Compression Molding of Green Composite made of Wood Shavings

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SUMMARY

The purpose of this research is to develop a green composite using only wood material. Wood shavings in which the shapes are in a linear form are used in this paper. In order to compress these linear wooden materials, an intricate structure board can be produced. Moreover, board made by longer and larger elements had higher mechanical properties.

Keywords: wood shavings, compression molding, self adhesive, aspect ratio

INTRODUCTION

Creation of recycle-based society is an important factor in order to resolve geo-environmental issues that are happening recently. A general recycling method for wooden materials is to make engineered board from wasted woods. For example, particle board, fiber board, ply board are used widely in architectural industry and so on. However, these boards contain chemical compounds such as urea resin and phenol resin, which are not effective for promoting a recyclable society. Therefore, development of wooden board without using oil resource is required.

Wood mainly contains cellulose, hemi cellulose and lignin. Lignin holds 20-30% of the whole material, and it is defined by past studies that lignin has a function as an adhesion materials [1], [2], [3]. It is known that intenerating lignin is possible with heating by second-order transition point [1]. A wooden board can be produced using wooden elements by heat pressing, though it is not clarified that the adhesion of the elements was caused by the adverse development of the lignin [4], [5]. Furthermore, using only wood powder as a molding material, the resultant board at high density can be used as a fall back for fabric materials [4].

In this research, self adhesive wooden board is produced by compression molding using this knowledge. Wood shavings are focused as a molding material. Wood shaving is an industrial waste formed by the fabricating process (planer finish) in wooden building sites or lumber mills. Wood shavings are mainly in a thin and linear form. Using this as an element of the board, production of a self adhesion board even in medium density will be possible because of the form of the element. In this study, optimal molding condition including molding temperature and element form is investigated in experimental. Deliberation of a method for recycling wooden materials can be made bringing out the mechanical and adhesive properties of the board.

EXPERIMENTAL

Materials Used

Since wood shavings are shaved manually, the form of it has varied sizes. The difference of the size will be expected to affect the mechanical property of the molded board. In this study, the aspect ratio of the shavings is considered as the factor of molding condition. Figure.1 shows different types of wood shavings. Shavings P, N, and L were shaved actually in wooden building sites. Shaving P is powdered state and it is collected from Shaving N by screening with opening of 2mm. Shavings 5-S, 10-S, 15-S, 5-L, 10-L, 15-L were shaved artificially in prescribed sizes controlling the aspect ratio. Aspect ratio of the shaving was calculated as below.

$$\text{Aspect Ratio} = \frac{\text{Breadth (minor axis)}}{\text{Length (major axis)}}$$

