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HATSCHEK MACHINE AND EQUIPMENT FOR NON-ASBESTOS FIBER REINFORCED CEMENT SHEETS

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ABSTRACT

This paper presents a newly developed Hatschek machine and equipment for a complete production line of non-asbestos fiber reinforced cement sheets. The machine adopted pneumatic mechanism in its operation shows many advantages, especially the easy assigning of pressure at various important positions. A set of highly automated equipments for raw material treatment, product forming and de-moulding and lab test was developed in a simple and environment friendly oriented way. The machine and equipment have been implemented into a PVA fiber-reinforced cement sheets production line. After 3 years of operation, the machine and equipment show good performance and efficiency. The factory products are good in both the mechanical and physical properties, and meet all strict requirements of the Japanese Industrial Standard JIS A 5430:2004, "Fiber reinforced cement boards".

KEYWORDS:

Hatschek machine; non-asbestos technology; fiber-reinforced cement sheets.

INTRODUCTION

Asbestos cement sheets with good mechanical strength and durability have widely been used for well over a century. However, the hazard of asbestos to human health leads to the ban of using asbestos in construction material industry in many countries. Therefore, the investigation on new fibers for asbestos substitution as well as development of new technology, including manufacturing process and equipment for non-asbestos cement sheets, is of great interest of researchers and engineers.

Vietnam is a developing country, and the demand for roofing material, especially the low cost material increases year by year. According to the statistic data from Vietnam Association of Roofing Materials, in 2009 Vietnam imported around 64,000 tons of asbestos, mostly for application in manufacture of corrugated cement sheets. With the data, Vietnam belongs to the most asbestos consuming countries in the world.

However, being aware of the danger of asbestos, since 2001 Vietnamese government has issued some decisions to regulate and restrict the use of asbestos in the field of construction material industry. At the same time, the government encouraged the research on finding fibers for asbestos substitution as well as development of new methods in manufacturing non-asbestos cement sheets. Since then many organizations, including the government research institutions and private companies have been highly paying attention on the topic. In 2003, in a cooperation project between Navifico, a Joint Stock Company in Vietnam, and Elkem of Norway, the first non-asbestos corrugated cement sheets have been manufactured in Vietnam (http://www.navifico-corp.com). However, to the authors knowledge, due to the low quality of the products as well as the instability and inefficiency of the production line, Navifico stopped to produce the non-

asbestos sheets, just after some trials. In the circumstances, some foreign companies came to Vietnam and tried to introduce their equipment and technology for making non-asbestos cement sheets. However, the equipment and technology require a large amount of investment, which Vietnamese companies can hardly afford.

With some support from government, since 2002 RITM (Research Institute of Technology for Machinery) started to conduct the research on non-asbestos cement material, in both the machinery and process technology. The research focuses on the development of new equipment and technology based on the Hatschek process, which is widely used by Vietnamese fiber cement manufacturers. The modification of the existing machine and equipment of the asbestos production lines for production of non-asbestos cement products is also of interest. In the research process, a close cooperation with Japanese PVA fiber manufacturers, namely Kuraray and Dipro International led to significant results, in both equipment and process technology. As a result, the first factory for non-asbestos cement sheets was built in Vietnam in 2007. After 3 years of operation, the machine and equipment show good performance and the products have high quality, which meet all requirements of Japanese Industrial Standard (JIS A 5430:2004. "Fiber reinforced cement boards"). .

The objective of this paper is to describe the characteristics of machine and equipment developed by RITM for production of non-asbestos cement sheets. An emphasis is put on the newly developed Hatschek machine with highly automated operation. Some aspects of process technology and product properties are also presented.

HATSCHEK PROCESS

The Hatschek process, invented by Ludwig Hatschek in 1900 and registered as Austrian Patent number 5970, results in a strong and durable laminate composite material, which has been widely used as roofing material in many countries around the world. In the process, a slurry with concentration of about 10% is formed by mixing Portland cement, asbestos and a small percentage of Kraft paper with water. The slurry is then led to some vats, where the solid materials are taken onto a felt by using sieve cylinders, which continuously rotate during manufacturing process. The thin lamina of the solid materials is steadily transferred to a forming cylinder to form a sheet. Until a desired thickness is reached, the sheet is cut and transferred to an area where products with specific geometry are formed by using some specific equipment. A sketch of the Hatschek machine is depicted in Figure 1.

