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Thermal Analysis and Waste Reduction in Asbestos Cement Sheet Production

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Abstract - Asbestos cement sheets were used as roofing materials because of its high tensile strength and resistant to corrosion. In the production of asbestos cement sheet there are many wastages are produced due to uneven cooling, addition of foreign particles and improper bonding among the raw materials. In order to avoid such wastages, inclusion of Kaolin as partial replacement of cement results in good inter-bonding between raw materials. The inclusion of kaolin with fiber cement mix will eliminate edge cracking. The asbestos sheets subjected for the application of roofing leads to emission of enormous amount of heat on the work environment. Paraffin Wax and Calcium Hydroxide Coating were made to analysis the heat reduction in the Asbestos sheet.

Keywords – *Calcium Hydroxide Coating, Hatschek Machine, Kaolin, Paraffin wax, Thermal Analysis.*

I. Introduction

Asbestos has been mined and used commercially world-wide since the early 1900’s. Asbestos is a naturally occurring family of fibrous mineral substances. Asbestos became a popular commercial product because it is non-combustible, resistant to corrosion, has a high tensile strength, and some groups of asbestos fibers have a low electrical conductivity. There are many types of asbestos fibers available in worldwide but among them only three types of asbestos fibers used commonly for preparing the AC sheets. Those three main types of asbestos fibers are Chrysotile, Crocidolite, Amosite among these except Chrysotile other two were banned due to their high toxicity level. Due to low level of toxicity content the Chrysotile fibers are used in the production of Asbestos Cement Sheet Production. These fibers were subjected to series of process to form a Complete Asbestos Cement Sheets. During the production of these Cement sheets there are wastages occurs in some stages. The wastages such as drum sticking, Shrinkages during curing stage are the major problems occurs in the survey. Hence to overcome these wastages and maintain a proper curing time the admixtures of superplasticizer and kaolin were used. For the perfect binding of green sheets few more modifications were made on the Hatschek machine. In order to reduce the heat in finished asbestos sheet Calcium Hydroxide Coating was made and compared with the Paraffin Wax mixed Green sheets after curing. Since the Paraffin Wax was a type of the Phase Change Material it can result in successful heat reduction but the addition of this Phase Change Material should takes place in the Green sheet due to its property of binding. The mentioned datum regarding wastages were collected from the RAMCO Industries Limited. The objective of this paper are to reduce the

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heat absorbed by the asbestos sheet, to reduce the drum sticking wastages during the production of green sheets and to reduce the shrinkages in the stage of curing process. The remaining part of the paper is organized as follows: Section II illustrates the review of related literatures; Section III explains the Methodology used to control the waste and heat. In Section IV Thermal Analysis made on the sheets is discussed and Finally, Section V concludes the study and outlines some future research directions.

I. LITERATURE REVIEW

Ravi Kumar carried out a study on Natural Cooling of building with Phase Change Material. In his paper a comparison of various roofs were made with use of Phase Change Material and without use of the Phase Change Material. As a result the heat transfer was reduced about 45% on comparing with the WC sheets. John Pockett and Marti Belusko made a review of Heat Reflective Paints which was based on the pigments to match the visible colours that naturally reflect the more infra-red radiations .It was concluded with the effective solution for the coating roofs of houses against the heat from sunlight with White paint.

A.T.Pise (2013) investigated the melting characteristics and estimated the effect on thermal performance of paraffin wax due to enhancement in thermal conductivity using alumina nanoparticles of paraffin as a phase change material. Pawan R Ingole and Tushar R Mohod made a review on the usage of Phase Change Materials in Construction of Buildings. In their paper the different types of PCM used based on their chemical properties were classified and review were made. Lin Qiu, et al. (2012) analyzed the reality melting and solidification of PCM set up the PCM heat transfer model which considering liquid-phase natural convection in this paper and exploits CFD software to carry out numerical simulation. Mario A Medina, et al. (2013) presented results of the potential thermal enhancements in building walls derived from using phase change materials. For the frame walls, the PCM encapsulated within reflective foil sheets yielded the highest reductions of 52.4% (peak) and 35.6% for a PCM concentration of about 15%, producing more stable wall temperatures. Amarendra Uttam, et al. (2013) presented the application of phase-change energy storage in air conditioning applications. It was concluded from the results that during day time temperature of air coming to the room is decreased by 2-4 K. The effectiveness of system is highly dependent on local climate. E.Gidarakos and K.Anastasiadou describe the technologies for the waste treatment of asbestos such as Asbestos land disposal, stabilization, Microwave treatment, Chemical treatment. Effect of asbestos cement sheet waste on flexural strength of concrete by Manu Chaudhary describes about the inclusion of superplasticizer with fine and coarse aggregates. Dr Zoltan Adamis detailed the view on Bentonite, kaolin and selected clay minerals in his presentation. It gives the overview about the kaolin's chemical properties and it uses on the compositions. It also described about the exposure level on human and the environmental levels.

