Structural Design for Improving Strength of Flat Wooden Pallets

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Introduction

The purpose of this study is to develop a new pallet structure using the inexpensive hinoki wood, which is produced in the Ehime Prefecture, having the same strength as the conventional Oregon pine wood. A pallet structure was proposed for achieving high strength by improving the flexural stiffness and compressive stiffness.

Pallet Fabrication and Strength Experiments

Production of Flat Pallets. two types of single-sided square difference (D2 type, JIS Z 0604) flat pallets were manufactured, which are commonly used in distribution sites. Oregon pine wood was used to manufacture the standard pallet, whereas hinoki wood was used to manufacture the proposed pallet. The external dimensions of both the pallets were 1100 × 1100 mm with a height of 144 mm and maximum loading mass of 2 t.

Flat Pallet Strength Tests. Flat pallet bending tests and compression tests were performed based on JIS Z 0602. In the bending tests, the deflection ratio was calculated by measuring the deflection in the central portion of the lower edge board. In the leg compression tests, the compressive displacement was measured in the central portion of the top surface of the two legs of the pallet, and calculated the average compressive strain using the compressive area.

Simulation Analysis of Strength Test

Wood Anisotropy. The anisotropy of wood is derived from the tissue structure. Wood is generally considered as an orthogonal anisotropic material with axes along three directions: the fiber (L) direction, radial (R) direction, and tangential (T) direction, as shown in Fig. 1. Table 1 shows the Young's modulus E_L, E_R, and E_T, shear modulus G_{RT}, G_{LT}, and G_{LR}, and Poisson's ratio ν_{LR}, ν_{RT}, and ν_{TL}, along the three axes used in the finite element method analysis. E_L = 12 GPa was used for Oregon pine wood and E_L = 9 GPa was used for hinoki wood. Furthermore, a stress–strain curve along the L direction was used. The Young's modulus for compression and tension are almost equal. The ratio of maximum stress of compression to tension is 1:2, whereas the elastic limit stress is approximately 2/3 and 4/5 of the maximum stress during compression and tension, respectively. In this study, the maximum stress was achieved by the bending strength. The strength in the lateral direction (T direction and R direction) for tension and compression was 5% of that in the L direction in the T direction and 10% in the R direction.

Simulation Analysis Model. A bending test model was made, that was a 1/4th of the actual model and accounted for the symmetry of the boundary condition. Additionally, a full-sized model for compression tests was created because of load asymmetry. Elasto-plastic analysis were performed though using three-dimensional isoparametric elements accounting for the anisotropy of wood and different flow stress behavior between the tension and compression sides. From the perspective of material mechanics, to achieve high structural strength by improving stiffness, we created six types of new pallet models.

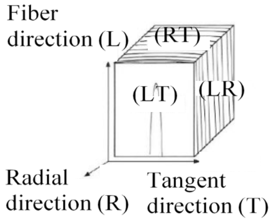

Fig. 1 Anisotropy definition

Table 1 Average Young's modulus for coniferous tree

E_R/E_L	E_T/E_L	G_{LR}/E_L	G_{LT}/E_L
0.075	0.040	0.060	0.050
G_{RT}/E_L	ν_{LR}	ν_{LT}	ν_{RT}
0.003	0.40	0.50	0.60

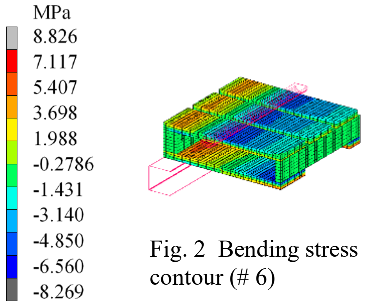

Fig. 2 Bending stress contour (# 6)

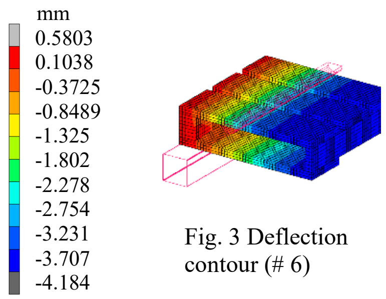

Fig. 3 Deflection contour (# 6)

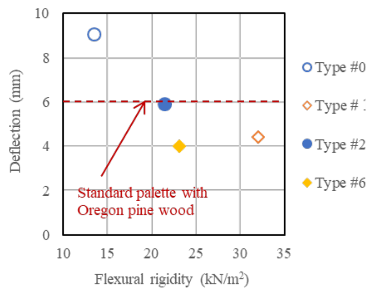

Fig. 4 Relation between deflection and flexural rigidity

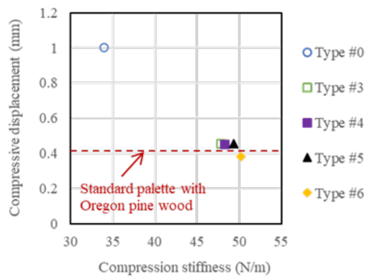

Fig. 5 Relation between compressive displacement and compression stiffness

Table 3 Comparison of new and standard type

Type \ Items evaluated	Deflection	Compressive displacement	Cost (Japanese yen)
Standard Type	12.85	2.96	1,264
New Type (# 6)	8.83	2.06	906

Results and Discussion

Figures. 2 and 3 show an example of bending stress and deflection distribution Fig. 4 shows the relationship between flexural stiffness and deflection. Fig. 5 shows the relationship between the compressive stiffness and compressive displacement of the legs. Table 3 shows a comparison of the strength test results and cost of the Oregon pine-made standard type and the hinoki-made type #6 pallets.

Conclusion

New mold pattern 6 made is higher in strength than the standard mold. Cost of the new type #6 is 72% of that of the standard type pallet, and the cost can be reduced by 28%.