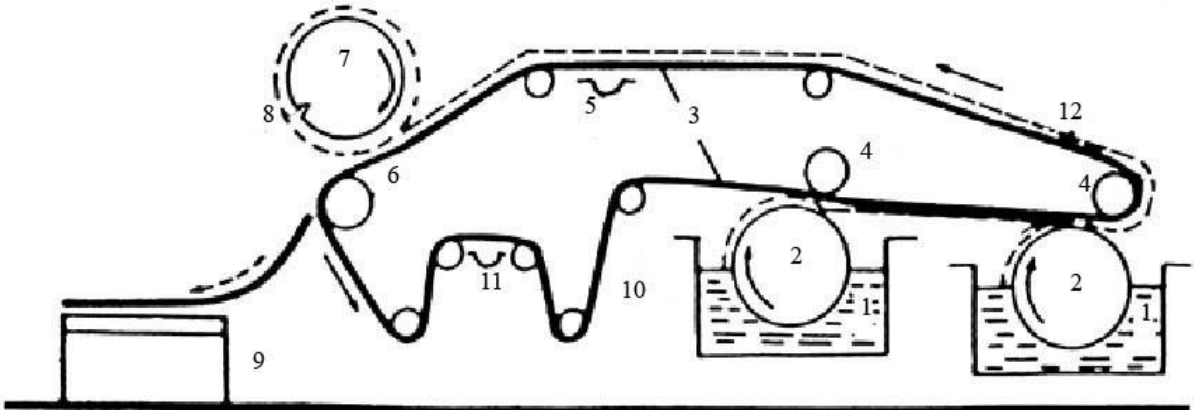

Figure 1 - Sketch of Hatschek machines: 1- Slurry vat; 2 - Sieve cylinders; 3 - Felt; 4 - Couch rolls; 5 - Vacuum box; 6 – Breast rolls. 7- Formation cylinder. 8- Cutting wire; 9- Take-off conveyor. 10- Whipper. 12- Lamina

It is necessary to mention that because of its special physical properties asbestos is easy to disperse in the cement slurry, especially because of its high specific surface area, asbestos shows excellent affinity for cement (Hannant, 1978). Other fibers such as PVA fibers do not have such properties, and many problems, including the fiber balling, delamination and low cement yield, occurred in the non-asbestos process. As an example, Figure 2 shows a cross section of a delaminated PVA cement product and back view of a product with fiber balling. The Figure 3 shows another defect easy to meet - cracks on the PVA sheets. The problem asks, between others, for improvement the properties of non-asbestos slurry by adding other materials such as silica fume, bentonite, mica, wollastonite, flocculant... The modification of the Hatschek machine as well as the development of new equipment for treatment of the above mentioned materials are also required. Thus, the non-asbestos technology is totally different from both the material and equipment points of view. Some manufacturers were not aware of the requirements, and tried to produce non-asbestos cement products just by using some new materials. As a results, the obtained products have very low mechanical strength, and failed to meet requirements of practice.