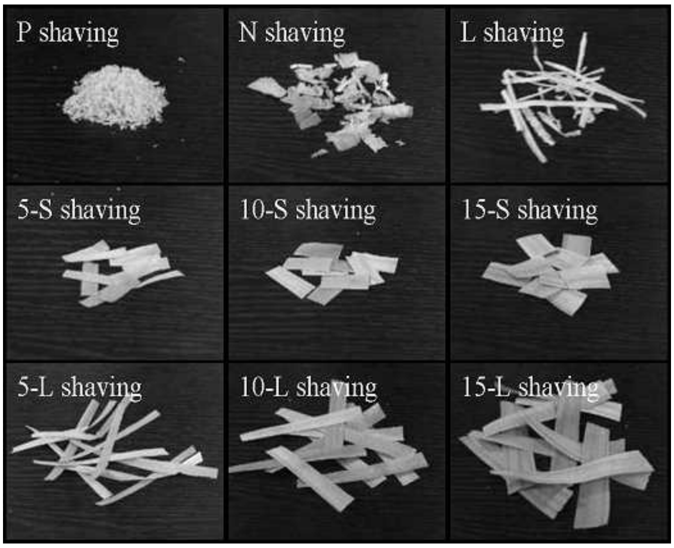


Fig.1 Aspect of wood shavings

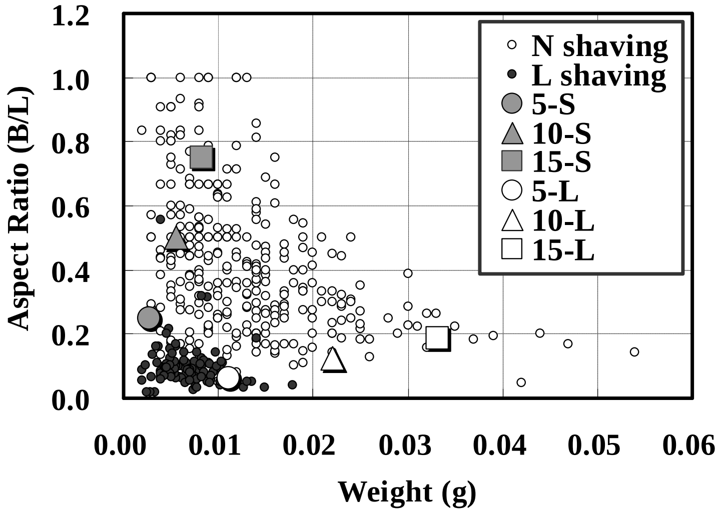


Fig.2 Configuration of N, L shavings

Each wood shaving was measured major axis as length, and minor axis as breadth. Fig.2 shows the configuration of the shavings. As the figure indicates, N and L shaved in building sites shows large variation of form. L has a lower aspect ratio, meaning that it is longer and thinner than N.

Molding Process

Molding conditions and the configuration of the elements for each board are shown in Table.1. To deliberate the effect of molding temperature gives to the mechanical property of the board, temperature was set to 110, 130, 150, 170, 190, 210, 230, 250 degrees Celsius. Board density was set to 0.8g/cm^3 that is equivalent to Medium density Fiber Board (MDF) which is normalized by Japanese Industrial Standard (JIS). Fig.3 shows the molding process of each board. In order to improve the formability, wood shavings was immersed in water for 10 minutes. These wood shavings were set into a metallic mold and heat pressed at a prescribed temperature for 60 minutes.

Table1. Molding condition and element configuration for each board

	Molding Condition			Configuration of Element			
	Moldiong Temperature	Molding Time	Board Density	Breadth	Length	Square Measure	Aspect Ratio
	(℃)	(min.)	(g/cm^3)	(mm)		(mm^2)	(B/L)
P	*110, 130, 150, 170, 190, 210, 230, 250*	*60*	*0.8*	*screening by 2mm opening*			
N				*9.07 (avg)*	*27.01 (avg)*	*244.98 (avg)*	*0.34 (avg)*
L				*3.60 (avg)*	*43.48 (avg)*	*156.53 (avg)*	*0.08 (avg)*
5-S				*5*	*20*	*100*	*0.25*
10-S				*10*		*200*	*0.50*
15-S				*15*		*300*	*0.75*
5-L				*5*	*80*	*400*	*0.06*
10-L				*10*		*800*	*0.13*
15-L				*15*		*1200*	*0.19*

