Possibility of Using Substitute Materials for Asbestos and Non-Asbestos Fibro Cement Roofing Tiles to Reduce Environmental Pollution and Increase Workers' Health Protection in Vietnam

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Abstract

The paper describes the process of discovering and researching asbestos substitute materials and the development of technology for manufacturing non-asbestos fibro cement roofing tiles which has taken place in the past 10 years in Vietnam. Work was undertaken using plant fibers which are available in Vietnam, such as jute, coconut and bagasse fibers etc., and using combined materials of cement– polymer – inorganic / organic fibers to produce lighter components. The development of technology to manufacture PVA-cement roofing tiles with optimal percentages of materials involved using wet-forming technology imported from Japan and China.

The paper makes some recommendations for the production of PVA- cement roofing tiles to eventually replace asbestos-cement roofing tiles in Vietnam.

1. Introduction

The asbestos-cement roofing tile industry in our country started before 1980 but has developed appreciably since the 90s with small capacity production lines producing 1-2 million m^2/year. In general, the price of the asbestos roofing tile product was low, about half the price of normal metal roofing tile. The low price made it affordable to a wide range of people and it contributed to an improvement in housing conditions for poor people and people living in remote areas. This industry has met the demand for local roofing tiles and also provided employment for a rather large group of workers.

In Vietnam, there are 17 asbestos mines, which are located mainly in the North, and 5 of these have been exploited. However, their fiber quality is not good, being of the amphibole type, and exploitation is difficult, so exploitation of the asbestos in these mines has ceased. In order to meet the domestic demand for asbestos, Vietnam has imported chrysotile asbestos from the Russian Federation, China and Zimbabwe. Most of this asbestos is used to produce asbestos-cement roofing tiles; the remainder is used to produce thermal insulation materials, brake shoes and other products.

In Vietnam, there are presently 37 asbestos-cement roofing tile production enterprises, located in 21 provinces and cities, engaged in small-scale production and mostly using the wet forming technology originated by Hatsheck in 1950, a manual and semi-mechanical process. Currently, there are three groups of enterprises classified by the types of technologies they use:

1. Forming product by machine and use of metal mould and curing by water vapor. This is the most advanced technology used, yielding a high quality product and waste of only 0.5-1%.
2. Forming product by hand and use of metal mould and natural curing so need a large field or yard; percentage of waste products reaches 3%.
3. Forming product by hand and no use of metal mould and natural curing so product quality was not good; percentage of waste products reached 5%.

Data on asbestos-cement roofing tile production in Vietnam are shown in Table 1.

Table 1. Asbestos-cement roofing tile production in Vietnam

Kind of enterprise	Number of enterprises		Capacity (Million m2/year)		Quantity for sale (Piece/year)		Number of workers (Person)	
	Number	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*
State-owned	24	69.0	34	51.0	35,348	50.0	3,427	60.0
Joint stock, Joint venture	5	14.0	24	36.0	26,780	38.0	1,670	29.0
Private-owned	6	17.0	8.6	13.0	8,300	12.0	642	11.0
Total	**35**	**100**	**66.6**	**100**	**70,428**	**100**	**5,739**	**100**

The data in Table 1 show that in the past the asbestos-cement roofing tile industry has contributed to socio-economic development with an annual production of 60 million m^2 of roofing tiles that are low priced, do not corrode, are easy to use and are essential products for poor people in rural, mountain, and coastal areas, and in the Cuu Long River delta. In these areas, asbestos-cement roofing tiles occupied a 40% market share (sheet iron – 27%), with receipts of US$38 million per year. In addition, the enterprises also employed about 6,000 direct workers and 10,000 others for service activities. Moreover, these enterprises also used local low quality cement (500,000 tons per year), helping to increase local cement production.

