Gypsum Boards Reinforced with Cotton Dust Fiber

Sujira Khorjitmate1,*, Ken Miyata2, Bintasan Kwankhao1 and Somboon Sukpancharoen3

1Department of Textile Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi, Pathum Thani, 12110, Thailand
2Graduate School of Engineering, Yamagata University, Yamagata, Japan
3Department of Mechatronics Engineering, Rajamangala University of Technology Thanyaburi, Pathum Thani, 12110, Thailand

*Corresponding author: sujira.k@en.rmutt.ac.th

Abstract. This research was aimed to study the production of gypsum boards mixed with cotton dust fiber for construction purposes. The cotton dust fiber 5, 10, 15, and 20% by weight was mixed with gypsum plaster and cast in the size 300 × 400 × 9 cubic millimeters. The water content was added 77 % by weight of the mixture. The ultimate strength, modulus of rupture, and weight of the gypsum board were investigated. The results showed that the ultimate strength and modulus of rupture of the gypsum boards without cotton dust fiber were 168.78 Newton and 3.66 Mega Pascal, respectively, which met the criteria for standard gypsum board under TIS 219-2524. However, the ultimate strength and modulus of rupture of the gypsum board mixed with cotton dust fiber were lower than the standard gypsum board. The weight of the gypsum board was decreased when the cotton dust fiber content was increased. It was found that the appropriate ratio of gypsum plaster and cotton dust was 90:10 incorporated with 6 wt. % PVA. The ultimate strength and modulus of rupture of the appropriate gypsum board were 135.31 N and 3.13 MPa, which was the criteria standard gypsum board products (TIS. 219-2524). The weight of the appropriate gypsum board was lighter than the gypsum board without cotton dust fiber addition about 289.75 grams (21 percent). Therefore the gypsum board mixed with cotton dust fiber could be developed for the construction, ceiling, and wall.

Keywords: Gypsum, Cotton dust fiber, Binding, Mold.

1. Introduction
Nowadays, environmental problems are of deep concern to all people and organizations because of their vital impact in everyday life. Likewise, these environmental issues are changing the world and affecting the life and livelihood of Earth inhabitants. Man-made pollution is generally a by-product of human actions.

For example, the global warming problem is caused by greenhouse gas discharged from motor vehicles and various industries. Water pollution is caused by waster waste from various industries [1-2]. Air pollution is caused by dust from the construction and agriculture industries. To address this
problem, there are several approaches such as the prevention of pollution, proper waste management, disposal strategy, and reduction of the amount of waste from the manufacturing process.

The textile industry is one of the dust polluters including cotton gin factories \cite{3}, spinning mills, and textile mills \cite{4}. Generally, the dust from the manufacturing process is the particle. The amount of dust from the cotton textile manufacturer is approximately 1,200 - 1,500 kg per month. The cotton dust fiber from these processes can be disposed of in several ways. However, most cotton dust is not properly disposed of which disposed of without waste sorting. As a result, it is smelly and putrid water. Sometimes the waste is disposed of by burning, leading to air pollution. In other ways, cotton dust is used in the agriculture field, mixed with sawdust and rice husk for fuel or blended with mushroom soil for the cultivation, however, it is a small quantity of usage compared to the proportion of waste.

The cotton dust from the textile industry is soft, light, and short fiber. To increase the value of cotton dust, it has been used to make products or as a part of producing construction materials. A gypsum board produced by using gypsum plaster mixed with cotton dust is a light, strong, low cost, and fire resistance of gypsum \cite{5, 6}. Therefore, this research was aimed to study the beneficial uses of cotton dust fiber by producing a gypsum board mixed with cotton dust fiber for construction purposes such as an interior wall and ceiling. The appropriate ratio of gypsum plaster and cotton dust with and without polyvinyl alcohol (PVA) were determined. The properties, ultimate strength, and modulus of rupture of gypsum boards mixed with cotton dust fiber were investigated \cite{7-11}.