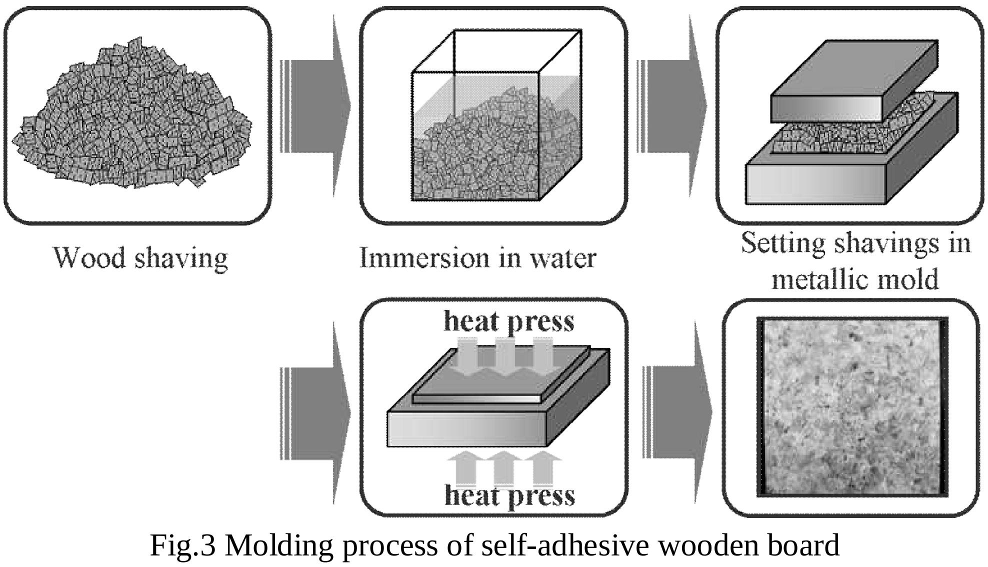


Fig.3 Molding process of self-adhesive wooden board

Flexural Test

In order to investigate the mechanical property of the boards, flexural test was carried out in a 3-point bending mode following JIS K 7203 standard using a desk testing machine (JTT LSC-01-1/30). Specimen dimension was 160×15×8, and 10 samples for each molding condition was tested in a test speed of 2mm/min.

Observation of Adhesion of the Board

The specimen surface was observed using a scanning electron microscope (SEM, HITACHI S3000) to examine the adhesion state of the elements in difference of molding temperature.

Observation of Fracture Morphology

To examine the effect that molding temperature and the aspect ratio of the elements gave to the fracture morphology of the board, fracture cross section was observed using a light microscope (KEYENCE VH-8000).

RESULTS AND DISCUSSIONS

Effect of Molding Temperature

Flexural Property

Figure.4 shows the relationship between molding temperature and flexural property of N shaving board. In addition, wood shaving did not adhere with molding temperature under 100 degrees Celsius and was not able to perform a strength test. Flexural property improved from molding temperature 110 degrees Celsius and showed the peak value in 210 degrees Celsius. It can say that in this temperature, lignin softened enough, and adhesive property between the wood shavings was provided. However, flexural property fell at after 230 degrees Celsius. This occurred because of the heat decomposition of the cellulose.

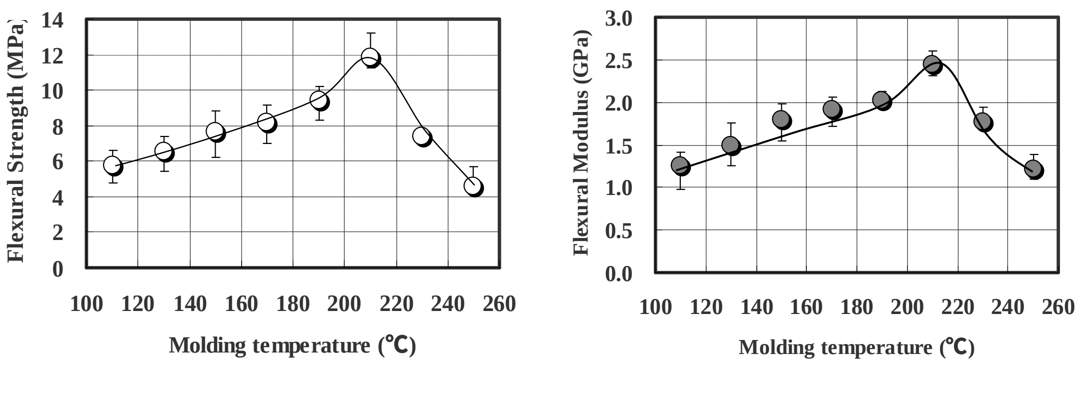
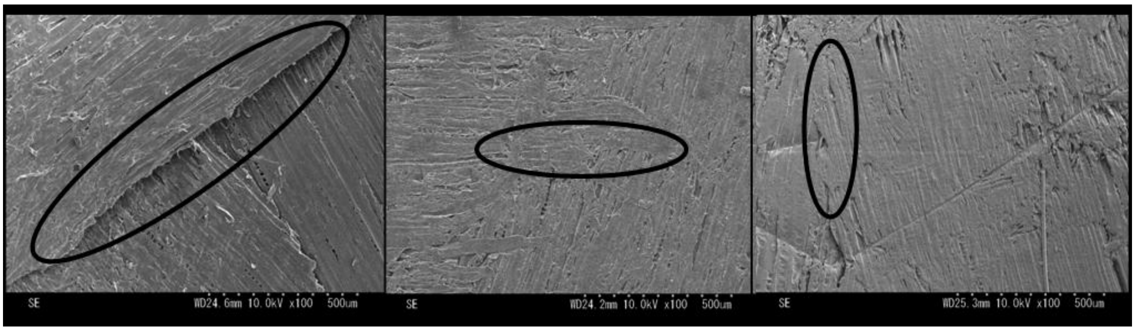