I. METHODOLOGY

The general raw material composition in the production of Asbestos Cement Sheet is Pulp 1%, Chrysotile Fiber 9%, Fly Ash 35%, Cement 40% and Water 15%. The common wastage occurs at the end of Hatschek machining process and shrinkages occurs at the stage of curing process. These wastages are due to the improper bonding among the raw materials hence in order to overcome these problems kaolin is introduced. The chemical formula of kaolinite is $Al_2O_3.2SiO_2.2H_2O$ with the following composition 39.5% Al_2O_3; 46.5% SiO_2; 14% H_2O. The size of the kaolin particles is less than that of cement particles and thus

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able to fill the gap spaces formed between cement particles. Although replacement of cement with 5% kaolin resulted in the highest density values throughout the curing period, the significant increase in density was attained with 1% - 3% substitution of cement. Permeability depends on the packing of the material. Supplementary cementing materials having size less than that of cement can improve the permeability of the matrix. The kaolin mixture shows the relatively high flexural strength than the standard mixture. The strength increase is comparison with standard mixture. The strength enhancement is due to a combination of the filler effect and accelerated cement hydration. The more dense structure reduced the ingress and egress of moisture in the sheets thereby reducing or preventing drying shrinkage. Along with the inclusion of kaolin some other materials such as superplasticizers can also be used. The size of the superplasticizer less than that of the cement particle and thus these materials also able to fill the gap formed between the cement particles. The addition of superplasticizer of about 10%-20% with cement. Based on the addition of superplasticizers ratio of cement in raw materials can be reduced. In order to get good results along with addition of superplasticizers the kaolin and silicon resins are introduced. The flexural strength of the sheets can be increased by the addition of more amount of superplasticizer.In case of heat reduction using the Phase Change Material the following procedure was carried out. The solid paraffin wax was melted at 20^{o}C using microwave oven to form 25 ml of liquid paraffin wax. The two layers of green sheet was separated in a uniform manner to avoid deformation. Then the liquid paraffin wax was gradually poured between the layers of two sheet and tightly binded. By the inclusion of paraffin wax the binding property of the green sheet increases. Then the green sheet was subjected to curing process for about 6-8 hours. After the curing process the sheet was analyzed at various conditions comparing with ordinary Asbestos Cement Sheet and Calcium Hydroxide coated sheet. The Calcium Hydroxide coated sheet was obtained by the following procedure. Calcium Hydroxide of 200grams was mixed with 250ml of water and stirred well. The 5ml of synthetic adhesive binder was added to the above mixture. Then the mixture was coated in the 1st day and 21st day corrugated asbestos sheets and dried for several hours. The above process was repeated along with the addition of 10ml of stainer solution in the mixture and coated in the corrugated sheets. These sheets were examined with the temperature sensor and the observations were made.

IV. THERMAL ANALYSIS

The use of Paraffin Wax Phase Change Material results in the following readings

TABLE I
OBSERVATION OF PCM

TIME (Hrs)	Surface Temperature (^{o}C)	Temperature with PCM (^{o}C)	Temperature without PCM (^{o}C)
Initial (9.30)	35	33.6	31.2
After 2hrs	45	41.3	38.7
After 4hrs	62	55.0	59.4
After 6hrs	59.8	50.9	57.7
After24hrs	57.3	51.8	54.4

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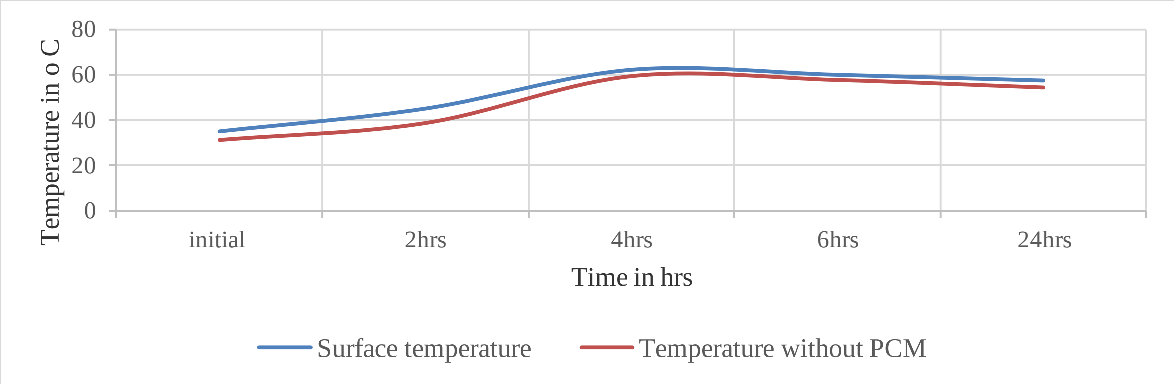

