COMPRESSION MOLDING OF PAPER USING TWISTED PAPER YARN AS REINFORCEMENT

Yamamoto H.*,Kimura T.*,Chikamori K.*
*Kyoto institute of technology

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Abstract

As one of the attempts to develop the high performance paper board consisted of all natural fibers, the bamboo pulp paper reinforced by twisted paper yarn was molded and the mechanical behavior was discussed to obtain the finding to create the functionality paper board. The contents of twisted paper yarn in the composites paper and the molding pressure were varied in wide ranges. The technique of paper making and the tensile properties of composite paper were discussed in detail.

1 Introduction

Recently, natural fiber reinforced composites have been focused as environmentally friendly material[1)]. Usually, the plastics are used as a matrix material of composites and the biodegradable and bio-base plastics are paid attention in the many engineering fields[2)].

Meanwhile, paper is one of the necessities for our human life and many efforts are being turned to the development of high performance paper now. The paper and paper board consisted of all natural fibers are also expected as environmental-friendly materials. So, we are aiming at the creation of functionality paper board by using the paper making technique.

In this paper, as one of the attempts to develop the high performance paper board consisted of all natural fibers, the bamboo pulp paper reinforced by twisted paper yarn was molded and the mechanical behavior was discussed to obtain the finding to create the functionality paper board.

2 Materials Used

Base materials used were bamboo pulp with 727ml in Freeness CSF. The average fiber length and diameter are 0.43mm and 11μm, respectively. The standard weight (W) of paper based on JIS P 8222 is 133g/m^2. The value of weight (W) was changed from 1W to 12W through experiments.

The twisted paper yarn made of manila hemp was used as the reinforcement of composite. The fiber length and diameter of hemp fiber were 3~12mm and 16~35μm, respectively. The paper with 4mm width was twisted 340times/m. The manila hemp has a very high strength and also superior absorption property of carbon dioxide. Therefore, the manila hemp is characterized as an environmental-friendly material. Figure 1 shows the aspect of twisted paper yarn.

In this study, the content of twisted paper yarn (W_f) was varied in wide range by regulating the weight of bamboo paper.

Figure 2 shows the typical load-displacement curves for twisted paper yarn and non-twisted (before twisted) paper of manila hemp used here. It is noted here that the maximum load and displacement of twisted paper yarn are larger than those of non-twisted paper. Namely the strength of paper becomes larger by twisting the paper. Therefore the twisted paper yarn is expected as a reinforcement of paper or paper board.

Fig.1 Aspect of twisted paper yarn

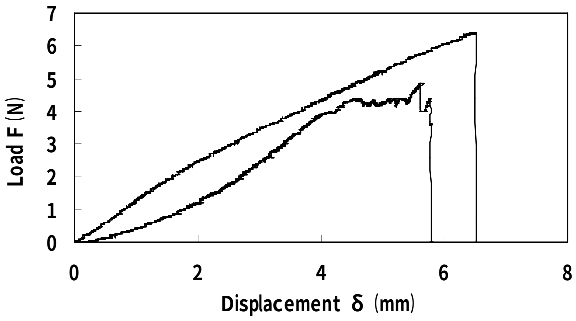


Fig.2 Load—displacement curve of twisted paper yarn used.

3 Paper-making Method

The sheet machine used is shown in Figure 3. The bamboo paper reinforced by manila hemp twisted paper yarn was molded as follows.

Firstly, the bamboo pulp was mixed with water well by using the mixing machine and was dispersed into container of sheet machine filled with water.

Secondly, the water was drained through the drainage canal installed at lower side of container after dispersing well the pulp by using the stirrer. Then, pre-molding paper can be obtained in the container.

Thereafter, the container was opened and the twisted paper yarns were placed on the pre-molded paper parallel with each other (3mm pitch). After that, the container was closed and the residual bamboo pulp was put into the container with water. And then the water was drained again through the drainage canal. Here, the wet composite paper with twisted paper yarns can be obtained.

The neighboring fibers were bonded by the hydrogen bond mechanism for the cellulose natural fibers. In this experiment, the hydrogen bond process was carried out by referring JIS P 8222. Figure 4 shows the aspect of lamination of composites.