### Nomenclature

| Symbol | Definition                        |
|--------|----------------------------------|
| b      | the width of the test specimen (mm) |
| d      | the thickness of the test specimen (mm) |
| l      | the length of the period (mm)     |
| W      | an ultimate force (N)             |
| MR     | the modulus of rupture (MPa)      |

### 2. Experimental

#### 2.1. Materials

Gypsum plaster, cotton dust fiber, and water were used for producing the gypsum board. Polyvinyl alcohol (PVA) was used as an adhesive.

#### 2.2. Gypsum boards preparation

Gypsum board preparations were divided into three parts in the combined weight of 1,300 g per board. For the first part, the gypsum plaster and cotton dust were mixed with the following ratios: 100:0, 95:5, 90:10, 85:15, and 80:20 to determine the appropriate ratio. Each ratio was filled with 1,000 cm$^3$ of water per board, which was a suitable volume to produce the gypsum board. For the second part, the gypsum plaster and cotton dust (95:5 ratio) were mixed with PVA 3, 4, 5, 6, and 7wt. % of 1,000 cm$^3$ added water. In the third part, gypsum plaster and cotton dust were mixed in the ratio of 90:10, 85:15, and 80:20 which incorporated with PVA 6wt.% of 1,000 cm$^3$ added water. Afterward, each mixture was formed a gypsum board by casting in the mold with the dimensions 300 × 400 × 9 mm$^3$ shown in Fig. 1. Finally, the board was dried in an oven at a constant temperature of 60 °C for seven hours, and then it was tested for the ultimate strength and modulus of rupture.
2.3. Testing

- Weighting
  The five gypsum boards with the size of $300 \times 400 \times 9 \text{ mm}^3$ were weighed and then their weights were recorded.

- The ultimate load test
  The gypsum board with the size of $300 \times 400 \times 9 \text{ mm}^3$ was placed on the supports according to TIS 219-2524 standard. The steel tube with 360 mm long and 12 mm diameter was placed on the center of the gypsum board as illustrated in Fig. 2. The gypsum board was pressed by the steel tube with a rate constant of 300 newtons per minute (30 pounds-force per minute) until the gypsum board was fractured. The ultimate load of the fractured gypsum board was recorded as the ultimate strength. The modulus of rupture of the gypsum board was calculated using equation (1).

$$MR = \frac{3WL}{2bd^2}$$

Where MR is the modulus of rupture (MPa), W is an ultimate force (N), l is the length of the period (mm), b is the width of the test specimen (mm), d is the thickness of the test specimen (mm).

3. Results and discussion

The ultimate strength, modulus of rupture, and weight of the gypsum board at different ratio of gypsum and cotton dust fiber were summarized in the Table 1 and Fig. 3. It was found that the ultimate strength, modulus of rupture, and weight of the gypsum boards were decreased when the cotton dust content was
increased. The ultimate strength and modulus of rupture at 100:0 ratio of the gypsum and cotton dust were more than 135 N and 3.0 MPa which met the TIS. 219-2524 standard. However, the ultimate strength and modulus of the rupture of the gypsum board mixed with cotton dust were lower than the TIS. 219-2524 standard.

### Table 1. Summary of the ultimate strength, modulus of rupture and weight of the gypsum board at different ratio of gypsum and cotton dust fiber

| Ratio of Gypsum: cotton dust fiber | Ultimate Strength (N) | Modulus of rupture (MPa) | Weight (g) |
|-----------------------------------|-----------------------|--------------------------|------------|
| 100:0                             | 168.78                | 3.66                     | 1,407.42   |
| 95:5                              | 95.10                 | 2.21                     | 1,245.07   |
| 90:10                             | 74.39                 | 1.70                     | 1,110.83   |
| 85:15                             | 50.67                 | 1.14                     | 942.42     |
| 80:20                             | 37.81                 | 0.89                     | 818.38     |

In general, the fiber-reinforced material constructions had a high strength. Surface treatment and good arrangement of fiber were required to achieve the compatibility between fiber and matrix for a force distribution of load. However, cotton dust fiber was quite short and fine. The strength was decreased when cotton dust fiber content was much increased due to a random alignment. Therefore polyvinyl alcohol was used as an adhesive for producing gypsum board. To increase the strength of the gypsum board, the adhesive PVA was for good interfacial adhesion between the fiber and gypsum plaster.