Fig1. Temperature difference without PCM

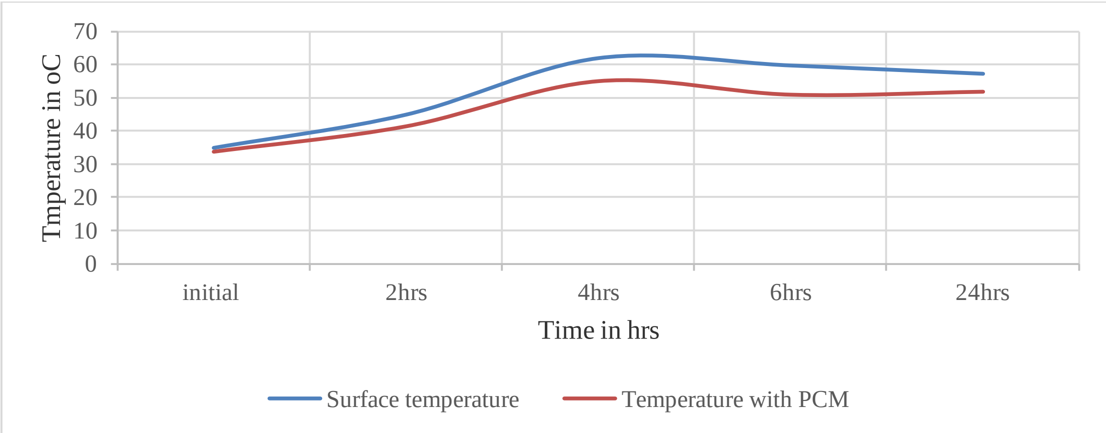

Fig2. Temperature difference with PCM

From the above graph it is clear that the initially at the stage where the melted Paraffin wax added in green sheet results in the rise of temperature level but after some time the Paraffin wax sheet tends to decrease the temperature level than that of ordinary Asbestos Cement sheet. This initial high temperature level is due to inclusion of Paraffin wax at the melted stage thus it result in increase in temperature and cools the sheet gradually after the process of curing. The breaking load for the PCM mixed was calculated by the following mathematical expression.

$$\text{Breaking load (KN/m)} = \frac{\textbf{Force at breaking point (KN)}}{\textbf{width of the sheet (m)}} \qquad (1)$$

The applied breaking load = 0.52 KN

Width of the sheet = 1.05 m

Hence force at the breaking point is

Force at breaking point = Breaking load * Width of the sheet

Using equation (1) = 0.52*1.05

= 0.546 KN/m

According to ISI norms the force at breaking point must be in the range of 0.51 to 0.55 KN/m. The temperature level reduces from 2-4°C by using the Paraffin Wax as PCM in the Asbestos Cement sheet.

The Calcium Hydroxide coating results in the following observations.

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TABLE II

FIRST DAY SHEET

Nature of asbestos	Without coating (°C)	Coating Without stainer (°C)	Coating With stainer (°C)
Temperature at upper side	46.7	43.9	37.8
Temperature at lower side	41.4	39.0	35.8

TABLE III

FIRST DAY SHEET AFTER 24 HOURS OF CURING

Nature of asbestos	Without coating (°C)	Coating Without stainer (°C)	Coating With stainer (°C)
Temperature at upper side	47.8	42.6	44.8
Temperature at lower side	43.8	38.0	38.6

TABLE IV

21ST DAY SHEET

Nature of asbestos	Without coating (°C)	Coating Without stainer (°C)	Coating With stainer (°C)
Temperature at upper side	46.5	40.7	41.1
Temperature at lower side	41.8	36.6	37.5

TABLE V

21ST DAY SHEET AFTER 24 HOURS CURING

Nature of asbestos	Without coating (°C)	Coating Without stainer (°C)	Coating With stainer (°C)
Temperature at upper side	51.7	45.1	44.7
Temperature at lower side	46.7	42.1	41.4

Thus the heat transfer in the asbestos can be calculated using the following mathematical expression.

