ANALYSIS FOR INTENSIFICATION OF COIR FIBRE FIRE RETARDANT PROPERTY

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ABSTRACT

Application of porous material in acoustic panel has shown its effectiveness to control noise in term of sound absorption. Optimizing synthetic fibre as resource in current market contributed several issues related to the depletion of environment. Hence, engineer has turned to natural fibre from agriculture waste as alternative strategic solution. Despite having certain beneficial properties in acoustical field, to fulfil the building standard, property of fire retardant are yet to be implemented. This study has focused on two potential fire-retarding chemicals on coir fibre, namely, Di-Ammonium Phosphate (DAP) and urea.Vertical burning experiment was executed based on standard of ASTM E69–02 (Standard Test Method for Combustible Properties of Treated Wood) using Fire-tube Apparatus prior to chemical treatment. Based on experimental results, DAP and urea-treated fibre shows mass loss of 6.67% and 9.48% respectively. Compliance with NFPA 704, DAP was shown to exhibit superior ability to retard fire in coir fibre over other additives based on mass loss and low degree of hazards in terms of health, flammability and reactivity. In conclusion, fire retardant chemical like DAP is an essential component to be improved on to bring about the success commercialization of the acoustic panel.

Keywords— Acoustic absorption panel, natural Fibre , Fire retardant, Chemicals

1. INTRODUCTION

With the advancement of scientific technology into a new era, sound exposures become inevitable in daily life. A widespread of environmental potency that has shown to disrupt the balance of life is termed nuisance or noise pollution. One should not judge the above issue lightly because cumulative, excessive exposure to high-intensity sound level consequences to sensorineural hearing deficit called Noise-Induced Hearing Loss (NIHL) of which the hearing damage would be permanent. Hence, one vital way of eliminating this hazard is through noise-control equipment called acoustic absorption panel. Strike of incident sound waves onto the surface of acoustic panel gives rise to vibration of air molecules outside and within the fibres pores. Thus, energy to heat conversion is accomplished through friction [1]. Despite acoustic panel has been employed since the early 90s to provide good sound coverage for pleasing environment, sound-absorbing materials constituent often associated with asbestos, mineral wools and foams have brought about reluctance to consumers. The drawbacks of being non-biodegradable, hazardous and costly thus provoked the study of feasibility of natural fibre as optimal substitution.

Ordinarily, natural fibre is hairlike structures originated from plants and animals, having the advantages of being low-density, economical and eco-friendly. One example of natural fibre that has been vastly-produced is coir fibre, obtained from the fibrous husk of a coconut. Besides having good acoustical properties, stress resistant, bio-degradable and being buoyant, coir also comes cheap and abundant as it is the second largest agricultural product. However, characteristics of natural fibre such as fire retardant and anti-fungus are far more significant issues to be pondered for the applications of acoustic panel in buildings. Coir fibre is made of cellulose fibres having lignin and hemicellulose as the bonding material. Thus, being a lignocellulosic material, it catches fire and propagates promptly [2].

The growing demands of biodegradable and sustainable raw materials for most of the industrial products have encouraged the manufacturers and engineers to seek alternative resources for a healthy and ssmore eco-friendly environment. Natural fibre, of which is easily adaptable to a variety of applications and possesses good acoustical properties have been chosen as a substitution for the synthetic fibre in acoustic absorption panel. With the aim of reducing the fire risks and contributing to a substantial refinement in living quality, this research was proposed to enhance the fire retardant property of natural coir fibre in acoustic absorption panel by treatment of fire retardant addictives. Flame retardants have enabled the usage of natural raw materials which have evident environmental and sustainability benefits over man-made materials while assuring the accomplishment of fire standard by the materials.

2. LITERATURE SURVEY

Liodarkis et al. [3] had researched on the effectiveness of di-ammonium phosphate (DAP) and ammonium sulphate (AS) on flammability and thermal degradation of forest fuel by implementing spontaneous ignition tests and TG analysis. The outcomes proven that both of the tested fire retardants (DAP and AS) considerably raised the ignition delay time and the pyrolysis mass residue. However, DAP has a better performance compared to AS. Another research done by Liodarkis et al. was to investigate the efficiency of phosphorus compounds in retarding the combustion of cellulosic materials. It was postulated that both mono-ammonium phosphate (MAP) and DAP were effective in lowering the combustion rate of cellulosic materials and substantially increased the mass residue [4]. This study obtained a better comprehension of pyrolysis and combustion of cellulosic materials.