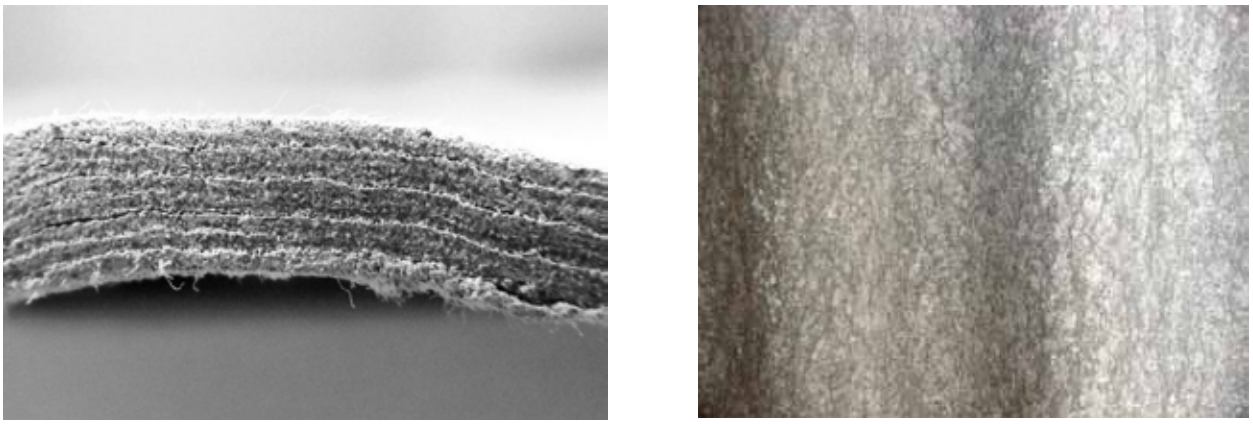

Figure 2 – Delaminating and fiber balling PVA cement products

Figure 3 - Cracks on the PVA sheets

HATSCHEK MACHINE AND EQUIPMENT FOR NON-ASBESTOS TECHNOLOGY

As above explained, the non-asbestos technology is very different from that of the asbestos one, and in order to ensure an efficient production line with high quality non-asbestos products, a Hatscheck machine with new features is required. Since the required pressure at the important positions such as the making cylinder, couch and breast rollers much depends on the felt speed as well as on the compositions used, an easy and highly automated control system is desirable. To this end, RITM has developed a Hatschek machine based on the pneumatic mechanism in its operation. A 3-vat Hatschek machine for non-asbestos technology,

recently designed and fabricated by RITM is shown in Figure 4. Due to characteristics of the fiber cement production, cleaning, maintenance and sieve mesh changing is often required at the vat, a simple system for removing the vat manually is adopted for this purpose. Figure 5 shows the detailed system of the manually removable vat.

Figure 4 - A new Hatschek machine developed by RITM

Figure 5 - Vat removing system of RITM Hatschek machine

In general, the Hatschek machine for PVA cement production is very similar to that of the asbestos-based one, from outside appearance, at least. However, many features of the non-asbestos machine are different from that of asbestos machine. The speed of agitators at the vats should be adjusted to assure that the PVA fibers are properly dispersed in the cement slurry, and the solid materials are be able to stick on the cylinder meshes. The pressure at the formation cylinder and rollers should be controlled as well as the green sheet should not be over dried, which could cause difficulties in the forming stage. Many other machine parameters also require to be properly adjusted.

As already mentioned above, different from the asbestos technology, in addition to the Portland cement and fibers for reinforcement, the non-asbestos technology requires a wider set of different raw materials in its production for improving the production process as well as the properties of final products. The function and effectiveness of these raw materials are different. Table 1 lists some raw materials commonly used in production of PVA cement sheets as well as their respective function and performance (effectiveness).

Table 1 - Common raw materials used in production of PVA cement sheets

No.	Material	Function	Performance (Effectiveness)
1	Portland cement (already in asbestos process)	Binding agent	Strength of matrix, binding composite
2	PVA fibers (f.e. KURALON)	Reinforcement, asbestos substitution	High bending strength & impact strength
3	Wollastonite, mica (additional)	Stabilizer	Dimensional stability, preventing crack formation
4	Silica Fume (additional)	Filler	Densification of matrix, control gravity, better bonding between fibers and matrix, better appearance
5	Attapulgite, Bentonite (additional)	Improvement of Forming	Improvement of productivity, layer adhesion
6	Polyacrylamide (additional)	Agglutinate Agent	Improvement of Productivity

The additional raw materials such as that listed in Table 1, however are not ready for application in the Hatschek process and pre-treatment of the materials is required. Thus, in order to produce the non-asbestos products in general and the PVA cement sheets in particular, a set of new equipment for treating these raw materials has to be developed. The equipment should be designed in way it can treat the materials properly and efficiently, but without expanding the production line too much. Among the additional materials, the treatment of Kraft pulp is the most important, and it requires strict control. The fineness of the pulp after treating plays an important role in the non-asbestos production process. Figure 6 depicts the equipment for pulp refining, as designed and fabricated by RITM.

THE FIRTS VIETNAMESE NON-ASBESTOS PRODUCTION LINE - A CASE STUDY

PVA production line

Based on the machine and equipment research and development for the non-asbestos technology at RITM, in 2007 a joint project between RITM, Kuraray of Japan and Dipro International resulted in the first production line for PVA cement corrugated sheets in Vietnam. The production line was built at a factory of TTC Joint Stock Company, a company located in the Northern part of Vietnam. All the Hatschek machine and equipment implemented at TTC have been fabricated by RITM. For the first step, the factory aims to a capacity of 2 millions square meters of corrugated sheets per year.Figure 7 shows Flow chart of the PVA fiber production line of TTC factory. A view of the production line with main equipment is depicted in Figure 8.

