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A Comparative Analysis between Crushed and Pulverized Green Mussel Shells as a Fire-Retardant Coating to Plywood

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Abstract: **The Asia green mussel (Perna Viridis) is a widely consumed sea animal that belongs to the family of mollusks and are commonly found in the Asia-Pacific region. Mussel shells are proven to contain high amounts of Calcium Carbonate ($CaCO_3$), which is a chemical compound that is dubbed as an ideal fire-retardant substance. This research aimed to compare and determine the effects of using crushed and pulverized mussel shells as a fire-retardant coating to plywood. In this study, fire-retardancy of mussel shell coated plywood was evaluated. The shells were acquired in Kawit, Cavite, which were then cleaned, dried, and crushed into sizes passing through ASTM sieve no. 3 ½ (5 mm) but retained in sieve no. 4 (4.75mm) and pulverized into powder using a high-powered blender. The proponents prepared 7" x 7" x 3/4" plywood specimens and subdivided into 4 categories upon fire testing: no coat, wood glue coating, powdered shell coating and crushed shell coating. The specimens were then subjected Bunsen burner test. Temperatures were taken by using a digital multimeter and result were noted for further analysis. Upon analysis of gathered data, results showed that mussel shell coated plywood did not ignite in the standard 90 minute fire exposure test, proving that the application of crushed and pulverized mussel shell on the surface of plywood is an effective way to delay the propagation of fire throughout the material.**

Keywords: **Calcium Carbonate, Fire-retardant, Green Mussel Shells, Plywood Coating.**

I. INTRODUCTION

In the field of natural occurrence and man-made disasters, fire played a large role. Fire disaster is an unfortunate incident that often happens every year, thousands of lives and billions worth of property are lost because of seemingly inescapable fires where people lost their assets, properties, homes and even their lives. Fatalities and casualties of fire usually happens to those who are trapped in the fire with the most vulnerable victims like children, elderly and persons with disability.

Since the Philippines is a tropical country, there is a high risk of fire disaster to occur any moment, and people have to deal with the damages and the aftermath of the disaster. This can be prevented if there are construction materials that can retard fire to prolong its damage until the corresponding fire extinguishing unit arrives and at the same time, a fire-retardant material that is economical for the people. In this regard, the researchers came up with the idea of using mussel shells as a fire-retardant coating agent to lightweight building materials like plywood.

The Asia green mussel *(Perna Viridis),* also known as the Philippine green mussel (tahong), is a sea animal that belongs to the family of shells (Figure 1.1). It can be widely found in the Asia-Pacific Region. The mussel has a big part on the fishing trade industry of the Philippines as it is harvested as a food delicacy, although it is known that mussel shells harbor toxins and can be hazardous to humans that is caused by red tide. Otherwise, it also contains a high amount of $CACO_3$ - calcium carbonate that is an ideal fire-retardant substance.

Literature Review

Perna Viridis, locally known as the Philippine green mussel, is an invasive species of marine bivalve that belongs to the phylum Mollusca and widely distributed across the Asia-Pacific region. Mollusks are composed of chitin, protein, and calcium carbonate. The mineral part of the shell is typically made entirely of calcium carbonate, calcite and/or aragonite (Nehrke et al., 2012). These minerals are derived naturally from seawater precipitation at the time the mollusks start calcifying their shells. Calcium carbonate (CaCO3) is a chemical compound known for its applications as a fire-retardant agent because it delays fire expansion and reduce the fire load of a burning material (Hirschler, 2014). Mussel shells are mainly composed of calcium carbonate, which is a known substance that releases carbon dioxide into the surrounding air as it undergoes thermal decomposition when exposed to high temperatures. The release of carbon dioxide will then push oxygen away, putting out flames in the process. This research may help with the government's fire prevention measures and impart significant information and knowledge regarding the use of what is already considered as wastes, to something beneficial in the construction industry.

