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Mixture of natural fiber with gypsum to improve the fire resistance rating of a fire door: The effect of kapok fiber

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Mixture of natural fiber with gypsum to improve the fire resistance rating of a fire door: The effect of kapok fiber

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Abstract. A composite mixture of gypsum and natural fibers has been considered in this study to enhance the fire resistance rating of a fire door. Previously the materials used to make a fire door are gypsum and fiber wool where it acts as a protective coating. Normally this fire door must be compact and able to close on its own. Natural fibers have the ability to replace glass fiber cotton because of its features that are available in fiber glass wool. When using fiberglass, it can cause health problem once it is swallowed and inhaled, and may remain in the lungs indefinitely. It also can contribute to lungs cancer. Kapok fiber has been used in this experiment as natural fibers. The objective of the experiment is to analyze the fire resistant rating of the composite mixture of gypsum with kapok fiber. The scopes of the experiment consist of a preparation of composite mixture samples of gypsum with kapok fiber with different composition and thickness, and the fabrication of a fire resistant testing furnace. A testing of samples which were conducted in accordance with the standard MS 1073: PART 2:1996.

1. Introduction

Nowadays, the materials used to make a fire door consist of materials that are able to withstand fire for a long time. Buildings, offshore structures, ships, etc. are equipped with doors. Generally, it is a movable structure which is used to close off an entrance, typically comprises a panel that swings on hinges or that slides or rotates. Past experiences have taught humans a good lesson to use a fire door instead a conventional wooden or steel door. Usually a fire door is provided with a rating of 30 or 60 minutes. It is related to the duration of time the door can resist fire before becoming unstable [1]. Fire resistant rating has been traditionally determined standardized fire testing performed in accordance with ASTM E-119, Standard Method for Fire Tests of Building Construction and Material. However, in accordance to the ASTM standard which is the American standard, other countries to have adopted tentative standard accordance to the national Institute for standard in the respective countries, among them are BS476 which is used in Britain, MS 1073 (1996) which is used in Malaysia under Standard and Industrial research Institute of Malaysia.

Natural fibers are increasingly being used as reinforcement due to their low cost, high specific properties and renewable nature. Kapok with its scientific name is (Ceiba Pentandra) is the best insulation material and readily available. Now, it is grown worldwide in several plantations in Southeast Asia. Kapok fiber poses an excellent hydrophobic-oleophilic characteristic that we can label it as a natural plant fiber. It has a penetrable hollow lumen structure and waxy material on its surface.

Kapok has high cellulose content and has the potential to replace glass fiber. Kapok fiber has a unique characteristic which does not get wet easily with water. This characteristic shows that kapok fiber is a hydrophobic [2-3]. The raw kapok is yellow to brownish or whitish in color. Kapok is an excellent thermal and acoustic insulation because it contains 70%-80% of air. Kapok cannot withstand a strong stress due to its brittleness. Nowadays kapok is used as a stuffing and for insulation of sound due to good thermal insulating properties. For kapok fiber, it can improve the crystalline structure of fibers and will induce topographic changes of the fibers surface due to the alkalization of kapok. It has a good resistance at high temperatures but sensitive to ultraviolet rays. Nowadays, for a small refrigerating system, kapok is used as an insulating material. It also can be used for a lining in sleeping bags and as gloves for dry ice handling. This is because kapok is equipped with its excellent thermal insulating properties. Beneficially, due to its good thermal insulation, it also can be used for thermal insulation of conduit pipes and as an acoustic insulation of dwelling rooms [4].

Gypsum is a natural resistance of fire and its scientific name is hydrated calcium sulphate (CaSO4 2H2O). It has thermal conductivity of 0.17 W/(m.k) and has a monocline structure. Pure gypsum is a white rock. Generally gypsum can be found in laminated, granular or compact masses. Gypsum is also known as a product of reducing the emission levels of coal-fired power stations. The United States of America leads the world in gypsum production. Synthetic gypsum is generated worldwide with over 110 million metric tons [5].

Fire resistance is a performance of a given complete system and also as a construction when it is exposed to the standard heating conditions [6]. It also can be illustrated as a measurement of the building element ability to resist a fire. Besides that, fire resistance also is assessed as a time when the element exposes to a standard fire resistance test, and must meet certain criteria [7]. It also can be described as an element of a building construction property and as an ability of measurement for a stated period. There are some criteria for the fire resistance which are resistance to collapse, resistance to flame and hot gases penetration, and resistance to temperature rise on the unexposed face which is up to a maximum of 180oC [8]. Furthermore, it is also as a length of time for a structural element that performs well in the standard furnace test. It can be specified for the exposure of a fire on side of walls, partitions, and floors [9].