Figure 6 - Pulp refiner developed by RITM

The PVA cement production line of TTC contains two main units, namely the Hatschek machine and the set of equipment for raw materials treatment. The set of the raw material treatment is totally new, and it is not necessary for asbestos cement technology. As seen from the Figure 8, this set of equipment for the raw material treatment has been designed in a compacted way, and it does not require much space. The size of the non-asbestos production line at TTC, thus is not much larger than that of the asbestos one. In addition, this raw material treatment unit has been positioned just at the beginning of the Hatschek machine, and thus minimizes the pipeline and energy necessary for transporting the treated materials to the Hatschek machine.

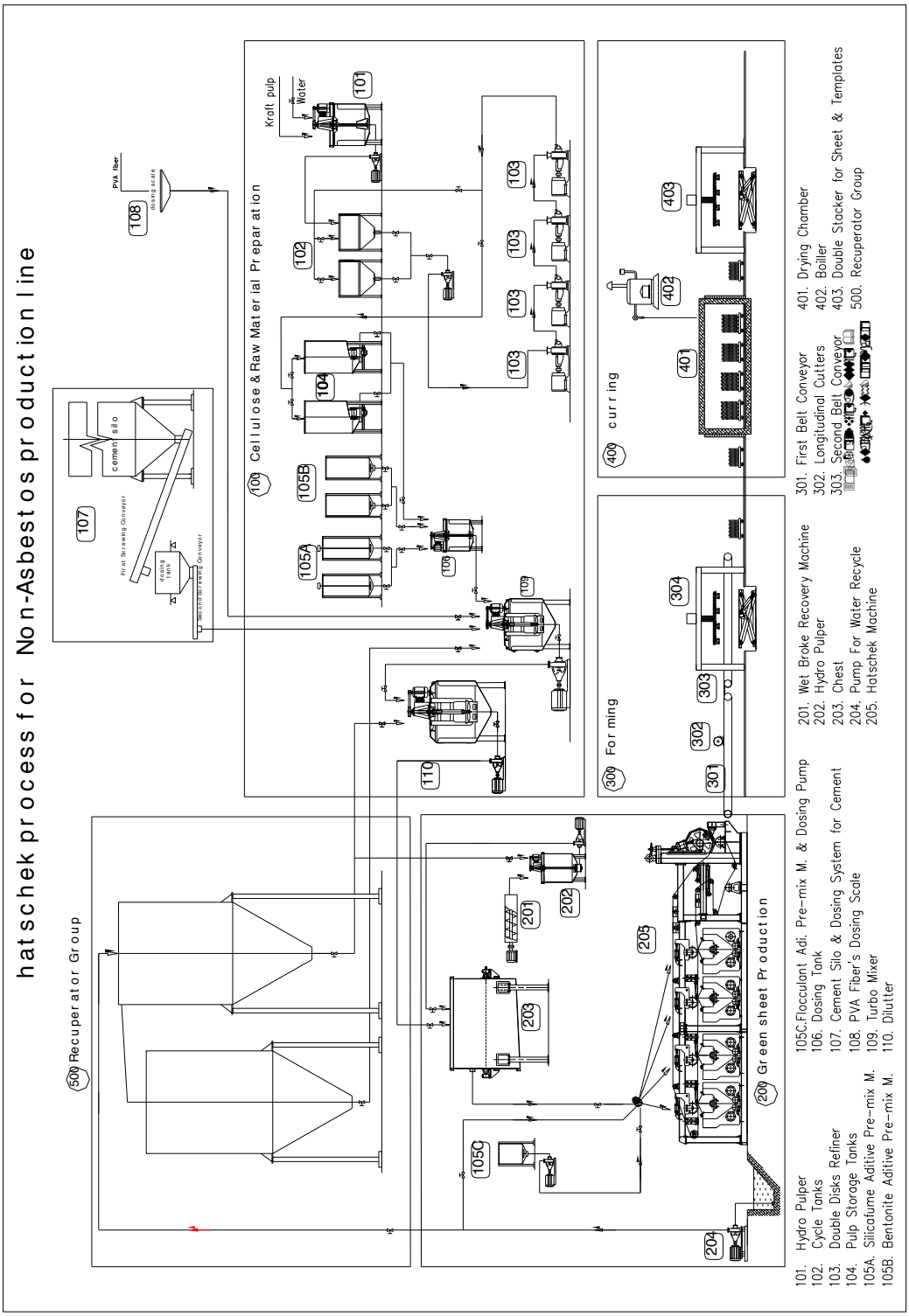

Figure 7 - Flow chart of PVA fiber cement production line

Figure 8 - Main equipment of non-asbestos cement production line at TTC

In addition to the above-mentioned two main units of the PVA production line, some equipment for product forming and de-moulding is also necessary for producing high quality PVA cement sheets. The equipment should be highly automated to prevent crack and defect formation during the forming and de-moulding process. The equipment for product forming at TTC company is positioned just at the end of the production line. The equipment designed and fabricated by RITM is fully automatic. In the latest version, the forming machine designed and fabricated by RITM has a cycle time of 15 seconds.