II. METHODOLOGY

In this study, the specimen to be used will be plywood (7" x 7" x 3/4") and the coating to be used is made up of crushed and pulverized mussel shells. The specimen would be subjected to a Bunsen burner test in a closed and controlled environment This experiment will set to compare the behavior and the effect of the specimen (crushed and pulverized coated) upon exposure to fire. The test specimen is to be subdivided into 4 categories upon fire testing: no coat, wood glue coating, pulverized shell coating and crushed shell coating. A multimeter is used in order to constantly measure the temperature of fire in Celsius (˚C) that is released by the Bunsen burner. Temperature and time will be recorded, and the following situation needs to be noted and recorded, the time when the specimen ignite, the time the fire penetrated the coating, and the time that the flame spread into the specimen. Comparative analysis of the time gathered on to the two type of coating will be conducted to evaluate the study. It will determine which of the two coating is more effective as a fire-retardant coating for plywood.

III. RESULTS AND DISCUSSION

The graph given below illustrates the relativity of the ignition, flame spread, and penetration of the specimen with respect to time in minutes.

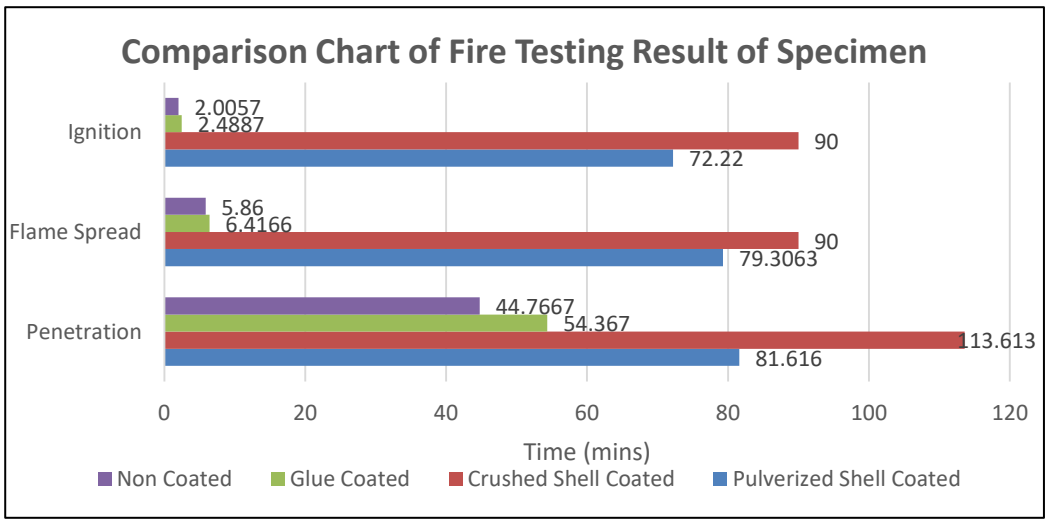

Fig. 1. Comparison Chart of Fire Testing Result of Specimen

The non-coated samples gained an average ignition time of two minutes and zero point twenty seconds (2:00.20) and average flame spread time of five minutes and fifty-one point six seconds (5:51.6). The temperature obtained from the three sample specimen ranged from 169 °C to 370 °C. Glue-coated samples displayed an average ignition time of two minutes and twenty-nine point twenty seconds (2:29.20) and average flame spread time of six minutes and twenty-five seconds (6:25). The temperature obtained from the three specimens ranged from 158 °C to 283 °C. The specimens coated with crushed mussel shells did not ignite upon exposure to fire within the 90 minutes control time. The temperatures of

the specimens during the fire test ranged from 281 °C to 785 °C. However, the specimens coated with pulverized mussel shells did ignite at an average of one hour twelve minutes and thirteen point twenty seconds (1:12:13.20). The temperature of the specimen during the fire test ranged from 112 °C to 728 °C.

The effect of the adhesive to the fire-retardant capability was also considered in this study. These computed factors show how the applied adhesive in the plywood affect the combustibility of the plywood, assuming the plywood has constant fire source coming from the burner. To get the glue factor of the ignition time, glue coated average ignition time is divided by the non-coated average ignition time, which would be:

$$f_{ignition\ time} = \frac{2.4887}{2.0057} = 1.24$$

Similarly, to obtain the glue factor in the flame spread, glue coated average flame spread is divided by the non-coated average flame spread:

$$f_{flame\ spread} = \frac{6.4166}{5.86} = 1.095$$

Since the computed results are greater than 1, that means the glue coated plywood ignites slower than that of the non-coated plywood. The adhesive applied to the plywood has a slight effect to the combustibility of the plywood. The difference in the time of ignition between the glue coated and non-coated plywood is 29 seconds. As for the case of the computed factor of flame spread, the result computed is 1.095, greater than 1 which means the non-coated plywood has faster flame spread speed compared to the glue coated one. The difference in the time of flame spread between the glue coated and non-coated plywood is 33.4 seconds. Having a factor closer to 1 has lesser delaying effect in the combustibility of the wood. As observed by the researchers, the adhesive used in the study has a slight effect in both ignition time and the flame spread time of the plywood.

