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FIBRE CEMENT INDUSTRY: A CRITICAL REVIEW OF CONVERSION FROM ASBESTOS CEMENT TO NEW TECHNOLOGY INCLUDING MARKETING TRENDS

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ABSTRACT

The health issues related to asbestos fibres are well documented. The conversion from asbestos cement to an alternative technology has been very successful. Alternative technology or new technology was introduced more than thirty years ago. However today more than 20 Million tons of asbestos cement are still being manufactured despite the health related issues. There are obviously varied opinions regarding this topic and also the conversion from asbestos cement to new technology poses new challenges and the economic viability is often questioned. This paper deals with the technical aspects related to conversion from asbestos cement to new technology and will also emphasis the technical challenges such as reduced strength and potential cracking with alternative technology. The paper will also present the political and supply problems related to asbestos cement worldwide.

KEYWORDS

Asbestos; Cement; New Technology; Raw Materials, Market trends

INTRODUCTION

The health related issues of asbestos fibres have been known for a long time. In the 1960's reports exist about asbestos fibres and cancer related illness resulting in death. However there is a lot of confusion and disputes about why some people die of exposure to asbestos dust and others don't. Evidence and the documentation are also not always complete. There also appears to be varied schools of thought with regard to the type of asbestos fibre causing cancer; e.g. Chrysotile, Crocidolite, Amosite, etc. The issue related to asbestos cement is also very much a political discussion in varied countries as well. For example in Brazil, asbestos cement is banned in the State of Sao Paulo but not in the rest of Brazil.

Therefor it is not surprising that the relatively slow conversion from asbestos cement to alternative technology has not been forthcoming for certain countries. In Australia and Western Europe strategic decision were made in the late 1970's to investigate alternative technologies to asbestos cement. The companies involved at this stage were James Hardie in Australia and Eternit in Switzerland. Intensive research programs were initiated and large investments were made. In Australia the conversion was completed in the early 1980's and in Switzerland in the early 1990's. Western Europe followed this trend and soon many countries in Western Europe were asbestos free. This was certainly not the case for many other countries worldwide. In fact latest information taken from a reliable source (Ref. 1) report that in 2012 more than 2 million tons of asbestos fibres were sold worldwide. The major asbestos mines are in Russia, China, Brazil and Canada.

In 2012 (Ref. 1) Asbestos fibre production was; China, Russia, Brazil and India. In total assuming that 10 % of fibres are used in asbestos cement the total manufacture of asbestos cement worldwide would be 20 million tons. In the section to follow a brief description of the alternative technology will be discussed and issues related to implementation of the technology. Finally a brief account of market trends in fibre cement will be mentioned.

BACKGROUND

Asbestos cement was basically an invention dating back to 1895. The product went through many phases of refinement and modification but essentially understanding of the mechanism of how it reinforced was not really clearly understood and the product was not investigated in depth. The reason for this was that empirical modifications to the mix could quite easily be made and to the mix design of asbestos cement using simple laboratory test methods based on a so called SAG test method. Consideration of varied asbestos fibres for example long fibre mixed with short fibres is common practice in the asbestos cement industry today. The search for an alternative technology however opened up a whole new area of research. It is obvious that asbestos fibres perform a dual function in the Hatschek process (filtration properties and reinforcing properties). Therefor the search for alternative fibres to asbestos fibres required replacement fibre for both properties. The obvious choice for filtration fibres was cellulose fibres used in the paper industry as the process used in the paper industry is closely related to the Hatschek process. However the reinforcing fibres are more complex to replace. Two technologies were developed in the 1980's: Autoclave and Air cured technology.

AUTOCLAVE ALTERNATIVE TECHNOLOGY

James Hardie in Australia pursued the cellulose fibre approach and worked very closely with the CSIRO and other institutes in developing the Autoclave Technology. The technology using 8 % cellulose fibre is a typical autoclaved mix and was successfully introduced in Australia in 1982.
The typical autoclave mix is well known: 8 % Cellulose, 34 % Cement, 54 % Silica and 4 % Aluminium Tryhydrate. Today small variations of the mix do exist but essentially the basic principles have remained the same.

The research behind this invention required intensive laboratory investigations particularly related to long term durability studies, cracking and reinforcing potential. Most manufacturers today considering conversion to new autoclaved technology are confronted with using local raw materials to be utilized for tailor made solutions. This involves the local cement and silica supply. In particular cement needs to be analysed according to the cement composition and physical properties in order to determine its suitability for alternative solution. This is not trivial as cement supply is continually changing and being modified for modern concrete applications. This could involve the use of additives such as fly ash, slag, amorphous silica, calcium carbonate, pozzolanic, etc., etc. These additives can have a significant influence on the cracking behaviour in the autoclave as well as many other factors such as pre-curing time before the autoclave, curing in the autoclave, etc., all of which will have a significant effect on the strength and durability of the final product. Choosing the correct cellulose fibre is well established and the choice is limited to a few suppliers and types. Finally the additive Aluminium Tryhydrate can be adjusted according to the product exposure and application. In general although the mix formulation is well established and well known the technology needs a complete understanding in order to adapt it to the local needs of the manufacturer. This also includes cost saving exercises using local raw materials. The autoclaved technology has been used largely for internal applications and limited external applications such as sidings and some large external panels. Autoclave technology developed for asbestos replacement is not used for roofing applications.