Fig.4 Relationship between molding temperature and flexural properties

Adhesive Condition

Figure.5 shows the SEM observation on conversion of adhesion by molding temperature seen from specimen surface. The parts which are surrounded with circles are the border part of the wood shavings. A void between the upper and lower shavings was seen in N110. This can say that, adhesion of the shavings was not enough in the low temperature area. Meanwhile, no void between the shavings was seen in N210 which showed the highest flexural property, and N250 which was the highest molding temperature in this experiment. Therefore, molding temperature near 210 degrees Celsius is the temperature that is enough for the softening of lignin and the temperature that doesn't reach the decomposition temperature of cellulose. It can say that it is the most suitable temperature in order to mold the board.

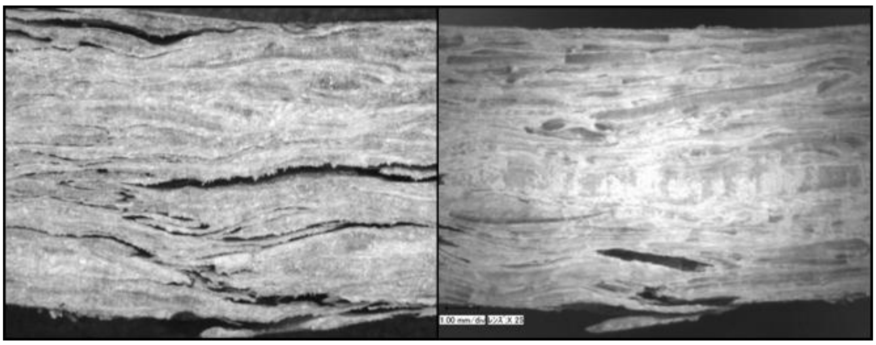


N110 N210 N250

Fig.5 SEM observation on conversion of adhesion by molding temperature seen from specimen surface

Fracture Morphology

Figure.6 shows the relationship between molding temperature and fracture morphology seen from specimen cross-section. As the picture shows, there are more delaminations in the board molded at low temperature such as N110, and it can say that adhesion between the wood shavings was not enough. On the other hand, delaminations of N210



N110 N210

Fig.6 Relationship between molding temperature and fracture morphology seen from specimen cross-section tends to be little. Therefore, enough adhesion with wood shavings by high temperature contributed to improvement of flexural property. In addition the flexural property of this board was dependent on the adhesion state between the elements, and the adhesion state was influenced by molding temperature.

