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Effect of Veneer Quality on Bonding- and Bending Strength of Softwood Plywood[*1]

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침엽수 합판의 접착력 및 휨강도에 미치는 단판 품질의 영향[*1]

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要 約

국내 합판 산업계는 오랫동안 남양재 활엽수를 주로 사용하여 왔으나, 환경 보존적인 측면에서 열대재의 벌채를 규제하는 등 여러 요인으로 인하여 합판용 원목의 수입이 어려워지고 있다. 이에 대응하기 위하여 합판용 원목을 침엽수재로 대체할 필요가 있으며, 침엽수 합판 제조를 위한 기초 자료를 제공하기 위하여 본 연구를 수행하였다.

공시 수종은 국내에서 조림한 낙엽송과 시베리아산 낙엽송 및 뉴질랜드산 라디에타 소나무 였으며, 공시원목으로부터 얻어진 단판의 품질과 이들 단판으로 제조한 합판의 접착력과 휨강도를 조사하였다.

이면 할렬실험에서 시베리아산 낙엽송은 다른 수종에 비해 할렬 밀도가 낮게 나타났다. 단판 품질은 접착력 및 휨강도에 거의 영향을 미치지 않았으나 합판의 휨강도에서는 심재와 변재에 따른 차이가 있음을 알 수 있었다. 이는 합판제조시 심재와 변재를 구별하여 사용할 필요가 있었다. 라디에타 소나무의 변재부로 만든 합판 MOR은 다른 수종에 비해 우수하게 나타났다. 접착력 실험에 있어서는 페놀 접착제를 사용하여 만들어진 합판만이 구조용으로써 사용할 수 있음을 알았다. 목파율은 동일 수종 합판에서는 라디에타 소나무 구성이 가장 높게 나타났으며, 異樹種 합판에서는 표판을 국산 낙엽송, 심판을 라디에타 소나무를 사용하여 만든 합판에서 가장 높게 나타났다.

Keywords : Plywood panels, bond quality, sapwood, heartwood, MOR, wood failure

1. INTRODUCTION

Korea was exporting country of a tropical hardwood plywood in 1960's, and was a major plywood exporting country in 19705's in the world. It became an importing country of plywood by losing the competitiveness in exports due to increases of manufacturing cost which was resulted from the oil shocks in 1980's and thereafter changes of international log mar-

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kets. However, plywood industries in Korea are still valuable since the domestic demand for plywood has been kept to increase.

Recently, plywood industries are confronted with the important problem. That is the suitable substitution for the current raw material of plywood which is accompanied by the difficulty of tropical hardwood supply. To solve this problem, Korean plywood industries are manufacturing the softwood plywood. Especially, Korean researchers have to study to be able to substitute the domestic afforested wood for the imported wood as the raw materials of plywood.

Consequently, this study was carried out to offer the basic data using domestic afforested log and foreign log as the raw materials of plywood.

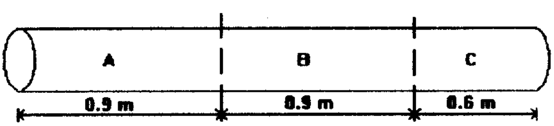
2. MATERIALS & METHODS

Japanese larch(***Larix leptolepis***), Radiata pine (***Pinus radiata***) and Siberian larch(***Larix gmelinii***) were purchased for total 48 logs(16 logs per each species). The two logs of 0.9m length for making veneer were cut from 2.4m length logs. The cutting configuration of logs is illustrated in Fig. 1. The logs were pretreated in heated and unheated conditions. The heat treatment were consecuted at constant temperature of 66℃(±2℃) in a hot water vat during 12 hours.

Veneers were peeled with rotary lathe. The peeled veneers were dried to moisture content 5% with jet-dryer(171℃). Larch veneers were dried for 4 and 6 minutes, Radiata pine veneers were dried for 6 and 7.5 minutes. The specimens for the test of lathe check(5× 10cm), thickness, shear bond test and bending test(30 × 30cm) were prepared from the veneers as shown in Fig. 2.

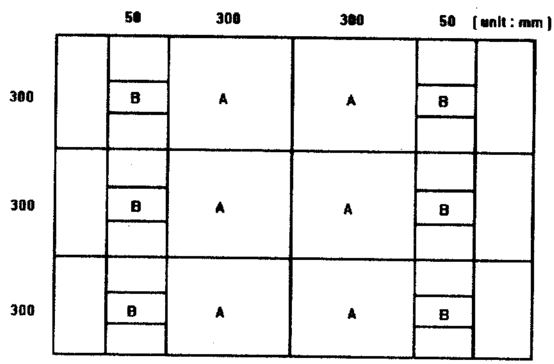
The specimens for lathe check test were measured their thickness at 3 points of the both ends and center. And then, the loose side were absorbed with black ink and were dried. Later on, they were cut. Finally, they were measured for depth, angle and density of check.