![Figure 3. Plot of the ultimate strength as a function of cotton dust fiber ratio](image)

### Table 2. Summary of the ultimate strength, modulus of rupture and weight of the gypsum board at various PVA contents.

| PVA (Percent) | Ultimate Strength (N) | Modulus of rupture (MPa) | Weight (g) |
|---------------|-----------------------|--------------------------|------------|
| 3             | 110.70                | 2.39                     | 1,326.16   |
| 4             | 123.60                | 2.68                     | 1,354.74   |
| 5             | 132.77                | 3.12                     | 1,361.53   |
| 6             | 150.55                | 3.32                     | 1,372.89   |
| 7             | 156.84                | 3.56                     | 1,389.12   |

The ultimate strength, modulus of rupture, and weight of the gypsum board at gypsum plaster and cotton dust 95:5 ratio incorporated with different PVA contents were summarized in Table 2 and Fig. 4.
It was found that the ultimate strength, modulus of rupture, and weight were increased with the addition of PVA. This was due to PVA acted as a binder between gypsum plaster and cotton that led to good adhesion strength. The addition of 6 and 7 wt. % of PVA was an appropriate amount because the ultimate strength, modulus of rupture met the standard according to TIS. 219-2524.

Table 3. Summary of the ultimate strength, modulus of rupture, and weight of the gypsum board at various ratios.

| Ratio of Gypsum: cotton dust fiber | Ultimate Strength (N) | Modulus of rupture (MPa) | Weight (g) |
|-----------------------------------|-----------------------|--------------------------|------------|
| 95:5                              | 150.84                | 3.36                     | 1,371.46   |
| 90:10                             | 135.31                | 3.13                     | 1,117.67   |
| 85:15                             | 112.40                | 2.65                     | 1,092.91   |
| 80:20                             | 77.22                 | 1.81                     | 957.84     |

Figure 5. Plot of the ultimate strength as a function of cotton dust fiber ratio.
4. Conclusions
This study was focus on producing a gypsum board mixed with cotton dust for construction propose. The appropriate ratio of gypsum plaster and cotton dust was 90:10 incorporated with 6 wt. % PVA. The ultimate strength and modulus of rupture of the appropriate gypsum board were 135.31 N and 3.13 MPa, which was the criteria standard gypsum board products (TIS. 219-2524). The weight of the appropriate gypsum board was lighter than the gypsum board without cotton dust fiber addition about 289.75 grams (21 percent).

Acknowledgements
The authors would like to acknowledge Mr. Montien Othongkham, Rajamangala University of Technology Krungthep, Thailand, for the advice of discussion as well as paper edited.

References
[1] E. GilPavas, I. Dobrosz-Gomez and M.A. Gomez-García, J. Environ. Manag., 191(2017)189-197.
[2] H. Yukseler, N. Uzal, E. Sahinkaya, M. Kitis, F.B. Dilek, U. Yetis, J. Environ. Manag., 203 (2017) 1118-1125.
[3] A.M. Kocabas, H. Yukseler, F.B. Dilek and U. Yetis, J. Environ. Manag., 91(2009)102-113.
[4] T. Chaichalermwong, spinning, Faculty of Engineering. Rajamangala University of Technology Thunyaburi (2007).
[5] Information on http://www.lib3.dss.go.th/fulltext/dss_j/2549_54_171_p15_18.pdf
[6] Information on http://www.dpim.go.th/dt/pper/000001190864806.pdf
[7] Thai Industrial Standards Institute, Standard Gypsum plaster for construction, (TIS. 188-2519), Bangkok: Post Republican Tradition (1976).
[8] Thai Industrial Standards Institute, Standard gypsum board. (TIS. 219-2524), Bangkok: Teachers Publisher Ladphro (1981).
[9] B.C. Goswami, Textile Sizing. New York: Marcel Dekker (2004).
[10] Information on http://palimpsest.stanford.edu/.byform/mailing-lists/cdl/1998/1368.html
[11] A. Krainiukov, J. Liu, E. Kravchenko and D. Chang, Cold Regions Science and Technology, 174, 103054(2020).