However, science has proved that asbestos dust is a factor causing lung cancer. In Vietnam, asbestosis has been recognised as an occupational disease and compensated since 1976. But up to now few cases have been thoroughly investigated. Due to the hazardous effects of asbestos on safety and health, the Ministry of Construction (MOC) and the Ministry of Science, Technology and the Environment (MOSTE) promulgated the joint circular No 1529/1998/TTLB/BKHCNMT-BXD on 17 October 1998 prohibiting the exploitation, manufacture and import of amphibole asbestos, allowing the use of chrysotile only, and defining the safety thresholds for airborne asbestos fibers to be 1 fiber/ml of air (average in 8 hours) and 2 fibers/ml of air (average in 1 hour). On 1 August 2001, the Prime Minister enacted the Governmental Decision No 115/QD-TTg on "not using asbestos in roofing tile production"; coming into effect from 2004. However, to stop operating nearly 40 asbestos-cement roofing tile enterprises would cause a lot of social problems; the Vietnamese economy cannot meet modern housing requirements for all the people as it is; the roofing tile enterprises are in no postion to transfer to the non-asbestos technology; and where would the workers go? That is why the Prime Minister subsequently signed the Governmental Decision No 133/2004/QD-TTg (on 20 July 2004) on regulation of the route of phasing out the use of asbestos-cement in roofing tile production: first, focus on improvement of the working environment, ensuring strict standards of environmental protection and hygiene, and reducing the number of people exposed to asbestos dust; meanwhile, quickly advance research on asbestos substitute materials.

2. Technology for roofing tile production using PVA fiber-cement.

From the point of view of technology, at present, there are two basic directions for asbestos substitution in roofing tile production: using natural or artificial fibers.

Use of natural fibers was a trend in roofing tile production in the 80s in developing countries, using some plant fibers such as jute, pandanus, grass and straw etc., This option has its good points; the product is easy to produce and cheap. But, there are also a lot of shortcomings; the product is not of good quality, not controlled, not strong and of low duration of use, so that it is difficult to produce on an industrial scale.

The use of mixtures of artificial fibers (mineral, organic, carbonate and metal fibers) with cement has produced products with highly suitable physico-mechanical properties. However, selection of types of fibers to be substituted for asbestos should take into account the toxicity of such fibers and the impact of this on workers' health.

The toxic properties of some asbestos substitute materials are listed below:

Artificial Inorganic fibers

* Ceramic fibers: usually used for making materials providing high temperature thermal insulation: protective clothing for furnace workers etc. Normally, manufacturers cannot specify the exact diameter of the ceramic fibers and most products containing ceramic fibers are harmful and carcinogenic.

* Glass fiber: nowadays considered by some to be as hazardous as chrysotile; though this is still is a matter of argument in the industry. Recent research work carried out by the London

Toxicology Center proved that glass fibers cause throat cancer. In addition, glass fiber products stimulate skin and eye irritation.

* Glass and stone fiber products normally comprise a mass of spongy fibers embedded in resinous substances to make the forms required and also to reduce dust emission. Both types contain respirable dust that is a factor causing cancer.

Quartz fibers and other natural fibers

* In general, these fibers produce respiratory tract problems, such as inflammation, sclerotization, allergic cough, change of lung function and carbonization of the lung membrane etc.,

Natural organic fibers.

* Cotton fibers can cause long-term effects often not diagnosed for many years, including byssinosis.

* Cellulose fibers are used to make insulation materials. Studies have shown them to be less carcinogenic than asbestos, but their possible involvement in causing respiratory diseases has been little studied. *(dealt with later).*

Artificial organic fibers.

* para-aramid fibers (*alternatively, p-aramid or Kevlar*). Reports from the British Occupational Safety and Health Executive Agency and conclusions reached by the WHO and the International Agency for Research on Cancer (IARC) suggest that para-aramid fibers are likely to pose a lower risk of causing pulmonary fibrosis, lung cancer and mesothelioma than chrysotile asbestos. The size of the fiber is easily controlled and it has qualities of toughness and thermal insulation.

* Polyvinyl alcohol (PVA) fibers do not readily split into finer fibers, so independent research organizations and experts think it is safe to conclude that PVA fibers of the diameters used commercially, are unlikely to pose a significant risk of causing the diseases which have been associated with durable respirable fibers.