AIR CURED ALTERNATIVE TECHNOLOGY

This technology was developed in Switzerland in the 1980's and shared with neighbouring countries in Western Europe. The development work was structured on a joint venture basis in Western Europe with Austria, Belgium, Germany, France, Holland and Ireland. Varied task forces were established and this assisted to speed up the research and development programs. Synthetic fibres were chosen as the reinforced fibres and the cellulose fibres were used as the filtration fibres. No crystalline silica is used and cement can vary between 60 to 80 %. Essentially both the Autoclaved Technology and Air Cured Technology have been compared in detail and presented at a workshop at the IIBCC Conference in Canberra, 2012 (Ref. 2).

ALTERNATIVE TECHNOLGY: DEVELOPMENT OF THE CORRUGATED SHEETS

Autoclaved

In the early 1980's James Hardie in Australia made the first attempts at replacing asbestos cement corrugated sheets with an alternative technology. It soon became evident that for this product the durability issues were not that easy to resolve; in particular water penetration problems with time were not able to be solved without using expensive water repellent agents. Even this was questionable as the preventative action using special hydroscopic liquids were not convincing over long periods and secondly the product became more porous with age due to carbonation. Attempts were made in other countries to improve the density of the autoclaved product using additives such as micro silica and fly ash. These however were disbanded as other problems like increased wet/dry shrinkage causing deformation and increased propensity for cracking were encountered. Also this solution did not improve the water penetration problems over time.

Therefore in summary the autoclaved corrugated sheet development programs worldwide were largely terminated and it is generally accepted today that the alternative technology for autoclaved roofing products is not a viable solution for asbestos replacement programs.

Air Cured - Synthetic fibre / Cellulose fibre

In the latter half of the 1980's some European countries and some parts in Latin America, attempted to produce corrugated sheets (non-autoclaved) using Cellulose pulp without Synthetic fibres. Although the strength requirements were found to be acceptable, the product showed severe embrittlement with age and because of the advanced wet/dry shrinkage problems the product cracked in field application tests. Although several attempts were made to post cure the product after production, all attempts were not successful at producing a crack free product without severe embrittlement with age. Some of the measures to reduce the undesirable ageing mentioned were; steam curing without pressure, post production, drying, varied mix related additives and hydrophobic agents. The approach using only Cellulose pulp without Synthetic fibres was abandoned in the late 1980's.

However using a combination of Synthetic fibre and Cellulose pulp, the ageing properties were found to be very positive. The Cellulose pulp is mainly regarded as the process fibre for the Hatschek (air cured) technology with limited reinforcing potential and the Synthetic fibre is used for reinforcing potential and long term durability. Many Synthetic fibres were considered in combination with Cellulose pulp and essentially the most production experience was gained using Polyvinyl Alcohol Fibre (PVA), Polyacrylonitrile Fibre (PAN) and Polypropylene Fibre (PP). PVA proved to be the most successful and many grades of this fibre are available today. PAN fibres provided strength values in the final product, similar to PVA, however embrittlement and cracking appeared to be more evident toward the end of the 1980's. In 1990 PAN fibres were generally accepted in Europe as not being a viable replacement for asbestos fibres. This was related to the interfacial bond and the brittle nature of failure of the fibre itself. Some European countries tried to use a combination of PVA and PAN fibres but this idea soon was abandoned. With regard to PP fibres, improvement in the PP fibre properties such as interfacial bond, dispersibility and E-Modulus resulted in revived interest in the early 1990's. In fact there are many successful products on the market today using PP fibres as an alternative to PVA or in combination with PVA.

In general PVA and PP fibres are Synthetic fibres used in combination with Cellulose for air cured fibre cement products worldwide. Although the solution has been found for replacement of asbestos fibres in fibre cement products, the product is by no means equivalent to asbestos cement. These product differences will be addressed in the next section.