Fig.3 Sheet machine

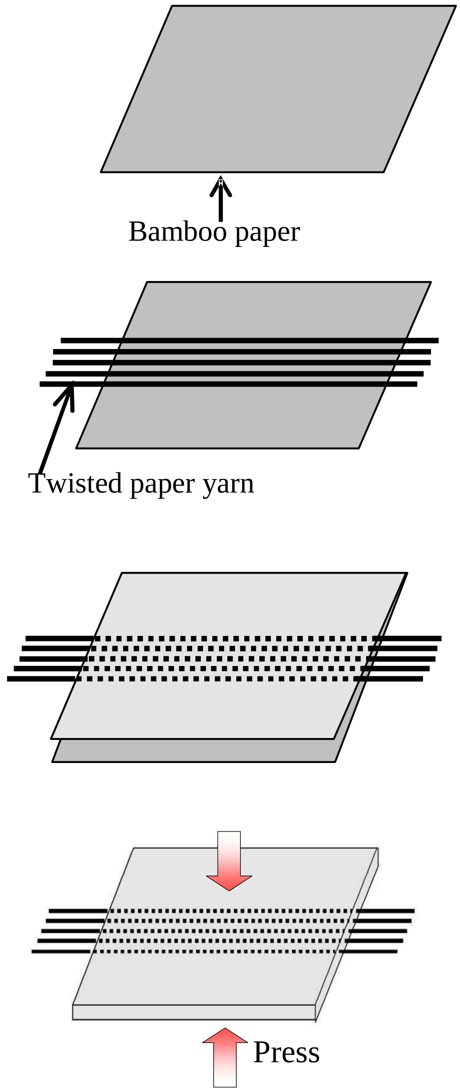


Fig.4 Aspect of lamination of each material

The mechanical properties may largely depend on the value of molding pressure P during the dry process. Therefore, the pressure was varied from 5MPa to 50MPa in this study.

4 Experimental Procedure

Tensile properties were measured by using “INSTRON model 4206” according to JIS P 8113. The cross section and the surface of molded composites were observed by using the microscope.

5 Results and Discussion

The sketch of structure and aspect of molded paper are shown in Figure 5 for W_f = 0.39. The twisted paper yarns exist inside the bamboo pulp paper.

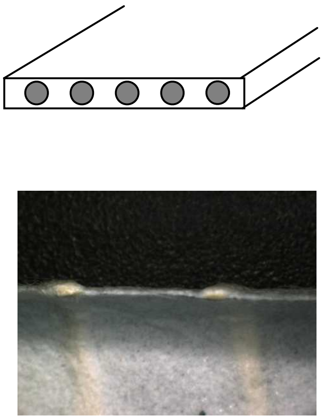
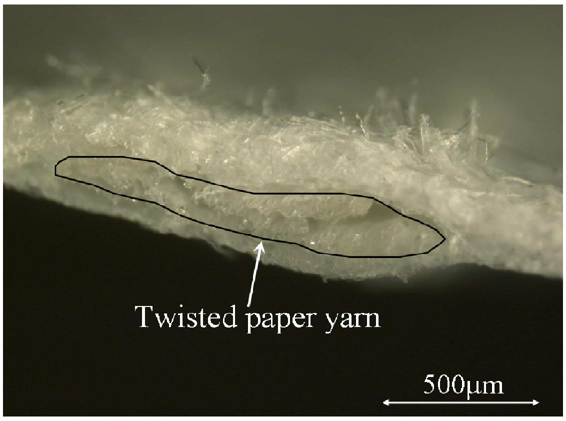
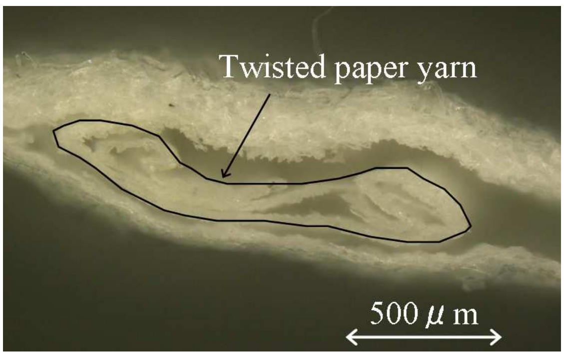


