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PHYSICAL AND MECHANICAL PROPERTIES OF RICE STRAW TREATED WITH SOLUTION OF POTASSIUM HYDROXIDEFROM WOOD ASH

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Abstract
The use of agricultural waste as alternate building material has had great deal of interest in recent years. Therefore, these wastes have often bad physical properties that need to be improved. This experimental research investigation aims to explain the influence of potassium hydroxide on the rice straw properties. The potassium hydroxide was obtained by crystallizing wood ash solution. Five solutions containing different ratio of potassium hydroxide were made and used to treat rice straw. Water absorption, direct tensile test and density were performed on straw to determine the influence of treatments on their physical and mechanical properties. Modifications in rice straw structure were investigated by dissecting microscope and scanning electron microscopy (SEM). All applied solutions resulted in a reduction of the water absorption capacity and increament in tensile strength. For improved physical and mechanical properties of vegetal straw, treatment with solution pH 9.92 (containing 8 kg/l) of potassium hydroxide was recommended.

Keywords:
Rice straw; water absorption; tensile strength; potassium hydroxide, agricultural waste

1 INTRODUCTION

In recent years several studies have been conducted to investigate the possibility of using natural fibers as replacement of synthetic fiber reinforced composites. Likely in construction industry and building materials vegetable fibers have appeared. Many studies have been carried out and the results obtained show an improvement in durability, strength and ductility [Melo Filho et al. 2013; Silva et al. 2009; Silva et al. 2010; Sreekumar et al. 2009]. In addition the vegetable fibers have a low cost and great advantage of being renewable so looked as environment friendly materials.

In this context of environmental protection, agricultural wastes became one of the alternative building materials. They have advantages being availability in many countries, improving thermal comfort and maintaining cultural heritage building. Different agricultural wastes for example rice straw have therefore been used to enhance the properties of soil in different countries. However they present high water absorption capacity which causes volume expansion when they are added to fresh soil.

The aim of this study is to investigate the properties of rice straw. To achieve this, the physical and mechanical properties of rice straws were measured. Moreover they have been treated with potassium hydroxide solution from wood ash, natural alkaline, to fill the lack of information on the use of such treatment. Therefore, the objective of the present research is to investigate the effect of natural alkaline on rice straw physical and mechanical properties.

2 MATERIALS

2.1 Rice straw

Rice straw used in this study was obtained after the harvest of rice from rice field near Dabou, in south of Côte d'Ivoire. The dry rice straw was cleared of its leaves and kept at a room temperature in the laboratory during two weeks. The rice straw had an average moisture content of %; thickness ranging 0.1 mm to 0.3 mm and length ranging 10 to 300 mm. The specific gravity of rice straw was about 0.33. The dried straws were carefully sieved and cut at 100 mmof length, which were selected for this investigation.

2.2 Potassium hydroxide

The potassium hydroxide used in this study for current experimental tests was made from wood ash. The "fromager" wood was air-dried and broken into pieces. The dried pieces were burnt and the ashes were collected. These ashes were carefully sieved and passed through 500 µm aperture sieve. This passing was dispersed in water and left for hour. Then, the solution was filtered on clean cloth and collected into a bowl. Bowl was heated until the

water has been completely evaporated, leaving potassium hydroxide tablet at the bottom.

3 EXPERIMENTAL PROGRAM

3.1 Rice straw treatment

Rice straw was treated with different solution of potassium hydroxide. These solutions were obtained by dissolution into water of different tablet potassium hydroxide weight. The concentration of different solutions and their pH were shown in table 1.

Rice straw specimens were completely immersed in the different potassium hydroxide solution during 24 hours. Then they were taken out and were air-dried in the laboratory until their weight remained constant. After being dried, the specimens were prepared for experimental tests including direct tensile test, water absorption and observe the structure by dissecting microscope and scanning electron microscopy (SEM).

Tab. 1: Summary of characteristics of potassium hydroxide solution used

Solution index	Concentration (kg/l)	pH
S0	0	7
S1	6	9.1
S2	8	9.92
S3	10	9.95
S4	12	10
S5	14	10.24

3.2 Direct tensile test

The tensile test was performed in mechanical testing machine manufactured by the laboratory team. A load cells was associated to the machine for the load determination. The ends of the rice straw length 100 mm were glued to two papers for better alignment in machine and for better griping with the upper and lower jaws. To calculate the tensile strength of rice straw, their areas were measured with caliper of precision 0.002 mm.

3.3 Water absorption

For the water absorption test rice straw weighing 200 g in the dry state was used. The specimens were dried into oven at 60 °C during 24 hours. A synthetic permeable bag in advance completely immersed in water during 10 min was put in salad spinner and the spinner was turned at 100 times at approximately 2 rounds per second. Then 25 g of dry specimens were put in bag and all were weighted (M_0). The bag content specimens were immersed during 24 hours in water. Then it was taken out, put in salad spinner and the spinner was turned at 100 times at approximately 2 rounds per second. After this the bag and the specimens were weighted (M_t). The following formula was used to calculate the value of absorption (W):

$$W=100x(M_t-M_0)/M_0 \quad (1)$$

All the results shown in this study are the average of 5 specimens.