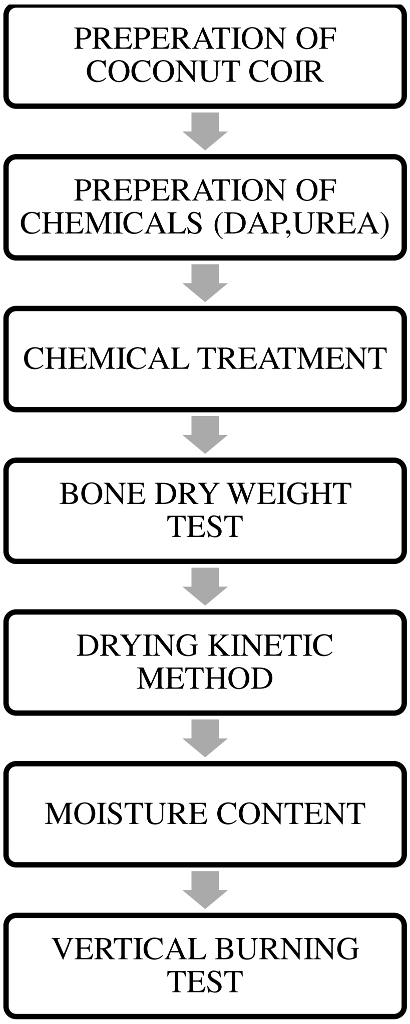
The studies executed by **Khidir et al.** [5] have attested that the application of urea-diammonium phosphate as flame retardant for coir fibre was effective and the mass residue was increased.

As declared in the Uniform Buildings By-Laws 1984, it is imperative for the acoustic panels to comply with the fire resistance requirement of building regulation for applications in high rise buildings [6].

Fire retardant chemicals have been an invisible yet essential elements in most of the innovations due to its ability to diminish the spread of fire and delay the combustion process, conforming the required standard of fire. **Liodarkis et al**. [7] has mentioned that phosphorus, chlorine, antimony, boron, bromine, and nitrogen are the majorchemical elements responsible for fire retardancy. In accordance to this statement, urea and DAP have been chosen to be used in the enhancement of fire retardant property of coir fibres.

Nagieb et al. [8], who previously studied on the fire retardancy of DAP on laminated veneer lumber with melamine-urea-formaldehyde (MUF) adhesive showed that a concentration of 5% of DAP had the best performance [9]. On the other hand, the fire retardancy of urea itself will be figured out in this research since it is often being used in a mixture with different fire retardant chemicals. Henceforth, a concentration of 5% has been selected in preparing the chemical solutions of urea and DAP in order to perform the chemical treatment of coir fibre.

3. METHODOLOGY



3.1 PREPARATION OF COIR FIBRE

Coir fibres are of great importance in the agricultural industry and they have attracted substantial attention as alternative renewable resources in various applications. No specifications were stated regarding the physical characteristics of coir fibres such as staple length, diameter, density and processing conditions. The specimen used in this experiment was prepared by twisting the coir fibres into rope shape with a weight of 25.0 ± 1.0 g

Fig.1 Twisted coconut coir

3.2. PREPARATION OF CHEMICALS

CHEMICAL	**UREA**	**DIAMMONIUM HYDROGEN PHOSPHATE (DAP)**
CHEMICAL FORMULA	NH2CO.NH2	(NH4)2HPO4
MOLAR MASS [g/mol]	60.06	132.06
CONCENTRATION [M]	0.05	0.05
MASS IN 1L SOLUTION [g]	3.003	6.603

Table 1. Details of chemicals

Two outstanding chemicals, as shown in Table 1, were selected based on their fire retardant abilities, degree of hazards against the health and reactivity in order to accomplish chemical treatment for coir fibres. These chemicals were purchased from Sundar chemicals ,Hosur.These chemicals are DAP and urea and one litre of each chemical solution was prepared.

3.3 COCONUT COIR CHEMICAL TREATMENT

The prepared coconut coir specimen was treated with chemicals at the room conditions. At every 10 minutes, the specimen was removed from the chemicals and allowed to settle down for 3 minutes. Subsequently, the weight of each specimen was weighed / measured and recorded. This process was repeated until the specimen reaches an equilibrium level, in other words, no change/ increment in weight has been observed.

3.4 BONE DRY WEIGHT

Bone dry weight is stated as the weight without a trace of moisture. In order to determine the bone dry weight of the specimen, it was dried in the oven (Protech, Model: FAC-350) under constant temperature of 105°C for 24 hours (AOAC,1990) [10]. The final weight of the specimen was weighed/ measured and recorded.

3.5 DRYING KINETIC

The treated specimen was dried in oven under constant temperature of 60°C. The weight of the specimen was measured and recorded at 15 minutes interval until no increment in weight is observed. By combining the results for both chemicals, a graph of drying rate against moisture content which is well known as drying kinetic was plotted to give a better view of the outcomes.

