-dimensional aerated fibrous cement products. Ultimate Masonry Australia Pty Ltd. (UMA), from their factory in Brisbane, is using this technology to produce what they claim to be the world's first commercial, hollow aerated concrete block. Production is currently limited to the full range of $400 \times 400 \times 200$ hollow 'SmartBlocks'. These blocks achieve superior compression strength to conventional concrete blocks at half the weight.

In 1999 Assedo Pty Ltd. consulted to ATP with reference to the utilisation of wood pulp fibres as reinforcement in cement products. The UMA SmartBlock is currently made from an aerated slurry of cement, flyash, cellulose fibre and water. In this application compression strength is of primary importance. A low fibre content is used to stabilise the rheology of the three phase air, water, powder mix during the vacuum dewatering stage of the Micro Internal Compaction moulding process. SmartBlocks are autoclaved after moulding. The material density in this application is 1100 kg per cubic metre while the hollow product with a 50% void ratio has a gross density of 550 kg per cubic metre. There is no significant alignment of fibres and the process produces an essentially isotropic material.

UMA claims a wide range of advantages for its product including environmental and occupational health and safety benefits, reduced construction costs and improved thermal and other functional characteristics. The fine-grained high precision surface of the SmartBlock may be sanded and painted to achieve a plaster style finish for both internal and external applications. It was proposed that by 2001 a new three head moulding machine will allow production to increase from the current 5000 blocks per week to 50,000 blocks per week. In the longer term UMA plans to establish a series of plants adjacent to coal fired power stations to take full advantage of the benefits of industrial ecology. The first of these is planned to commence production in 2002 and will have a capacity of 10 million blocks per annum. Negotiations are underway regarding plants in both India and China.

ATP continues research directed towards exploring other applications of its Micro Internal Compaction technology. In particular it is working with high cellulose fibre mixes on a variety of linear, sheet and decorative products where flexural strength becomes significant. They aim to utilise the unique characteristics of their production technology, including the ability to mould aerated low-density products, to open up new applications for fibre cement products.

Australian research led the world in finding an alternative to asbestos in fibre cement products. That revolution in relation to the material was not matched by any significant change to production processes. Cellulose fibre cement sheeting and pipe products continue to be made using century old Hatschek process originally developed for use with asbestos based products. The Australian developed, Micro Internal Compaction process together with the cellulose material technology opens up possibilities for new environmentally sustainable products that could transform the building industry.

4. Global expansion of James Hardie industries

In 1983 James Hardie Industries and Cape Industries of the UK formed a joint venture, Fibre Cement Technology [57]. The objective was to market the new technology they had developed, to manufacture asbestos-free fibre cement building products, to interested companies throughout the world.

It was stated in 1985 that the UK manufacturers had replaced asbestos in about 50% of the fibre cement sheeting products [58]. James Hardie Industries by this time had totally replaced asbestos fibre from its range of building products, which included flat sheet, corrugated roofing and moulded products, throughout Australia and New Zealand. Part of the Malaysian production by the company was also free of asbestos. The Indonesian interests had been sold in 1986 for financial reasons. The shareholdings in UAC was also sold at that time.

As well as flat sheet products, James Hardie Industries had become a world leader in injection moulded fibre cement products and non-pressure fibre cement pipes, all based on wood fibre as the reinforcement material. The first experimental production of WFRC pipe was undertaken at the Brooklyn factory in September 1980. Commercial production began in Western Australia at the Welshpool factory in July 1984. The last asbestos pipes made by James Hardie were manufactured in March 1987.

In the late 1980s James Hardie introduced imported wood fibre reinforced cement products into the USA market. At that time fibre cements represented less than 1% of the large sidings market. The market was comprised of wood-based materials (~51%), vinyl (~28%) and inorganic products (~20%). Last year fibre cement could claim more than 9% of the sidings market in the USA.

In 1990 James Hardie built their first plant at Fontana, California to start manufacturing in the USA. Although acceptance of the product by the building industry was initially slow, the superior durability, fire resistance and value for cost won through and by 1994 they started to build their second plant at Plant City, Florida. It was not until 1995 that demand for the product really indicated the technology had been accepted. In 1997 a third plant at Cleburne, Texas was opened followed by the fourth plant at Tacoma, Washington, 1999. In November 1999 James Hardie announced that a fifth plant would be constructed at Peru, Illinois. This plant is now either in operation or in the final stages of commissioning.

The in-house research that James Hardie's has invested in over many years has provided them with proprietary product and process technology which enables them to offer the widest product range and to benefit from significantly lower capital and operating costs, compared to competing fibre cement technologies.

Recent research by James Hardie, involving a team of staff from the Australian Sydney and Perth laboratories and the Fontana laboratory in USA, has resulted in "Harditrim". This innovative material is a lower density product that can be made thicker than normal panel products and so can be used on corners, columns, windows and gables where current products were unsuitable. James Hardie commits some A$25M per annum to continuing research into wood fibre reinforced cement products and process technology. James Hardie estimates the potential long term fibre cement market in the USA, in areas such as sidings, roofing and trim products could be worth up to A$4.8B a year. At the moment James Hardie has ~A$670M sales, which is 85% of the fibre cement market in USA.

The global market could be as large as A$15B when it is noted that more than two-thirds of the fibre cement industry still uses asbestos, but global pressure will drastically change this situation in the near future. The European Union has declared a ban on asbestos cement by 2005. South American countries are also starting to move against asbestos.

A joint venture with Jardine Davies Inc. provided the opportunity to build a $50M plant in the Philippines. This plant was commissioned in 1998. Hardie's have recently further expanded their manufacturing capability in Asia. Once again they have joined forces with Malaysia's UAC Berhad by forming a joint venture. The 50/50 venture will combine Hardie's Philippines plant with UAC's plant in Malaysia, giving the combined group a capacity of 220 million square feet a year. James Hardie estimated that within five years its Asian business could be as big as James Hardie's billion square feet a year USA business. They are confident fibre cement will replace traditional materials such as plywood in house construction in Indonesia, Malaysia and the Philippines and masonry products in Taiwan and Hong Kong.

5. Conclusions

Australian research groups have been major contributors to the global success of wood fibre reinforced cement products—products totally free of asbestos fibres.

James Hardie Industries deserves the position it holds in the global marketplace due to its commitment and perseverance, especially during the early years in the USA when it experienced a period of operation without profit.

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