Heat conducted in the material $Q = \frac{\Delta T}{R}$ (2)

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Where, $R = \frac{1}{A}[\frac{L}{K}]$

ΔT = Change in temperature

Area of the AC sheet (A) = 3.15 m^2

Length of the AC sheet (L) = 0.06m

Thermal conductivity (k) for asbestos = 0.1163 W/mK

Calculation:

$$R = \frac{1}{3.15}[\frac{0.06}{0.1163}]$$

$$= 0.1637$$

For first day sheet without coating

$$\Delta T = 46.7-41.4 = 5.3$$

Using equation (2) $Q = \frac{5.3}{0.1637}$

$$Q = 32.37 \text{ W.}$$

For first day sheet without stainer coating

$$\Delta T = 43.9-39 = 4.9$$

Using equation (2) $Q = \frac{4.9}{0.1637}$

$$Q = 29.89 \text{ W.}$$

For first day sheet with stainer coating

$$\Delta T = 37.8-35.8 = 2$$

Using equation (2) $Q = \frac{2}{0.1637}$

$$Q = 12.21 \text{ W.}$$

For 21st day sheet without coating

$$\Delta T = 46.5-41.8 = 4.7$$

Using equation (2) $Q = \frac{4.7}{0.1637}$

$$Q = 28.7 \text{ W.}$$

For 21st day sheet without stainer coating

$$\Delta T = 40.7-36.6 = 4.1$$

Using equation (2) $Q = \frac{4.1}{0.1637}$

$$Q = 25.04 \text{ W.}$$

For 21st day sheet with stainer coating

$$\Delta T = 41.1-37.5 = 3.6$$

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Using equation (2) $Q = \frac{3.6}{0.1637}$

$Q = 21.19$ W.

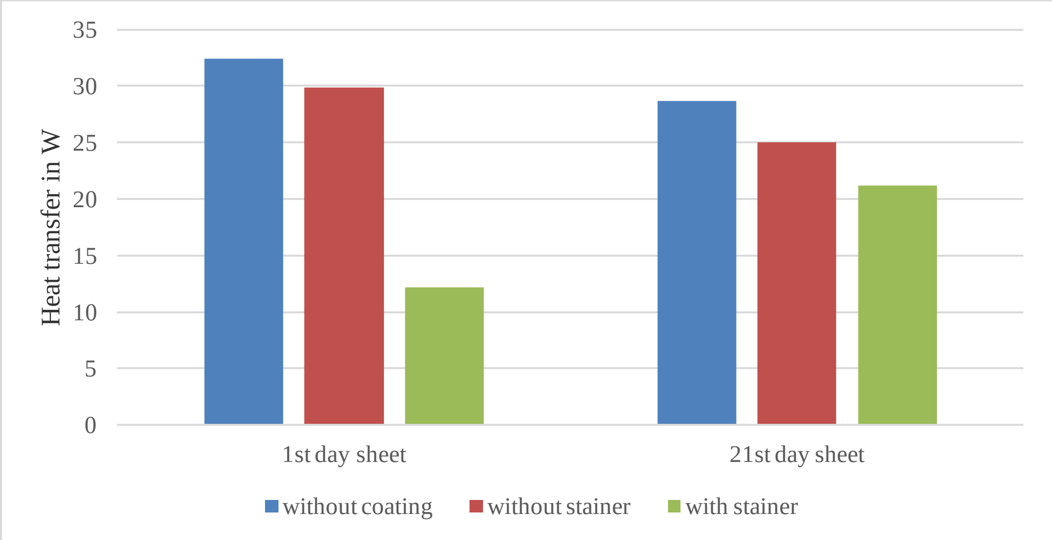

Fig 3. Heat Transfer take place in various sheets

From the observations and calculations the heat transfer takes place in non-coated asbestos sheet was more than that of heat transfer take place in coated asbestos sheet. Though there were good results of heat reduction in first day coated asbestos sheet, it is better to use the 21st day coated asbestos sheet in order to avoid damages. The coated asbestos with stainer lead to more reduction of heat and provide color to the sheets. These Calcium Hydroxide coating reduced the temperature level about 3-5°C. The cost for these coating preparation was lower than that of the preparation of Green sheets with the Phase Change Materials.

V. CONCLUSION

Thus addition of kaolin is the best mitigation process in-order to avoid cracking and the wastages occurring during the production. The optimum treatment for minimization of drying shrinkage in stacked corrugated fiber cement sheets was found to be the inclusion of three percent of kaolin, as replacement of cement, in the standard mix formulation. Due to the reduction of the shrinkage losses and drum wastages dry piece wastes can be reduced. Paraffin wax which is a Phase change material (PCM), this material is binded between the green sheets and let it to dry for one day. This may result in tight bonding between the two layers. Temperature decreases up-to 2-4°C. But adding phase change material in asbestos cement sheet was tedious process and expensive. Thus as the result mixture coating on asbestos cement sheet is the best mitigation process to avoid heat reduction. Adding coating prevents from dry cracks and leakages. It also satisfies the customer needs and gives more attractive color than ordinary cement sheet. As compared with phase change material and coating the mixture coating gave good result than the paraffin wax. The temperature decreases up-to 4-7°C on coating. This shows that the mixture coating was more effective than phase change material and also inexpensive. Future research can be possible by varying the mixing ratio of Phase Change Material and the Composition of the Coatings. In case of the waste reduction the kaolin added sheets are to subjected for long term and to be examined.

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