* Polystyrene can be used as a loose filling in insulation sheets. It will give off toxic fumes when heated.

In a comparison of fibers mentioned above, the three organic fibers (PVA, cellulose and p-aramid) are considered the most likely candidates for chrysotile asbestos substitute materials because they have less hazardous characters than chrysotile asbestos. Moreover, they have been used in many other countries, particularly in Europe, and there exist initial results on evaluation of their impact on workers' health.

3. Some results on the use of PVA in Vietnam.

Based on an analysis of physical and hazardous characteristics of roofing tiles containing PVA and cellulose fibers to substitute the asbestos, several Vietnamese organizations have started developing experimental studies on using PVA fibers as a substitute for asbestos in roofing tile production.

Seeking asbestos substitutes and studying technology for fibro-cement roofing tile production have been ongoing projects since the mid 80s, in Vietnam. But developments have been slow and results not positive.

In 1986-1992, with the project "Roofing tiles using local materials" assisted by the United Nations, Vietnamese scientists carried out research on using plant fibers, such as jute, coconut and sugar-cane fibers to produce plant fiber-cement roofing tiles.

Recently, in 2001, one company in Vietnam carried out research on using organic fibers with Wolastonite to produce non-asbestos fibro-cement roofing tiles. However, its investigations have not proceeded beyond research laboratory level; it still has not produced an effective asbestos substitute material.

In the research programme on construction materials in 2001-2005 "Study on technology appropriate for combination of polymer-cement-inorganic-organic fibers to design light components for use in construction projects on unstable land and earthquake areas," coded RDN-05, the research team conducted a study on identifying technology for non-asbestos fibro-cement roofing tile production based on use of the existing equipment system for asbestos-cement roofing tile production. The experts used cellulose fibers, PVA, cement and other catalytic substances for experimental production of flat and wave roofing tiles on an industrial scale. After theoretical and experimental studies the research team cooperated with a Construction Material Production Company in Vietnam to conduct an experimental industrial production (stage 1) of 1,600 wave roofing tiles and 400 flat roofing tiles in October 2002; in stage 2 in July 2003, 4,000 wave roofing tiles were produced. The study identified the proportions of raw materials required, the technological process of production and additional necessary equipment. Thorough tests showed that the PVA-cement roofing tiles were as good as required by the national standard TCVN 4435-2000 *(Technical requirement of asbestos-cement roofing tiles)*. The study was reported at the final review meeting in September 2003. Its experimental production has been developed in some enterprises in the North, such as Hanoi Roofing Tile Joint-stock Co. (3,500 roofing tiles), Ha Tay Cement Concrete and Construction Factory (2,000 roofing tiles) and Ninh Binh Cement Co. (2,000 roofing tiles).

In 2003, another research team from the Vietnam National Institute of Technology (NIT) conducted a two year project (January 2003-January 2005) "To research, design and manufacture a production line for non-asbestos roofing tiles" as part of the programme "Application of advanced technology in production of export and essential products" coded KC.06.15.CN. The research team focused on: the optimal proportion of materials; the production line; appropriate technological equipment; pattern of product. The team had the co-operation of the Ninh Binh cement Co., to experimentally manufacture and display their products. The output of the experimental production was estimated at about 2,000 roofing tiles.

From laboratory results and experimental industrial scale production, the research team established the technological process of PVA-cement roofing tile production and the method for transition from asbestos-cement to PVA- cement roofing tile production.

The technological process of PVA-cement roofing tile production has the following main characters:

- Due to the PVA fibers having less elasticity it was needed to use catalytic substances, such as milled paper and milled minerals along with other catalytic substances to increase the dispersity of PVA in the spinner, increase filterability, supplement output and ensure proper bonding with the cement matrix.
- The speed of mixing and formatting and mixing concentration of the PVA-cement were higher than for asbestos-cement.
- The air required was lower for PVA-cement than for asbestos-cement.
- Other processes were similar to those used for asbestos-cement roofing tile production.