IMPORTANT ISSUES RELATED TO NEW TECHNOLOGY OF CORRUGATED SHEETS

A) IMPACT RESISTANCE

First and foremost the fibre cement manufacturer is aware of the fact that the strength of asbestos cement is better than alternative technology. It is often argued that although the strength (breaking load) is less for alternative technology, the impact properties are superior to asbestos cement. This may be true for early laboratory tests, but experience soon showed that alternative (PVA/Cellulose) technology revealed embrittlement with age – not only on the roof but also in the stack even after a few months of curing. This had a major influence on the early development work as it implied that a corrugated sheet roof did not have the same safety factors which applied to asbestos cement with regard to "walkability" during erection and possible roof repair on an aged product. The early development work of corrugated sheets was then focused on how to improve the impact resistance of the product. Reinforcement strips were glued onto the bottom of the wave of corrugated sheets. These ranged from glass fibre strips, PP strips, Kevlar, Carbon and many other externally applied reinforcing strips. The idea of incorporating the strips into the sheet during manufacture then evolved and PP (packing case) strips are being used today by certain fibre cement manufacturers. This is only a precautionary measure to improve the safety of the sheet. More recent developments pointed the way to use PP fibres instead of PVA fibres in the product. This resulted in significant improved impact resistant properties but at the same time revealed other disadvantages such as lower strength properties process changes. PP fibres have a density of 0.9 g/cm3 and PVA 1.3 g/cm3. This resulted in "floating" of PP fibres during the manufacturing process and therefore modification to the process is required.

Around 2005 the European Community considered investigating a classification of the corrugated sheet based on the impact resistance properties. This standard introduced the so called 600 J, 900 J, 1200 J corrugated sheet. The test method is based on the impact of a bag filled with glass beads (50 kg) which is released from varied fall heights from the sheet and the impact energy is then calculated using basic kinetic energy calculations. The test method is based on a very practical application method described in the EN standard. Corrugated base on the PVA technology passed the 600 J standards if taken from the stack after 21 days curing. The older sheets in the stack greater than 3 months however demonstrated significant reduction in impact resistance. This resulted in endless debates about the ageing impact resistance of the corrugated sheets and ended up in discussions about at what age to test according to the European Standard. In fact the test method itself caused interesting discussions as it became obvious that the impact resistance of the sheet was directly related to the type of failure around the fixing points as well as the entire sheet itself. Also the placing of the safety strips played an important role on the final results.

This had serious implication when compared with metal roofing. In particular positive arguments for metal roofing were appearing such as improved coating (less rusting), ease of application such as long length sheets, superior impact resistance, etc., etc. Fibre cement manufacturer on the other hand were propagating condensation, noise from rain, rusting, hail damage, etc., etc. These debates are now becoming a major concern for the corrugated sheet market in the European Community and will certainly impact on the future of this market in Western Europe. In general it is evident that the corrugated sheet market in Europe is declining. This is not only due to the metal industry threat but also aesthetic reasons such as lack of versatility. For example the owner standard family residence will not consider a corrugated sheet roof when other interesting products are available. Therefor the trend is certainly towards farming and industrial buildings. In the latter case industrial building prefer metal because of ease of construction and choice of colour.

B) CRACKING PROPENSITY DURING STORAGE IN THE STACK

After production corrugated sheets are stocked between steel form plates for initial curing and after this (approx. 8 hours) the steel form plates are removed and the product is stacked on wooden pallets for the final curing stage. The post curing after destacking of the corrugated sheets can vary from factory to factory; for example:

a) Stored in a closed room with approx. 99 % RH at room temperature for 21 days – impregnation – coating – wrapped in plastic – stored under cover until it is sold.
b) Pre-dried to 5 % water content in a drying tunnel – coated – wrapped in plastic.
c) Wrapped in plastic immediately after destacking – stored in stockyard.
d) Steam curing between form plates for 6 – 8 hours – destacking and removal of steel form plates – restacking and sent to stockyard without wrapping.
e) Steam curing between form plates for 6 – 8 hours – destacking and removal of steel form plates – wrapped in the stack – for 21 days – coated wrapped in the stack and sent to stockyard.

These post curing procedures are basically used as precautionary measures to counter act edge cracking in the stack which can occur. Edge cracking can occur due to water gradients which are set up between the edge of the sheet and the “covered” part of the sheet in the stack. This problem is well known and is one of the major problems which Synthetic / Cellulose fibre products have. It only occurs for longer sheets which are stacked. In general sheet lengths of up to 1.5 m do not require these precautionary measures like plastic wrapping, pre drying and others mentioned. Other preventative measures for cracking propensity can be made by modifying the mix formulation. These include additives of $CaC0_3$, lowering the Cellulose fibre content, additives of other fillers such as Kaolin, etc., etc.

C) CRACKING ON THE ROOF WITH AGE

Longitudinal cracking is a classic type of cracking that can occur if certain precautions are not taken. It has also been documented for asbestos cement sheets as well as alternative technology. The causes for longitudinal cracking can be related to two phenomena. These are:

- Over tightening of the fixing screws.
- Advanced deformation due to the top surface wetting of the sheet (e.g. rain) while the bottom of the sheet is still dry.