3.4 Binocular loupe and scanning electron microscopy (SEM)

The rice straw microstructure was investigates using binocular loupe and SEM. The binocular “LEICA” was provided with camera which allowed taking images. The SEM was operated under vacuum and accelerating voltage of 15 kV. A working distance of 3 mm was applied and tilt was set to 0°.

The obtained images were analyzed to identify the transformation into straw structure.

4 RESULTS AND DISCUSSIONS

4.1 Effects of treatment on water absorption

Figure 1 displays the effects of treatment with solutions of potassium hydroxide on rice straw water absorption. It can be noted that when the pH of solutions increased from 7 to 9.92, the water absorption ratio decreased gradually after being immersed 24 hours. Specifically, with solution pH 9.92, after being immersed 24 hours the water absorption ratio reduced by 25 % in comparison with rice straw untreated water absorption ratio. When the pH of solutions increased from 9.92 to 10.24, the water absorption ratio decreased suddenly. The significant reduction in the water absorption capacity could be attributed to the transformation of rice straw structure induced by their treatment with solution of potassium hydroxide. The rice straw was composed as all vegetal fiber of hemicelluloses, lignin, cellulose, pectin and wax. The treatment of vegetal fiber with alkali solution deletes wax, pectin and a part of hemicelluloses, lignin and cellulose [Methacanon et al. 2010, Beg et al. 2008, Ferreira et al. 2015]. This deletion was more important when the pH of the solution increased. From pH 7 to 9.92 deletion was gradually but after pH 9.92, it was very important.

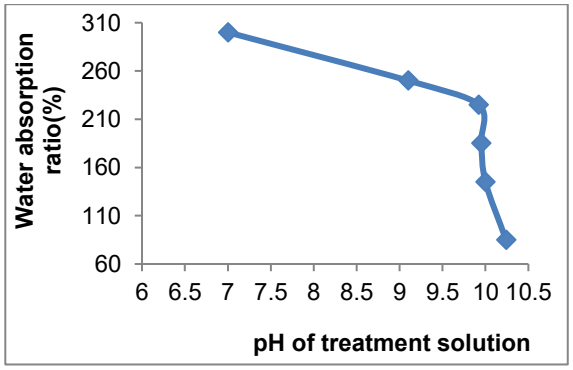

Fig. 1: Influence of treatment on rice straw water absorption

4.2 Effects of treatment on tensile strength

The curve of untreated and treated rice straw was shown in Fig. 2.

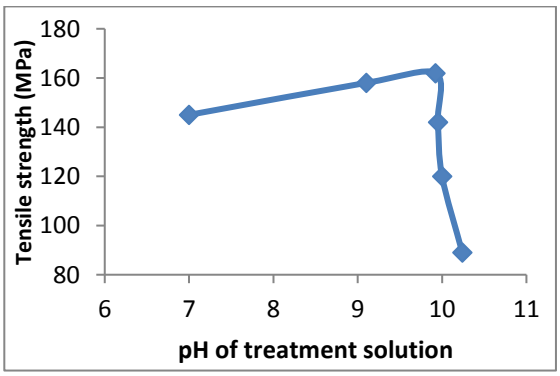

Fig. 2: Influence of treatment on rice straw tensile strength

The tensile strength of rice straw increased after treatment from pH 7 to 9.92 and it decreased beyond

pH 9.92. The improvement of treated rice straw the tensile strength was 12 % of the untreated rice straw. The result like this was found by Ferreira et al (2015), Saha et al. (2010). The reason of the increment in the tensile strength is the deletion of non cellulosic materials and impurities which remain dispensed in interfibrillar region [Kundu et al 2012] when the pH is lower than 9.92.

For pH higher than 9.92, the tensile strength degrades of 50 % when the variation of pH was 0.32. The suddenly reduction in tensile strength can be explained by the deletion of a part of hemicelluloses, lignin and cellulose

4.3 Effects of treatment on rice straw structure

Figure 3 and figure 4 depict the structural transformation of rice straw treated solution of potassium hydroxide at different pH.

The obtained images to binocular (fig. 3) show the variations in the rice straw aspect after treatment in comparison to untreated rice (fig. 3a).It can be observed that all treatments resulted in cleaning of straw and in slightly crystallinity. Below pH 9.92, cleaning was more important and beyond this value, crystallinity increased.