Effect of Aspect Ratio (P, N. L)

Flexural Property

Figure.7 shows the relationship between aspect ratio of the elements and flexural property in the case of molding temperature 210 degrees Celsius. As the graph indicates, flexural property increases when the element aspect ratio is lower. This shows that the board by wood shaving has a better flexural property than the wood powdered state board. Furthermore, comparing L210 which showed the highest flexural property, with quality of MDF prescribed in JIS A 5905 standard, the flexural strength was equal with Type15 (15MPa) and flexural modulus was equal with Type30 (2.5GPa).

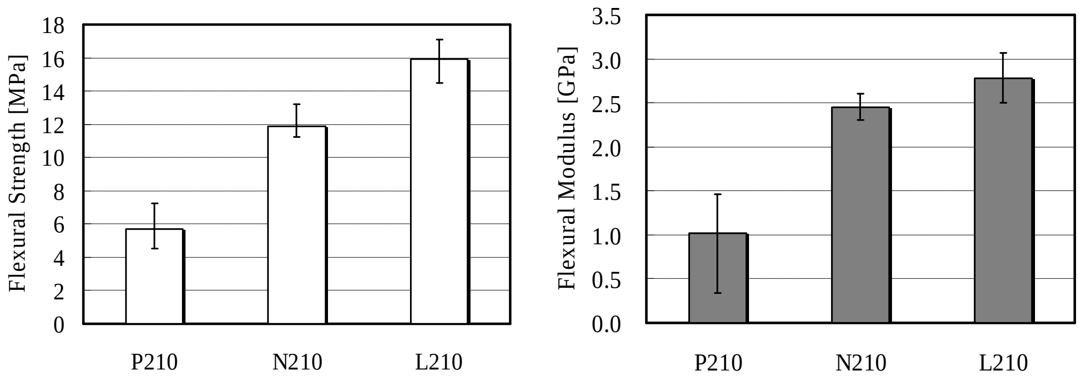


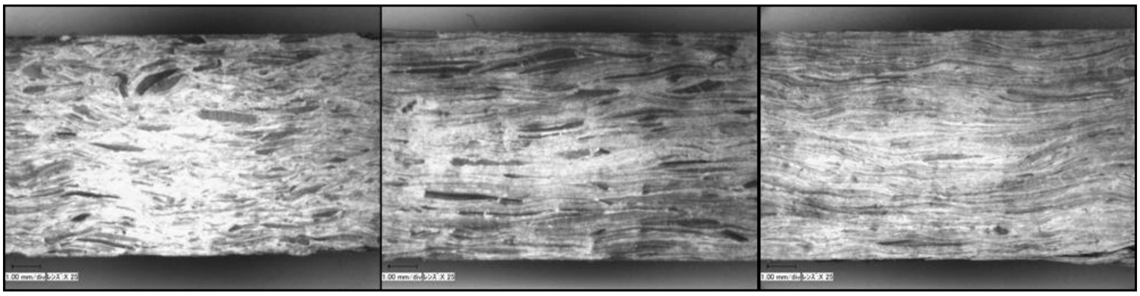
Fig.7 Effect of flexural property in difference of element aspect ratio

Adhesive Condition

Figure.10 shows conversion of adhesion in difference of wood shavings aspect ratio seen from specimen cross-section. The section is observed as long stratified formation in order of P210, N210, and L210. It is thought that this is because the adhesion side between wood shavings is long in the specimen longitudinal direction.