The former can be solved by correct training of roof layers and/or instruction leaflets given to the laymen who purchase sheets at a trading store. The latter on the other hand is rather complex as this requires special attention to coating and impregnation techniques. It is also related to the porosity and mix composition of the sheet. Lastly it can also be dependent on process in the production and curing procedures. Therefore the individual cases need to be reviewed and the cause needs to be established before solutions are adopted.

D) COATING

Varied coatings applied to fibre cement products is a relatively expensive operation and complex technology. Pigments added to the mix formulation are one of the obvious ways to adding colour to the grey base sheet. However not only is this expensive but it also requires additional treatment to the sheet for external applications if the product is subjected to wetting and drying during exposure to the elements. This will result in efflorescence (whitening) due to rehydration of the unhydrated cement clinker which releases $Ca(OH)_2$ and carbonates at the surface to form $CaCO_3$. Efflorescence can be counteracted by an acrylic based impregnation or coating. This implies again that the product needs to be subjected to a relatively expensive post curing coating line. Attempts have been made to perform the coating on-line, during the manufacture of the sheet but these have not been very successful as efflorescence occurs to a less extent in this as well. The result is that varied colour "shades" can be seen on the same roof and in most cases the customer regards this as aesthetically unacceptable. There are known cases however, where the architect prefers the colour changes on the roof as this adds to the natural look (a mottled appearance). In general however coating of the fibre cement product is expensive and adds a significant cost to the final product. Depending on the type of application and type of coating system applied, the additional costs can be from 10

to 30 % of the production costs of the sheet. Therefor it is very important for fibre cement manufacturers to make the cost calculations upfront before investing in expensive coating technology. If the product becomes too expensive it will obviously impact on the selling price of the product and will lose the competitive edge against metal roofing.

MARKET TRENDS AND POLITICAL ISSUES RELATED TO CONVERSION FROM ASBESTOS CEMENT TO ALTERNATIVE TECHNOLOGY FOR CORRUGATED SHEETS

The issues related to asbestos and health have become a political and cost related argument for many years. Why for example is asbestos cement banned in the State of Sao Paulo and not the rest of Brazil? In countries where asbestos has been banned like South Africa, the asbestos mines are closed and the availability of the "good" long fibre asbestos is reducing. Therefore in general good quality asbestos fibres are not so freely available anymore which impacts on the price and quality of the fibre cement product.

Countries producing good quality asbestos fibres profit from this at present but this is short lived as there is a positive move amongst the largest asbestos cement manufacturer in the world to replace asbestos cement with alternative technology. This strategy development impacts on the supply of cellulose fibres for the fibre cement industry. The demand for good quality cellulose fibre is increasing particularly since Solombala is no longer available.

PVA Synthetic fibre manufacturers are however increasing their capacity in China and Japan. In particular the opening of new PVA factories in China is evident over the last few years. Therefore the supply of PVA and Cellulose fibres at present is not critical. On the other hand, the fibre cement industry is faced with a real problem with regard to other roofing materials. In particular the metal industry is becoming more attractive and cost effective compared with fibre cement. In Europe certainly there is a decline in the fibre cement corrugated sheet market, which is not only related to the metal roofing threat. It is also related to the technical difficulties previously mentioned such as impact resistance, cracking, cost of coating and handling. This trend in Europe is also evident in South Africa and will no doubt follow soon in other countries as well. In other words not only is the competition from other materials a strong driver for the decline in corrugated sheets but also the technical changes related to the production of a good fibre cement asbestos free product. In general it is true to say that the fibre cement industry worldwide for corrugated sheets is not a growing industry. There are, however exceptions to this and in certain countries there is evidence of growth in niche markets which is keeping the fibre cement industry attractive for the end user. Therefore in summary it should be noted that any company considering conversion of asbestos cement to new technology corrugated sheets should consider the serious implications of the conversion (long and short term).

These are:

- Cost of conversion with respect to raw material preparation.
- Modification of existing outdated Hatschek machines.
- Overcoming the technical challenges with added costs to curing and storage procedures.
- Cost of coating lines to add colour.
- Increased cost of raw materials in particular Synthetic fibres (approx. 4 to 5 times the price of Asbestos fibres).
- Last but not least the threats of other materials such as metal and others.

CONCLUSION

This paper has provided an overall account of the conversion of asbestos fibre cement to alternative technology. This comprises Autoclaved and Air cured Technology. In particular the technology and trends in the corrugated sheet market has been addressed in detail. It is considered that there is a general decline in the market for corrugated sheets.

The Autoclaved Technology has however remained at a high level of demand and in certain cases there is a market increase. This however has not been dealt with in this paper. Also not included in this paper are new innovative trends in niche market products for example large facade panels for air cured products. It is the feeling of the author that there is a definite change in market trends in the fibre cement industry and certainly Asbestos cement manufacturers should be aware of these changes in the market when considering the changeover to alternative Technology.

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