Fig 2 Coir kept inside oven for drying

3.6 MOISTURE CONTENT

The moisture content of the specimen was maintained at 7±3 weight % throughout the experiment. It was calculated as follows:

Moisture Content% = x 100

3.7 VERTICAL BURNING TEST

The test method was in accord with ASTM E69-02 Standard Test Method for Combustible Properties of Treated Wood by the Fire-Tube Apparatus. The weight of the oven dry test specimen was diminished to 15g beforehand and it was then hung in the fire-tube apparatus. Thereafter, the Bunsen burner was placed beneath the fire-tube apparatus, so that the top of the burner is 6cm below it. The flame of the burner was regulated further to give a blue flame of approximately 4cm in height. The flame was applied to the test sample for a duration of 4 minutes and then it was removed from the fire-tube apparatus.

Fig. 3 Experimental setup of vertical tube apparatus

The percentage loss of mass experienced by the test specimen was measured and recorded at half minute interval. The equation of percentage loss in mass is given as follow:

$\%MASS\ LOSS = [M_i - M_f / M_f] * 10$

M_i – Initial Mass

M_f – Final Mass

4. RESULTS AND DISCUSSIONS

4.1 CHEMICAL TREATMENT

Figure 4 shows the increment in mass of fibre against the dipping time of all both chemicals for a period of 210 minutes. It is observed from the graph, it is notable that a rapid absorption occurred at the first 15 minutes when the 25 grams specimen was dipped into the chemical solution.

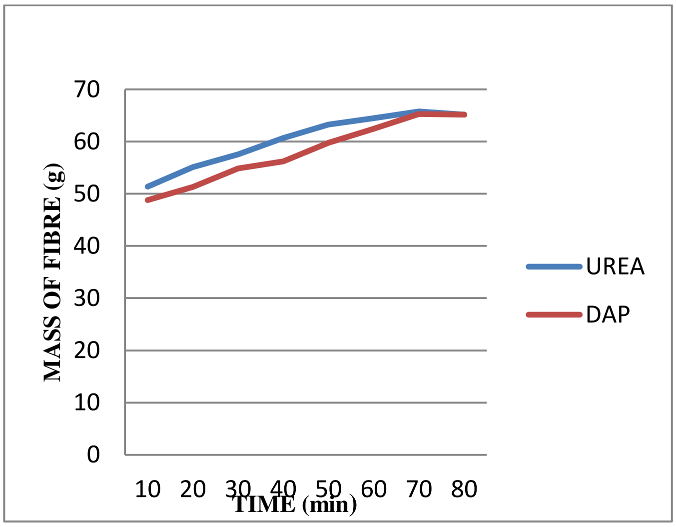


Fig. 4 Mass of fibre against treatment time for urea and DAP with 5% concentration under dry bulb temperature of 26°C and humidity ratio of 17.

This phenomenon is because initially the coir fibre is dry and pore of the fibre are empty. Therefore, rapid absorption is allowed to take place when coir fibre is treated with chemical. In the first 15 minute, the slop for coir fibre treated with DAP is about 5.63, followed by urea with the slope of 5.47. From 15 minutes onwards up to 210 minutes, the mass of fibre fluctuated within the range of 70 to 90 grams.

This phenomenon elucidates that the equilibrium condition is reached since no obvious increment in mass of fibre was achieved. Of both chemicals, DAP has the greatest chemical absorption in term of weight along the treatment process from zero until 200 minutes. The maximum weight of coir fibre treated with DAP is about 92 grams at 200 minute, followed by urea with maximum mass of fibre of 90 grams.Thus DAP-treated fibre was predicted to have the strongest fire retardant property since its absorption rate was the highest.This prediction was verified by later experiment, which is the vertical burning test.

4.2. DRYING

The liquid diffusion theory states that the diffusion of liquid occurs when there is a concentration difference between the surface and the inner parts of the solid. Basically, drying via evaporation process from the exposed surface of solid involves the moisture movement from the depths of the solid to the surface [11].

In accordance with ASTM E69-02, it is necessary to maintain the moisture content of the specimen at 7± 3 weight% of the dry material during the execution of vertical burning test. Equation (1) was used to calculate the moisture content of all specimens. The bone dry weight of coir fibre was obtained as 21.11g after 24 hours of drying while the drying time for urea and DAP were 300 minutes and 360 minutes respectively.

The drying kinetics of the chemically treated coir fibres is shown in Fig 5.