The above-mentioned factors show that it is necessary to renew and supplement some equipment on the existing production lines in order to move to manufacture of PVA-cement roofing tiles.

We can make a comparison of production technology, finished product and estimated costs for transition from asbestos-cement to PVA-cement roofing tile production. (See Tables 2,3,4).

Table 2. Price of raw materials, cost of electricity and manpower for each asbestos-cement roofing tile (Type 5½ waves; profile 177/51, length 1520mm)

Component	Amount (%)	Unit	Quantity	Unit Price (VND)	Total (VND)
Cement	89	kg	11.9	630	7,497
Asbestos	11	kg	1.6	4,620	7,392
Electro-energy	-	KW	1.0	1,000	1,000
Manpower	-	VND	-	1,200	1,200
				Total	**17,089**

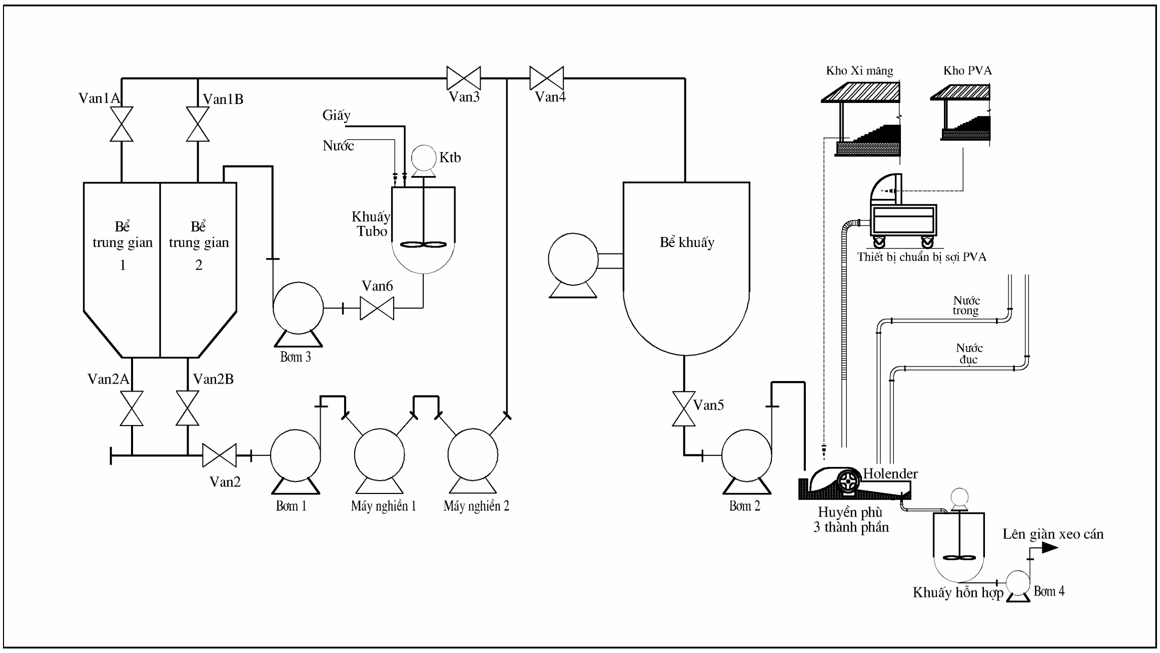
Table 3. Price of raw materials, cost of electricity and manpower for each PVA-cellulose-cement roofing tile (Type 5½ waves; profile 177/51, length 1520mm)

Component	Amount (%)	Unit	Quantity	Unit Price (VND)	Total (VND)
Cement	93	kg	12.55	630	7,909
PVA fiber	2	kg	0.27	38,248	10,327
Electro-energy	5	kg	0.67	1,800	1,215
Manpower	-	KW	1.40	1,000	1,400
	-	VND	-	1,200	1,200
				Total	**22,051**

Table 4. Evaluation of the possibility of transition to the production of non-asbestos roofing tiles.