2. Details Experimental

2.1. Materials and Experimental Procedures

The experiment was performed by setting up an experimental furnace and the specimen for the testing method. The testing was carried at ambient condition with reference to the Malaysian Standard MS 1073: PART 2: 1996. The essential materials required were stated as follows:

1. Gas Stove (Ignition Source)
   - It is required to yield the heat up to 1200°C. A high pressure of gas stove was used to produce the required heat and to start the ignition for the experiment. Therefore the ignition source was initiated to supply the required energy to carry out the combustion process.
2. Bricks
   - It is used to make up the furnace linings.
3. LPG Gas Cylinder (Fuel)
   -It is used as a combustion fuel.
4. Thermometer
   - The ambient temperature was found to be in the range from 27°C to 33°C.
5. Stopwatch (Timing Device)
   - It is used to measure the time taken for the specimen to refuse the fire.
6. Type K Thermocouple
   - Thermo K (chromel-alumel) thermocouples were used to obtain the temperature measurement of exposed and unexposed specimen surface. The standard specification was ASTM C 177. Its

function under the principle of resistance changes linearly with respect to the temperature changes. Five thermocouples were placed on unexposed side of the specimen to measure its temperature changes. The bare wire thermocouples were used for exposure process.

2.2 Sample Preparation

The steps for preparation of the sample as follows:

Table 1. Thickness of composite mixture of gypsum and kapok fiber

Sample	Thickness (mm)
1	6.4
2	9.5
3	12.7

Table 2. Composition ratio of composite mixture of gypsum and kapok fiber

Ratio (mixture)	
Gypsum (gram)	Kapok (gram)
1000	10
1000	20
1000	30

Step:

(1) Framing and mold base: The mold was designated and fabricated with dimension of 225x225x30 mm.it was made of wood and panel board.
(2) The kapok fiber must be in dry condition and the samples were dried under the hot sun for seven days.
(3) A balance weight is used to measure the weight of raw materials
(4) Kapok fiber and gypsum powder were mixed to get the slurry of the mixture
(5) The slurry mixture were poured into the mold and then compressed to get the required thickness of the sample. The mixture then placed under the sun to let them dried and hardened.
(6) Placement of thermocouples: Fixed the healed samples with five thermocouples at the selected points of an unexposed surface.

Testing:

To evaluate the fire resistance of the healed samples, each of the samples was tested using the experimental furnace. The non-combustibility method was used in this experiment because it was cheaper and simpler than the former method. During the experiment, the temperature of the furnace was kept constant in the range of 750-950°Celsius and flame temperature was recorded using a high temperature type K, and the temperature readings were also taken to face the unexposed samples at five different locations using a type of lower temperatures K. Readings were taken at each time interval of 3 minutes. Fire resistance rating for overall sample tested are shown in Table 3:

Table 3. Fire Resistance Ratings

Composition	Thickness (mm)	Rating (minutes)	Maximum Mean Temperature (°C)	Density, ρ (kg/m^3)
G = 1000g KF = 10 g	6.4	71	111.6	2469.14
G = 1000g KF = 10 g	9.5	90	117.3	1663.42
G = 1000g KF = 10 g	12.7	99	99.4	1244.29
G = 1000g KF = 20 g	6.4	81	119.6	2160.49
G = 1000g KF = 20 g	9.5	93	106.5	1455.49
G = 1000g KF = 20 g	12.7	105	126.3	1088.75
G = 1000g KF = 30 g	6.4	102	110.6	1098.75
G = 1000g KF = 30 g	9.5	126	136.4	984.91
G = 1000g KF = 30 g	12.7	153	146	836.39

- G = Gypsum, KF = Kapok Fiber

3. Results and Discussion

The fire resistant test was conducted on nine samples with different composition ratios with three different thickness of composite mixture of gypsum and kapok fiber. The composition ratio were gypsum 1000 g: kapok fiber 10g; gypsum 1000 g: kapok fiber 20 g; gypsum 1000 g: kapok fiber 30 g; and those ratios were prepared for each of these three different thicknesses of 6.4 mm, 9.5 mm and 12.7 mm.