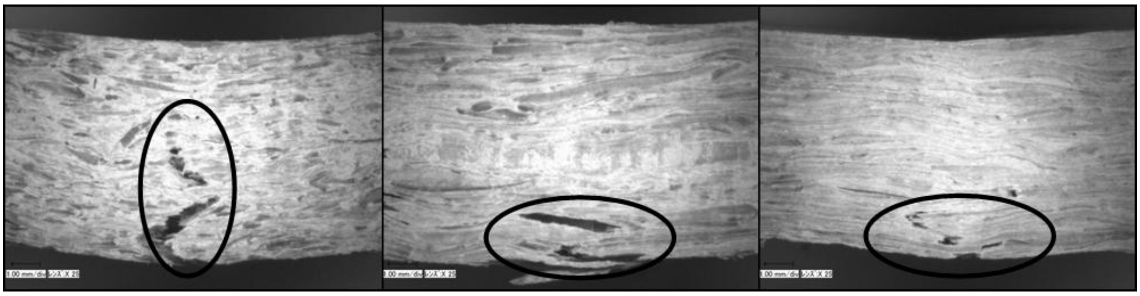
Fracture Morphology

Figure.9 shows the conversion of fracture morphology in difference of element aspect ratio seen from specimen cross-section. The points surrounded with circles are the fractured part of each specimen. P210 which is a powdered state board, the fracture evolve towards the thickness direction. In addition, as for P210, the main adhesion of the board



P210 N210 L210

Fig.8 Conversion of adhesion in difference of element aspect ratio seen from specimen cross-section



P210 N210 L210

Fig.9 Conversion of fracture morphology in difference of element aspect ratio seen from specimen cross-section

is dot to dot, so the strength that can be sustainable for the tensile force is lower comparing with N210 and L210. It can say that, this is the reason P210 showed the lowest flexural property. Adhesion of N210 and L210 are mainly adhesion between the surfaces of the wood shavings, so the fracture of thickness direction was restrained. Furthermore, L210 has more entwining between the wood shavings, so the delamination was restrained and it can say that this contributed the improvement of the flexural property.

Effect of Controlled Aspect Ratio and Surface Area of the Elements

Flexural Properties

As you can see, it is now clarified that the aspect ratio of the elements affects the properties of the resultant board, and board made of lower aspect ratio elements showed higher flexural property. Although, it can say that the surface area of the element will affect the mechanical properties of the board as well. Therefore, surface area of the element is also considered with the aspect ratio by controlling the size of the element artificially, shown in Fig.2 and Table.1.