After 3 years from the date of installation, all the machine and equipment at the TTC company are working well, and no major repair has been required. The machine and equipment are maintained monthly, mainly cleaning and lubrication. The simple operation of the machine and equipment and environment oriented design of the factory, where natural light has been used as mush as possible, ensure the effectiveness and efficiency of the production line.

PVA technology

Various types of fibers, including the natural fibers and Kraft pulp can be used as substitution for asbestos (Savastano Jr et al., 2000; Savastano Jr et al., 2003). However, since the question of durability of natural fibers in the high alkali environment of cement matrix is remaining, the PVA is the most favourable for this purpose. In this regards, we select PVA fibers as asbestos replacement at the TTC company.

In our research, PVA fibers with commercial name Kuralon, made by Kuraray of Japan are employed. Kraft paper, silica fume and bentonite have been used as additional raw materials for the non-asbestos Hatschek process. Typical raw material dosages for PVA cement sheets are as follows: PVA fibers 2%, Kraft pulp 4%, Silica fume 5%, Bentonite 4%. The remaining is ordinary Portland cement. A small amount of flocculant, pre-mixed with water is added to improve the process, including the retention, dewatering and formation. However, care should be taken in choosing a suitable flocculant and the way in that this type of chemical is applied since bad flocculant and wrong way of using it results in decreased strength of the final products (Negro et al., 2005; Negro et al, 2006).

It is necessary to mention that many problems, including low cement yield, fiber balling, delamination, cracks, low bending strength have occurred at the beginning of our work. Among that crack formation on the products such as that shown in Figure 3 is the most common problem. The problem is the most difficult to solve in the non-asbestos technology.

Thanks to the team of Japanese and Vietnamese engineers, all the problems of PVA cement sheets at TTC were solved in time. To reduce the defects and to use the metal moulds in an efficient way, a steam curing system based on Japanese know-how has been developed at TTC company. The system allows the products attaining the strength necessary for de-moulding after 8 hours from the time of moulding. Thus, the metal moulds can be reused in very short time, which helps the production line to be more economical.

Product properties

Various tests, including the bending strength, specific gravity, water absorption, breaking load of full-size products have been performed. The test has been performed in accordance with JIS A 5430:2004, in which the bending test specimens have been kept in the well-vantilated room for at least 5 days after curing before testing (air dried condition). The bending strength samples with size of 180mm x 50mm x 6.3mm have been cut out from the real corrugated sheets and tested in bending using three-point bending scheme as shown in Figure 9. The distance between the two supports is 150 mm. The testing data are transferred to a computer and the stress-deflection curves of the test are drawn.

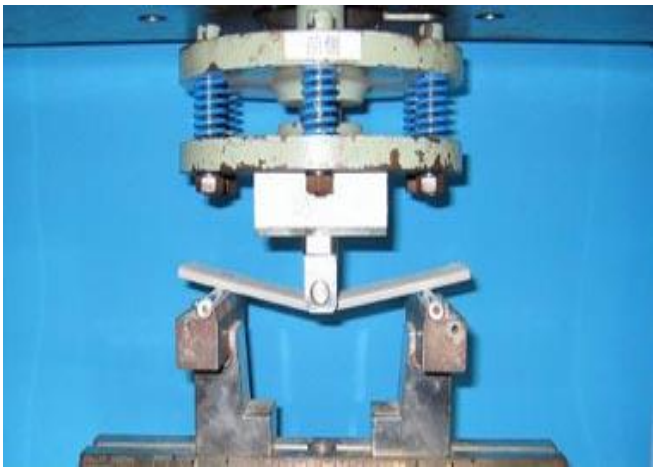

Figure 9 - Test set up for bending strength of PVA cement sheet

Figure 10 shows the stress-deflection curves for PVA cement sheets made by TTC by using the above-mentioned compositions. The bending strength of all tested specimens exceeds 22 N/mm^2, which is over the requirement of the Japanese Industrial Standard, JIS A 5430:2004. With the large deflections, the curves show the high ductility of the composite as evidenced by the large area below the curves.