Figure 3: Image of rice straw to binocular loupe: a) untreated pH 7; b) pH 9.1; c) pH 9.92, d) pH 9.95; e) pH 10; f) pH 10.24

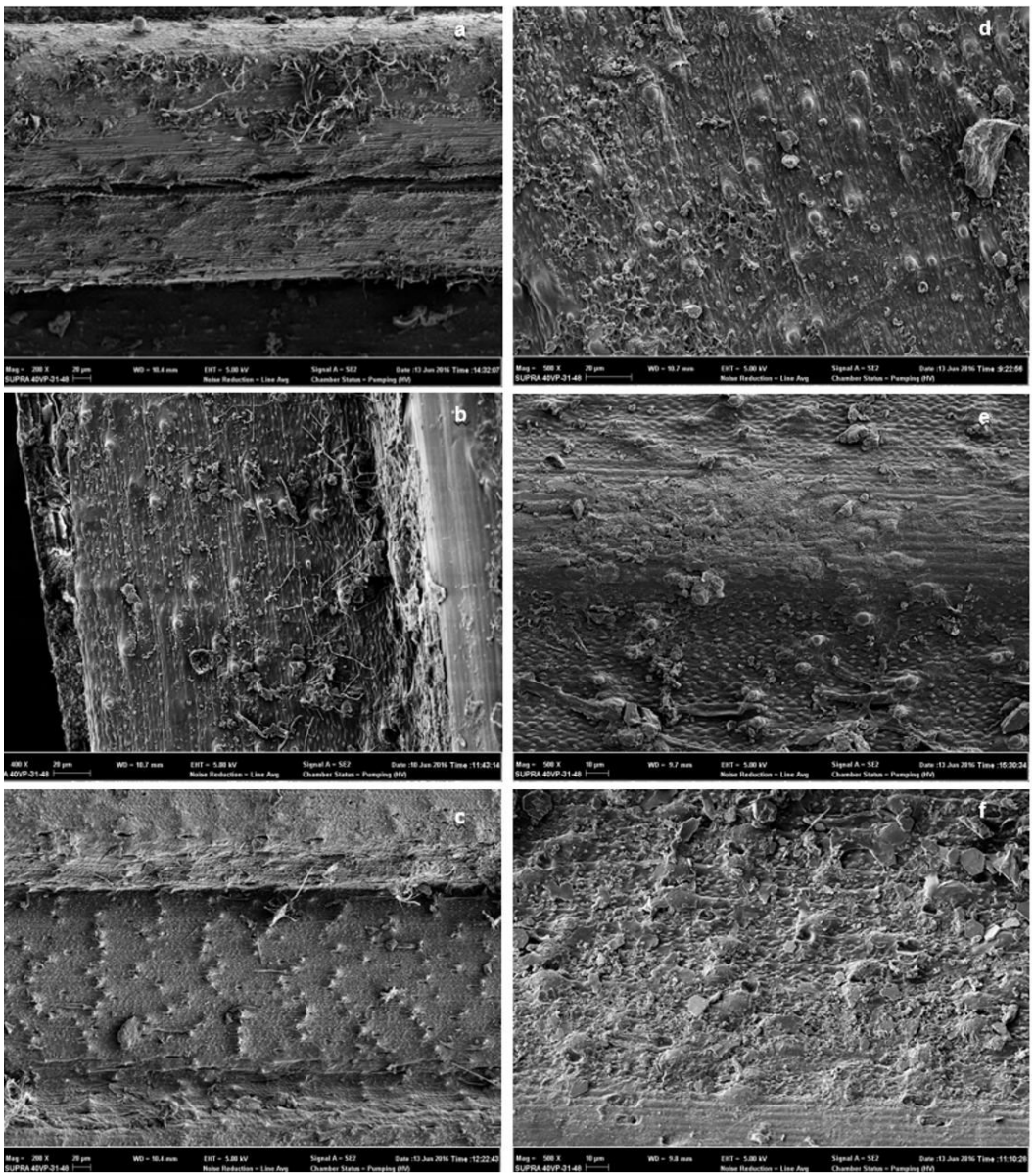

Figure 4: SEM micrograph a) untreated pH 7; b) pH 9.1; c) pH 9.92, d) pH 9.95; e) pH 10; f) pH 10.24

Indeed in SEM micrograph (fig.4), we observed a cleaning on rice straw surface. This cleaning deleted non cellulosic materials (wax and pectin) and impurities which improved water absorption capacity and tensile strength. The highest improvements were found in particular with potassium hydroxide solution when pH was 9.92 and the treatment during 24 hours.

The SEM micrographs of treated rice straw (fig. 4d; 4e; 4f) also show damage and peeling on the surface. Belong pH 9.92 (fig. 4d; 4e; 4f) rice straw surface covered with some swelling issues and peeling. The appearance of these elements results in chemical reaction between rice straw and potassium hydroxide which explains the decrease of tensile strength and water absorption capacity.

5 CONCLUSION

The key conclusions that can be drawn, based on experimental results, are as follows:

- Water absorption capacity of rice straw treated with potassium hydroxide solution from wood ash was reduced. This reduction can be explained by the deletion of non cellulosic and impurities and damage of celluloses, hemicelluloses and lignin.
- Tensile strength increased with augmentation of pH of the solution but less to 9.92. This can be explained by one part of chemical reactions which consequences were the change in celluloses, hemicelluloses and lignin crystallinity, and second part the reduction of amorphous material. But when the pH was belong 9.92, the chemical reactions between hydroxyl groups and rice straw induced damages of celluloses, hemicelluloses and lignin.

6 ACKNOWLEDGMENTS

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