Criterion	**Asbestos-cement roofing tiles**	**Non-asbestos roofing tiles**
Price	Cheap	Increasing 30%
Investment	Low	Much more
Physical characteristics	TCVN 4434:2000	Corresponding
Durability	20-30 years	20-30 years
Import of asbestos or substitute materials	400,000 tons/year	Reducing
Test of product quality in production	Simple	High requirement
Environmental pollution - Asbestos - Waste water - Other waste	High Average Average	No Similar Similar

Schematic of the technological process of preparation and material provision for PVA-cement production



4. Conclusion

Comment and evaluation

Assessment of both roofing tile types (asbestos-cement and PVA-cement) was carried out at the Laboratory of Vietnam National Institute for Building Technology. The assessment was based on the size and physico-mechanical criteria of the tested sample. The experiment was conducted in accordance with the Vietnam National Standard TCVN 4435-2003 and the evaluation of the test results was conducted in accordance with the Vietnam National Standard TCVN 4434-2000.

We can make the following comments on the test results:

- Both experimental samples have the same size.
- In comparison with the technical requirement according to the TCVN 4434-2000, for the wave roofing tile having a big wave, the height and width of both samples were as good as required, but the criteria of length and wave step were lower than the values required.
- The criterion of PVA-cement break loading capacity was lower than for asbestos-cement, but in comparison with the value required by the technical standard this criterion of both samples was lower.
- The density criterion for both samples was as good as required; the density of the PVA-cement sample was lower than that for the asbestos-cement one.
- The “water permeation time” criterion for both samples was as good as required.

In order to assess durability and capacity of PVA-cement roofing tiles to handle climate conditions in Vietnam, most of the PVA-cement roofing tiles we produced have already been sold to users whose addresses have been kept for testing. In fact, in the Ninh Binh Roofing Tile enterprise, the product has been used on their building; half the roof was laid using asbestos-cement roofing tiles and the other half using PVA-cement tiles. This will enable the testing of the effectiveness of utilization of both the above-mentioned roofing tile types by the time that PVA-cement tiles would be ready for widespread deployment.

- Conclusion

There have been some initial achievements in the search for asbestos substitutes and the production of non-asbestos fibro-cement roofing tiles. However, there are a lot of problems remaining to be studied, such as durability, adhesive capacity of the cement, toxicity of the substitute material and production technology.

In Vietnam, through research projects and the process of experimental production of PVA-cement roofing tiles at some enterprises and with observation of the obtained products, we are able to make the following comments:

- PVA-cement roofing tile production based on the asbestos-cement roofing tile production technologies existing in enterprises using wet-forming technology can be fully implemented.

- Material resourcing can be fully ensured:

- PVA fibers may be imported from Japan and China; those are the biggest suppliers and very near to Vietnam.
- The catalytic substances can be produced in Vietnam

- Redesigning production lines will not cost much and can be done by domestic mechanical enterprises.

- The price of PVA-cement roofing tiles will be about 30% higher in comparison with the asbestos-cement roofing tiles; that will make it difficult to market, particularly when consumers are poor people.

- Therefore, for PVA-cement roofing tile to be accepted properly in society, we should continue to study and solve the following matters:

- Are presses needed or not?
- How to reduce the electric energy costs (at present the electric energy cost is 1.5 times higher in comparison with the asbestos-cement roofing tile).
- The planning and organization of workshops should be appropriate, so that not much more space is needed when additional equipment for the PVA-cement roofing tile production is installed in the workshop.
- Can lower quality cement be utilized?
- How to ensure that enough catalytic substances will be produced for supplying to enterprises at low prices.
- The need to test the strength and durability of PVA-cement roofing tiles in tropical hot and humid climatic conditions and investigate the effect of the PVA and cellulose fibers on the strength and durability of the roofing tiles.
- How to establish production of PVA fibers in Vietnam.

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