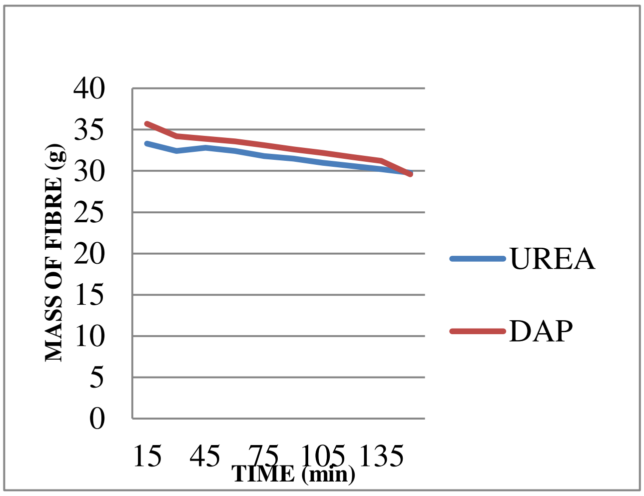


Fig.4 Drying kinetics of urea and DAP treated fibres

.4.3. VERTICAL BURNING TEST

Fire resistance is a crucial property of the acoustic absorption panel in terms of fire safety. With the aim of examining the flame resistance of fire retardant materials, the vertical burning test was invented and being widely used to determine various parameters concurrently.The vertical burning test, being one of the flammability test is capable of measuring and anatomizing the ignition time and optimum temperature to initiate the burning process; the propagation rate; the percentage loss in mass as well as the consequences of removing the flame. In this research, the vertical burning test was executed with the treated specimens to determine the percentage loss in mass, in which emerges to be a measure of the combustibility of the specimens. However, as hot air rises, the specimen, of which hanging vertically in the fire-tube apparatus was allowed to burn at a faster rate

The impact of fire retardant chemicals on mass loss of the specimens throughout the vertical burning test is shown in Fig. 6.

It is notable that the DAP-treated fibres possess the highest mass after combustion process, compared to that of Borax-treated and urea-treated fibres. No remarkable distinction was observed from Fig 6 between the urea-treated fibres and the untreated fibres, of which serving as a control in this experiment.

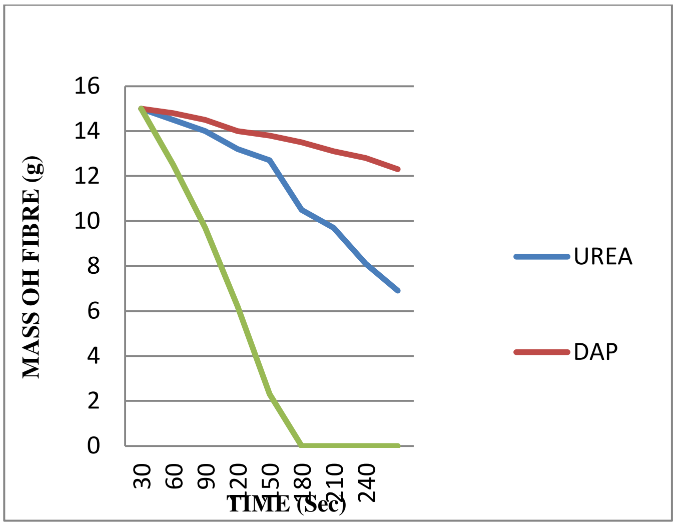


Fig.6 Changes in mass of fibre in the vertical burning test.

Numerations from Equation (2) demonstrates that the percentage mass loss of the DAP-treated fibres, with a value of 6.67%, was the lowest among the three chemicals, indicating that DAP itself owns the strongest ability of fire resistance. Meanwhile, the combustion process has reduced the mass of urea-treated fibres and untreated fibres by 9.48% and 9.60% respectively.

Considering all the properties and prices of chemicals DAP not only has a fair price, but also poses low degree of hazards in terms of health, flammability and reactivity in accordance with NFPA 704. Therefore, DAP was opted as the best and well-rounded chemical than urea.

5. CONCLUSION

With the goals of enhancing the characteristics of coir fibre and meeting the safety demands, this study was executed to investigate the impacts of treating coir fibre with flame retardant addictives such as DAP, Borax and urea for the production of acoustic absorption panels. Combustibility of the chemically treated coir fibre was evaluated by the vertical burning test. Of all three chemicals used, DAP-treated fibre has exhibited superior fire retardant property with the percentage mass loss of 6.67%, followed up by Borax-treated fibre and urea-treated fibre with values of 7.60% and 9.48%. Overall, fire retardant addictive such as DAP, of which having good fire retardant performance and negligible impacts on environment and human's health, allows engineers to consider natural fibre as a substitute for synthetic fibre in acoustic absorption panel, which would otherwise have been neglected due to its high risks of fire. Natural fibre is acting a key role in the emerging green technology since its intrinsic properties such as outstanding mechanical strength, low density and low cost have attracted substantial attentions from various industries. It would be fruitful to pursue further research about the potential of natural fibre as an alternative resource besides raising global awareness of the importance of natural fibre to consumers and the environment with the aims of reducing carbon emissions and minimizing waste materials.

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