Fig .5. Sketch of structure of molded paper and aspect of molded paper



(a) P=50MPa

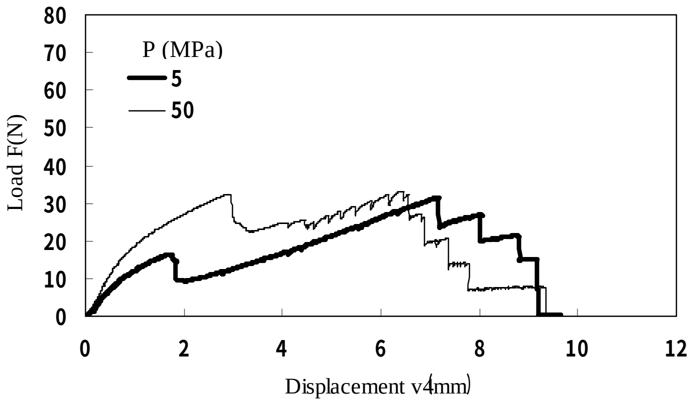


(b) P=5MPa

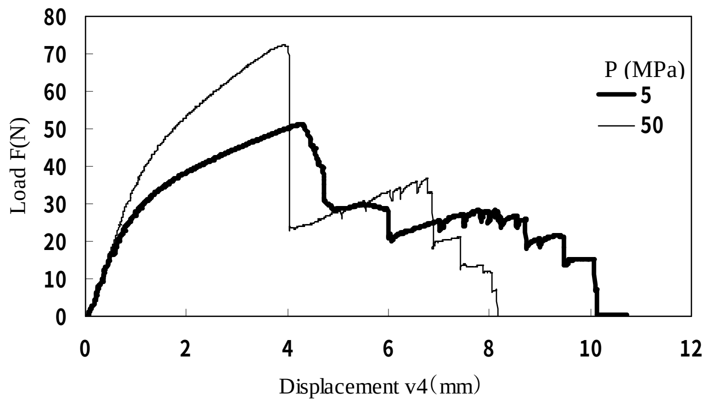
Fig.6 Aspect of paper yarn in composite

Figure 6 shows the aspect around the paper yarn of composite with W_f=0.49 in detail for P=5MPa and 50MPa.. It is noted that a lot of air gaps were caused around the paper yarn. However, the air gap in the top and bottom of paper yarn disappears for higher molding pressure such as P=50MPa. This may causes a good adhesion between the bamboo paper and the twisted paper yarn.

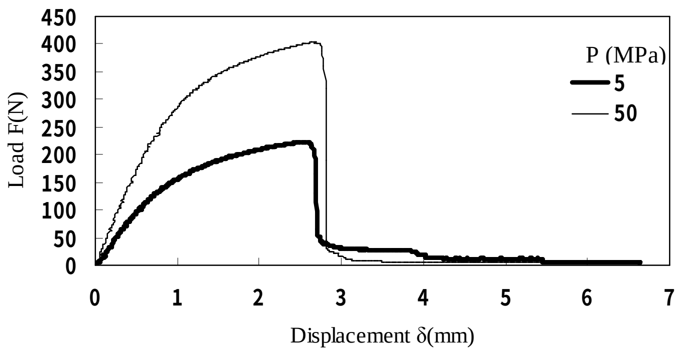
Figures 7 (a)~(c) show the typical load-displacement curves for various content of twisted paper yarn W_f and molding pressure P. It is noted from these figures that the two peaks of load can be seen for larger contents such as W_f=0.66, 0.49 and 0.14 of twisted paper yarn. In these cases, the thickness of bamboo paper is very thin. Therefore the breaking paper is caused firstly, and afterwards the fracture of twisted paper yarn occurs as shown in Fig.8 (a) of fracture mode of composites. This causes the appearance of two peaks of load said above. In the case of small content of twisted paper yarn, the fracture of paper and paper yarn is synchronal because of the thick bamboo paper as shown in Figure.8 (b). Therefore the fracture mode becomes brittle and then only one peak can be seen for the curves as shown in Figure.7 (c).



(a) W_f=0.66



(b) W_f=0.49



(c) W_f=0.14

Figure.7 Load-displacement curve for various W_f

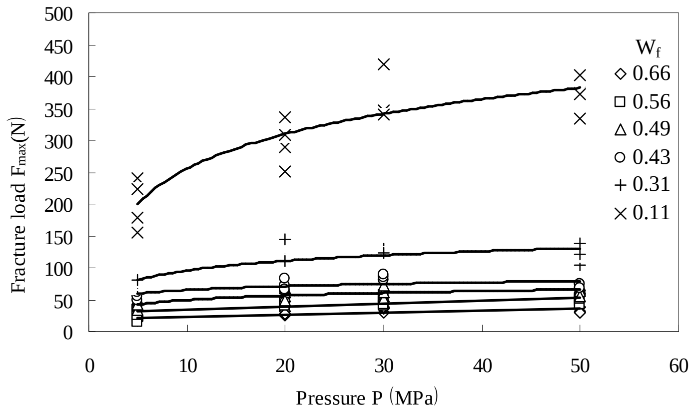
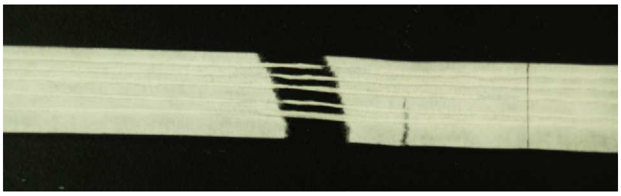
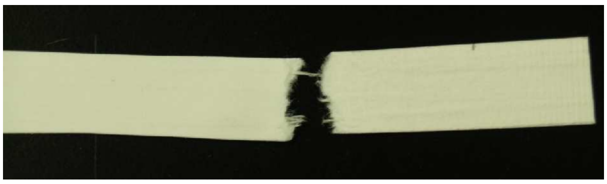