3.1. Composition of Gypsum 1000 g: Kapok Fiber 10 g

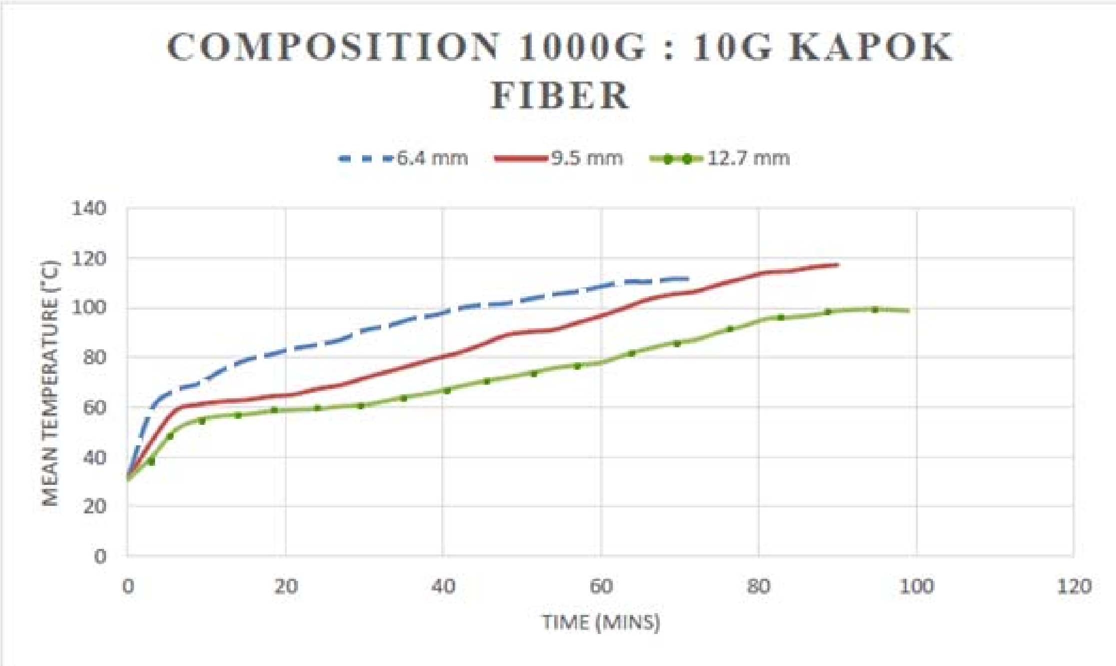

Figure 1. Fire resistant test results of gypsum 1000 g: kapok fiber 10 g for different thicknesses.

3.2. Composition of Gypsum 1000 g: Kapok Fiber 20g

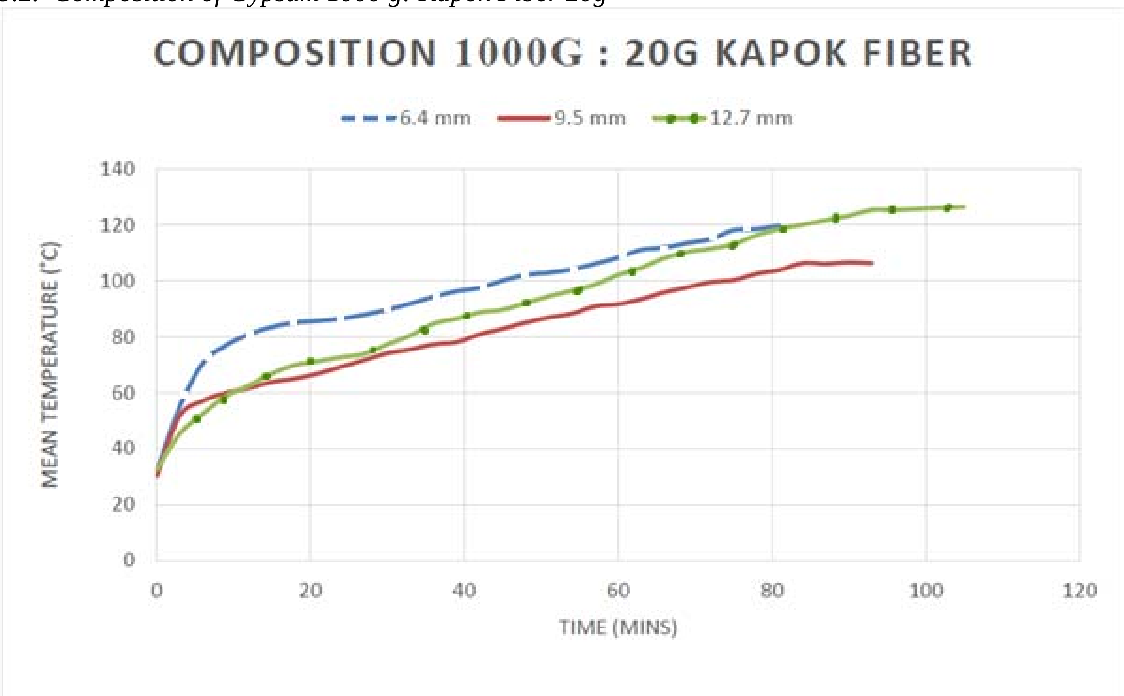

Figure 2. Fire resistant test results of gypsum 1000 g: kapok fiber 20 g for different thicknesses