The corrugated PVA cement sheets with dimensions in accordance with Japanese and Vietnamese standards were tested to determine the breaking load and water absorption. As an example, Figure 11 shows the test results of the JIS size sheets, performed by a Korean Institution. The test was done in accordance to the Korean Industrial Standard, KS L 5114: 2003. As seen from the figure, the breaking load exceeds the load required by the Korean and Japanese standards, which is more than 3,920 N. The water absorption, which obtained in the test is 26.9%, also meets the requirement of the standards (less than 29%). In consequence, this shows that the PVA corrugated cement sheets produced by RITM Hatschek machine and equipment have good performance, and satisfy strict requirements of Japan and Korea market. In practice, the PVA corrugated cement sheets of TTC have been exported to the Korean market.

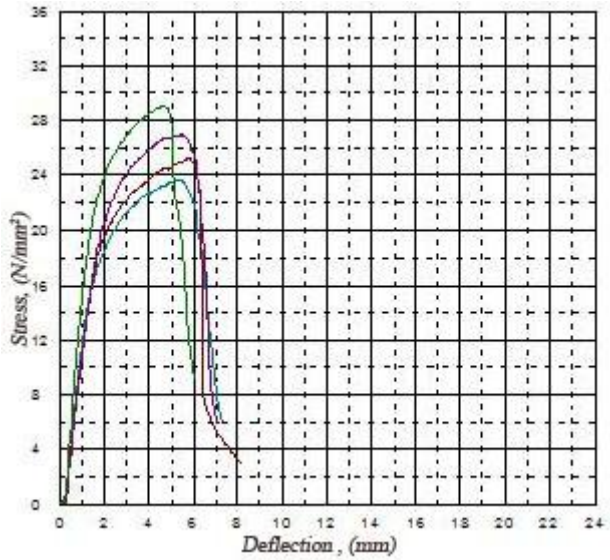

Figure 10 - Stress-deflection curves for PVA fiber cement

시 험 항 목	단 위	시 험 결 과	
휨 파 괴 하 중	N	4 335	
흡 수 율	%	26.9	KS L 5114 : 2003
투 수 성	-	뒷면에 물방울이 생기지	

Bending load (N)
3920 min.

Water absorption (%)
28 max.

Figure 11 - Test results of full size corrugated sheets

CONCLUSIONS

The paper presented a sheet production machine and accessory equipment for the production of non-asbestos cement products by using the principle of the Hatschek process which was originally developed for asbestos cement. Some features of the non-asbestos technology were also addressed. The first Vietnamese PVA cement sheet factory using the modified Hatschek machine and equipment mainly designed and fabricated by RITM based on the Japanese know-how, was built at TTC, a joint Stock Company in Vietnam in 2007. The main conclusions of the paper can be summarized as follows:

- The non-asbestos fiber cement technology is very different from the asbestos cement technology. Although the modified Hatschek machine used in the non-asbestos technology looks very similar to that used in the asbestos cement technology, many characteristics are different. Thus, a Hatschek machine used in the asbestos production line requires the necessary modifications before using in the non-asbestos production line.
- A unit of equipment for the raw material treatment is required in the non-asbestos production line. In regard of the traditional Hatschek process, the raw material treatment is an additional work, and it plays an important role in the production of the non-asbestos cement products.

- The Hatschek machine and equipment for the non-asbestos technology designed and fabricated by RITM are simple, efficient and energy saving. The case study shows that the machine and equipment are working well and stably, and require very few maintenance and repair. The equipment was designed and fabricated by integrating parts available in the market by which the total machinery cost could be reduced considerably.
- The PVA corrugated cement sheets produced by using the Hatschek machine and equipment of RITM show good performance in the physical and mechanical properties, and pass strict requirements of the Japanese Industrial Standard, JIS A 5430:2004, "Fiber reinforced cement boards". As a result, the products can be accepted by markets that require high-quality such as Japan and the United States.

The non-asbestos production line developed by RITM and Japanese team may not be the best one, however with the present conditions of Vietnam and other similar countries, the production line shows some advantages, including the low investment, easy operation, less maintenance and repair. The spare parts of the machine and equipment, which are easy to find in the market, help the manufacturers save time and money also.

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