Fig.9 Relation between fracture load and molding pressure



(a) W_f=0.66



(b) W_f=0.14

Fig. 8 Aspect of fracture (P=50MPa)

Figure 9 shows the relation between the fracture load F_{max} and the molding pressure P for various W_f. It is noted from figure that the fracture load increases with increasing the molding pressure. This may be caused by the decrease of air gap and the increase of surface contributing to the hydrogen bond as shown in Figure.6. In the cases of larger W_f, namely thin bamboo paper, the fracture load is non-sensitive to the molding pressure. This may means the lack of bamboo pulp for the composites paper.

Figure 10 shows the relation between the fracture load F_{max} and the content of paper yarn W_f for various molding pressure P. It is clearly seen that the fracture load decreases with increasing the content of twisted paper yarn. In this report the content of paper yarn was varied by regulating the weight of bamboo paper. Therefore the thickness of bamboo paper decreases with increasing the content of paper yarn. This fact caused the decrease of fracture load with increasing the content of twisted paper yarn.

As for the molded composite paper, the weight is different everything. The properties of composite paper depend largely on the weight of paper. Therefore, the consideration under the constant weight of composite paper is worthy to discuss the effect of twisted paper yarn on the properties of composite paper. Then the fracture load was divided by each weight. The results of relative fracture load F_r are shown in Figure.11. It should be noted here that the value of F_r decreases with increasing the content of twisted paper. Those results suggest that the twisted paper yarn used here doesn’t act as a reinforcement. This may be caused by the low strength of twisted paper yarn and the lack of adhesion between bamboo paper and twisted paper yarn. Namely it is conclude here that more strong twisted paper yarn is needed for the reinforcement and the binder material such as PVA is expected to improve the adhesion. These are our next themes of this study.

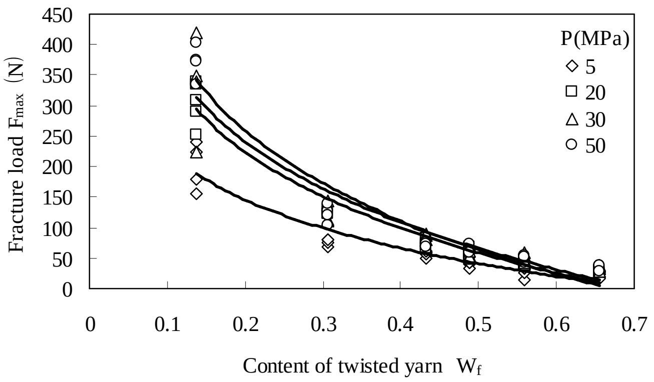


Fig.10 Relation between fracture load and content of twisted yarn

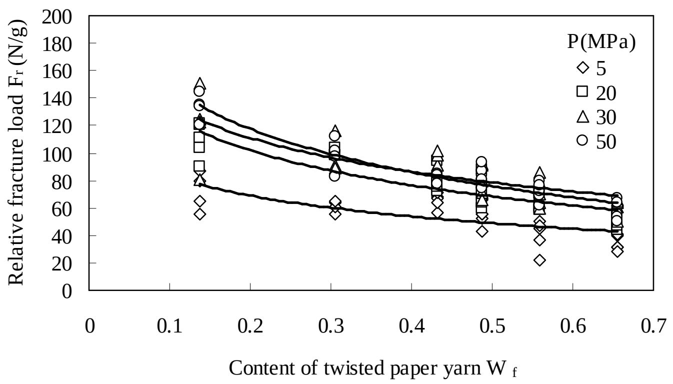


Fig.11 Relative fracture load

6 Conclusion

As one of the attempts to develop the high performance paper board consisted of all natural fibers, the molding of the bamboo pulp paper reinforced by twisted paper yarn was tried and the mechanical behavior of composite paper was discussed to obtain the finding to create the functionality paper board.

The tensile strength of composite paper increased with increasing the molding pressure. However, the twisted paper yarn didn't act as a reinforcement because of the inadequate strength of paper yarn. The improvement of adhesiveness became a next topix.

References

[1] Kihara Y., Ben G., Nishino M. and Matsuda T. "Development and Evaluation of Green Composites Composed of Yarned Kenaf Fiber Bundles and Biodegradable Resin by using Pultrusion and Hot Press Moldings". Proceedings of JCOM-36, Kyoto, pp 1-5, 2007.

[2] Cao Y., Goda K. and Shibata S. "Development and Flexural Properties of Bagasse Fiber-reinforced Composites". Proceedings of IWGC-4, Tokyo, pp 124-128, 2006.