In order to comprehend the effectiveness of the coating agents (Crushed and Pulverized Mussel Shell) used in the sample specimen to its fire-retardant capability, the data were computed with the following equations:

- Crushed Mussel Shell Coated (CMSC):

$$Efficiency\ in\ Fire\ Penetration = \frac{(CMSC\ Ave\ Time)-(Non-coated\ Ave\ Time)}{Non-coated\ Ave\ Fire\ Penetration\ Time}\ x\ 100\% = 145\%$$

- Pulverized Mussel Shell Coated (PMSC):

$$Efficiency\ in\ Fire\ Penetration = \frac{(PMSC\ Ave\ Time)-(Non-coated\ Ave\ Time)}{Non-coated\ Ave\ Fire\ Penetration\ Time}\ x\ 100\% = 82.31\ \%$$

Based on the computed results, both coating showed great efficiency percentage. Crushed Mussel Shell Coating is able to make the plywood last for about 145% longer than that it's supposed to last upon exposure to fire while the Pulverized Mussel Shell Coating with 82.31% additional time for the plywood to last in constant fire exposure.

The samples with crushed mussel shell coating, upon exposure to fire testing for at the first 90 minutes, do not give signs of fire ignition as well as fire spreading to the plywood. On the other hand, the samples with pulverized mussel shells coating, upon exposure to fire testing and despite having a significant fire-retardant property at first failed to last for 90 minutes but passed the minimum required time of 60 minutes fire retardant capacity. The physical changes of the sample specimen upon exposure to fire were visible, the crushed mussel shell coating and the pulverized mussel shell coating both turns black and some pieces falls off the plywood in the middle of the testing. Then when the part of the specimen exposed into fire turns gray, it means that the fire already penetrated the plywood. As time progresses, burn spots at the top part of the plywood is spotted.

Abbreviations and Acronyms

- $CaCO_3$ - Calcium Carbonate
- CMS - Crushed Mussel Shells
- NFPA - National Fire Protection Association
- PMS - Pulverized Mussel Shells

IV. CONCLUSION

From the analysis and testing conducted for this research and basing from the facts and observations of other researches and studies, it can be concluded that the application of crushed and pulverized mussel shell on the surface of plywood is an effective way to delay the propagation of fire throughout the material. It was observed that crushed and pulverized mussel shells are an effective fire-retardant coating to plywood. Mussel shells are mainly composed of calcium carbonate, which is a known substance that releases carbon dioxide into the surrounding air as it undergoes thermal decomposition, which then push oxygen away, putting out flames in the process. Through further analysis and testing, using crushed shell coating made the wood composite withstand a longer period while exposed to fire. Due to a greater surface area covered, the fire cannot propagate fast enough because it takes quite a long time to completely burn off the surface of the crushed shells. Crushed mussel shell coated plywood can withstand long fire exposures since it passed the maximum required exposure time of ninety (90) minutes.

Recommendations

Scope and limitations are set in this comparative and experimental study. The following are recommendations for future research which could help in the improvement of this study and other related researches.

1) Future researchers may use more proper equipment and effective methods in the fire tests. They may opt for looking for accredited testing centers that offer the said fire test. This will lessen the effort and time in acquiring the needed equipment and setting up the testing apparatus.
2) Other researchers may consider using different types of shells having the same natural component ($CaCO_3$).
3) The researchers recommend the production of separate testing specimen to undergo mechanical test, specifically the flexural strength test to see if the application of mussel shells affect the overall strength of the composite material.
4) The researchers also recommend the further degradation of the shells to be sieved as to which will be applied on the bottom, middle, and top layer of the coating.

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