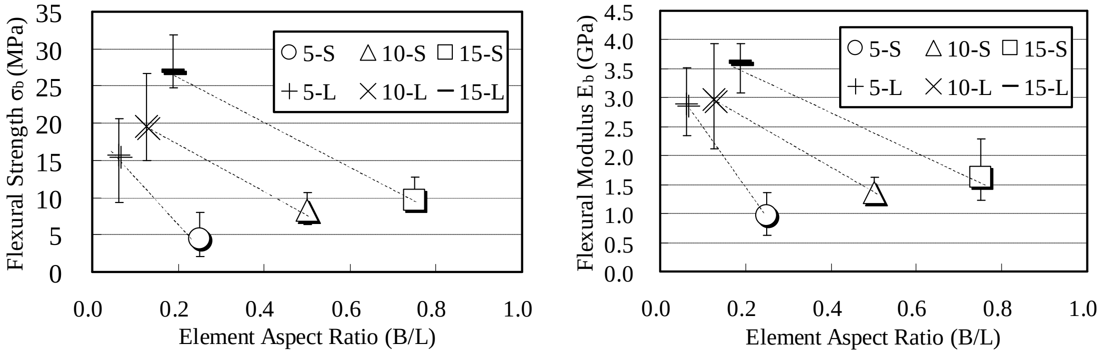


Fig.10 Relationship between flexural property and element aspect ratio

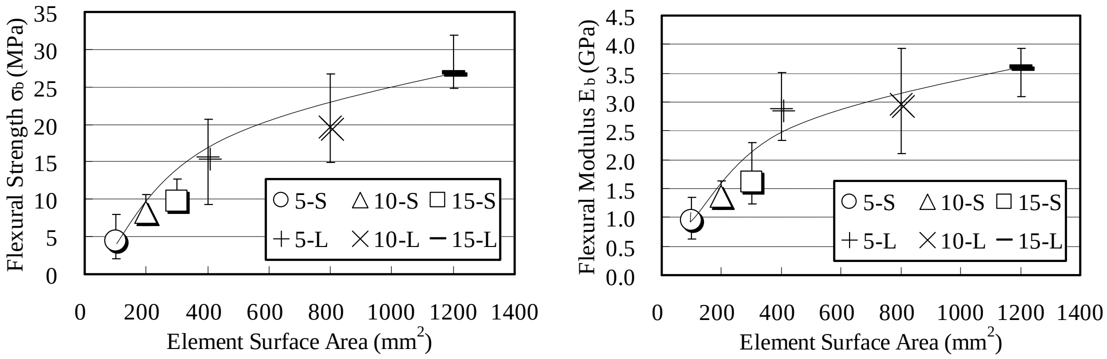


Fig.11 Relationship between flexural property and element surface area

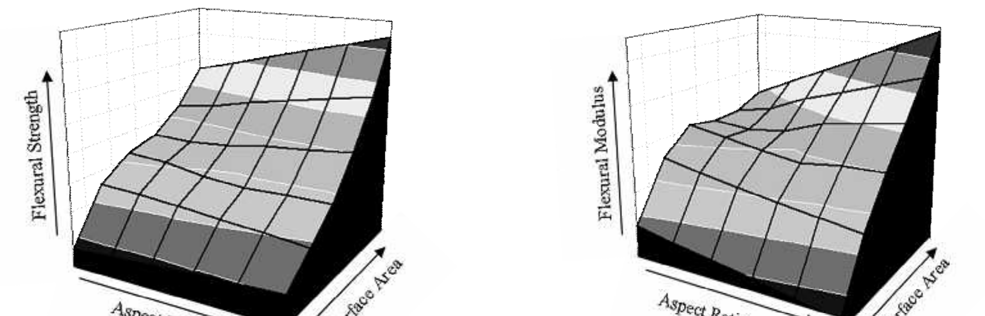


Fig.12 3D diagram of flexural properties with the variation of aspect ratio and surface area of the element

Fig.10 shows the relationship between flexural property and element aspect ratio. The results are in the case when molding temperature was 210 degrees Celsius. Comparing the pares of 5-S and 5-L, 10-S and 10-L, 15-S and 15-L which are in same breath but different aspect ratio, it can say that flexural property increases when lower aspect ratio. On the other hand, when comparing the groups of 5-S, 10-S, and 15-S or 5-L, 10-S, and

15-L which are in same length but different aspect ratio, flexural property increases when higher aspect ratio.

Fig.11 shows the relationship between flexural property and element surface area. The results are when molding temperature was 210 degrees Celsius. The figure indicates that when surface area of the element is larger, higher flexural property was shown.

In order to clarify the relationship of flexural property, element aspect ratio, and element surface area a three dimensional diagrams of flexural property with the variation of aspect ratio and surface area of the element are shown in Fig.12. As the figure indicates, flexural property increases when aspect ratio is low in smaller surface area. Although, in larger surface area flexural property increases when aspect ratio is higher. Therefore, improvement of flexural property can be made when the surface area and aspect ratio of the element is higher.

CONCLUSION

In this study, self-adhesive wooden board using wood shavings was produced. Molding temperature, aspect ratio and surface area of the element were focused as a factor for the mechanical property of the produced board. The major results obtained are summarized as follows.

1) Molding of self-adhesive wooden board using wood shaving as an element was possible, in more than molding temperature 110 degrees Celsius.

2) The board performed the highest flexural property when molding temperature 210 degrees Celsius. Higher temperature than this value caused heat decomposition of cellulose which made deterioration of the flexural property.

3) The flexural property of this board depended on the adhesion state of the wood shavings, and the adhesion state was influenced by molding temperature.

4) By using thinner wood shaving as an element, entwining of the shavings increased, and the improvement in the flexural property was shown.

5) Board L210 showed equivalent flexural property to MDF. Therefore, utility of the self-adhesion board was suggested.

6) Improvement of flexural property can be made when the surface area and aspect ratio of the element is higher.

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