3.3. *Composition of Gypsum 1000 g: Kapok Fiber 30 g*

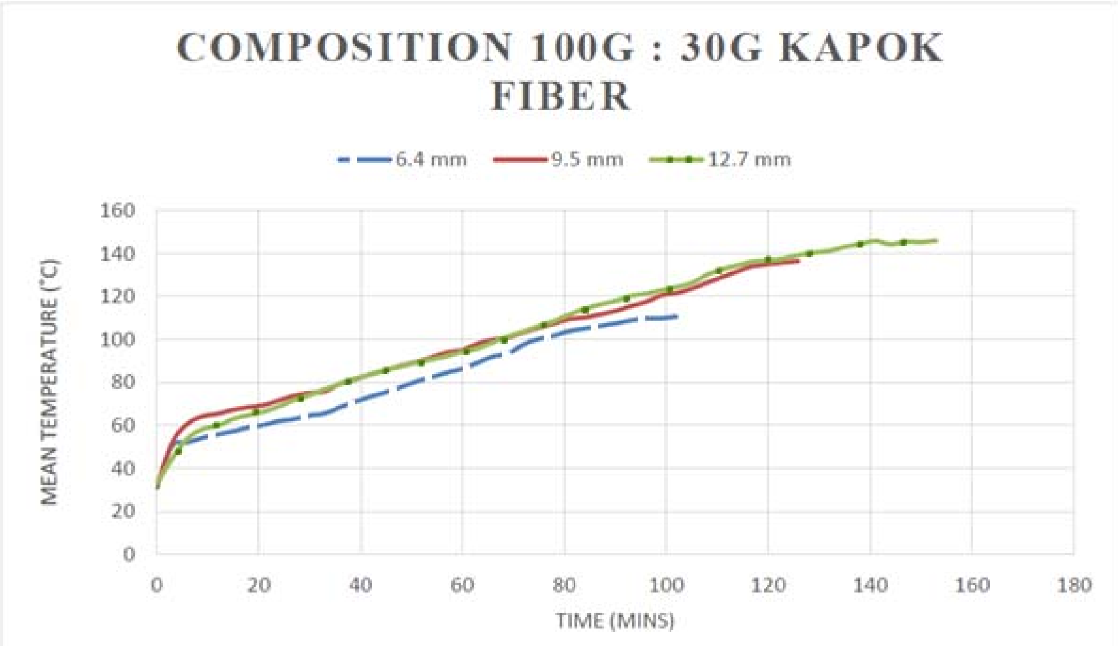

Figure 3. Fire resistant test results of gypsum 1000 g: kapok fiber 20 g for different thicknesses

Figure 1 shows that the composite sample of 12.7 mm thickness gave the highest fire resistant rating which 99 minutes. The second highest was the composite sample of 9.5 mm thickness which recorded 90 minutes. Lastly, the composite sample of 6.4 mm thickness produced the fire resistant rating of 71 minutes only.

Figure 2 shows the plots for gypsum 1000 g: kapok fiber 20 g for different thicknesses. The best fire resistant performance was shown by composite sample of 12.7 mm thicknesses which could last for 105 minutes before it failed. This was followed by the composite samples of 9.5 mm for 93 minutes and 6.4 mm for 81 minutes.

Figure 3 shows that the highest fire resistant rating recorded was 153 minutes, which was achieved by the composite sample of 12.7 mm thickness. This was followed by the composite samples of 9.5 mm thickness for 126 minutes and 6.4 mm thickness for 102 minutes.

These findings were based on the integrity failure. After a failure, cracks and smaller gaps were found on the samples. Generally it is found that the performance of fire resistant rating achieved by these composite samples increases with thickness. It means that the increasing content of kapok fiber gave better performance due to its structure and properties. The experimental works and observations that have been carried out revealed that a mixture of natural fibers and gypsum has the potential to be used in manufacturing fire resistant doors commercially. Based on the standards, scope, objective, and procedures of this experiment, the composite sample of natural fiber and gypsum could last for 30 minutes when it was burnt, so it can be said that the suitable good sample is for making fire resistance doors.

4. Conclusion

Natural fibers are a good insulating material which has the potential to be used in a fire door manufacturing. The highest fire resistant rating achieved was 153 minutes for the composition of 1000 g gypsum : 30 g kapok fiber with a thickness of 12.7 mm. The lowest fire resistant rating was 71 minutes for the composition of 1000 g gypsum : 10 g kapok fiber with a thickness of 6.4 mm. From the observation, it clearly showed that the thickness of the samples has a significant impact on the fire resistant rating. In addition, the different compositions of kapok fiber in the composite samples also were found to have an effect on the fire resistant rating. Therefore, kapok fiber should be considered as an insulated construction material in the manufacturing of fire resistant doors, ceilings, and wall panels in order to provide a better safety protection from fire.

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