Veneers were laid up into three-ply, 30 by 30cm and 5.5mm thickness. Moisture content of the veneer before spreading the glue was controlled into approximately oven-dry condition. Panels were glued with phenolic resin and urea-melamine resin adhesives. Assembly times of 4 minutes were used in gluing the panels using the urea-melamine resin adhesives. And the panel using the phenolic resin adhesives were assembled for 5 minutes. The panels were pressed, according to following temperature: urea-melamine resin adhesives, 110℃ (pressure : 10kg/cm^2, spread rate of glue(single side spread at each face veneer: 415g/m^2); phenolic resin adhesives, 135℃(pressure: 11.5kg/cm^2, spread rate of glue: 470g/m^2). As the panels were removed from the hot press, they were cooled to ambient condition. The 72 panels were made up each species and adhesives. The 1.5mm thick veneer was used at face or back layer, and



A & B: log for veneer,
C: log for testing specimen.

Fig. 1. Log cutting diagram for the preparation of veneer.



A: venneer used for plywood,
B: venneer used for lathe check test.

Fig. 2. Cutting method of veneer for lathe check test and plywood.

2.5mm thick veneer was used in core layer. Specimens for shear bond test and bending test of plywoods were prepared from panels as shown in Fig. 3. Especially, shear specimens were prepared from fabricated panels in such a manner that another half could be pulled 'open' and half 'closed'. The accelerating-aging test conducted according to KS F 3101. Shear bond strength and wood failures were measured from each specimen.

3. RESULTS & DISCUSSION

3. 1 Lathe check

The results of lathe check test were shown in the Table 1. Lathe checks are fractures that develop in the veneer because created by the peeling action of the knife. Therefore, the depth and frequency of lathe checks can be controlled by heating the logs, varying the angle and sharpness of the knife and using a pressure nosebar (Terry sellers, 1985). The difference of veneer thickness between sapwood and heartwood were hardly shown in this study, but the density of lathe check of Siberian larch was less than these of Japanese larch and Radiata pine. It was thought that Japanese larch and Radiata pine were the planting trees which grow rapidly, but Siberian larch grows in natural forest, therefore the latter has narrow ring width.

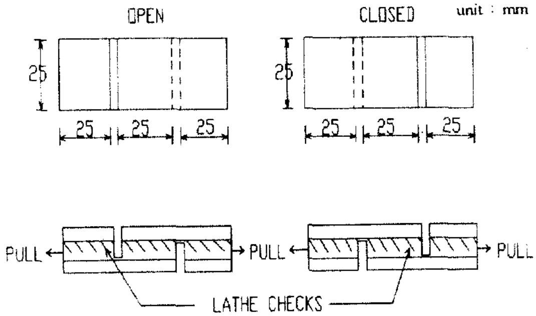


Fig. 3. Preparation method of standard shear bond strength specimens.

3. 2 Strength properties of plywood

3. 2. 1 Shear bond strength

The general influence of adhesives on shear bond strength within three accelerated-aging methods are shown in Table 2 to 5, and Fig. 4 and 5. Generally, higher shear bond strength were produced with phenolic resin adhesives than with urea-melamine resin adhesives. Reason why the differences in results are shown by two adhesives is that phenolic resin adhesives have more water resistance. In shear bond strength of single species plywood, there was little difference between the plywoods made of sapwood and heartwood veneer except Japanese larch. It was thought that roughness of veneer in Japanese larch were shown greater than that

Table 1. Results of lathe check measurement.

Species	Part of log	No. of Measuremnt	Veneer thickness (mm)	Lathe check angle (°)		Density of lathe check (numbers/cm)		Depth of lathe check (%)	
			Ave.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.
K	H	111	1.4	30.6	20.3	3.7	0.8	62.4	12.1
	M	139	1.4	21.5	10.2	3.5	0.6	56.5	17.3
S	H	50	1.3	12.9	7.7	1.7	1.6	43.8	22.9
	M	85	1.3	20.8	9.2	1.9	0.9	49.7	12.3
R	H	95	1.4	17.8	13.0	3.2	1.1	73.0	14.1
	M	195	1.3	13.3	17.8	4.3	2.0	70.2	32.0

Notes: K: Japanese larch, S: Siberian larch, R: Radiata pine, H: Heartwood, M: Sapwood.

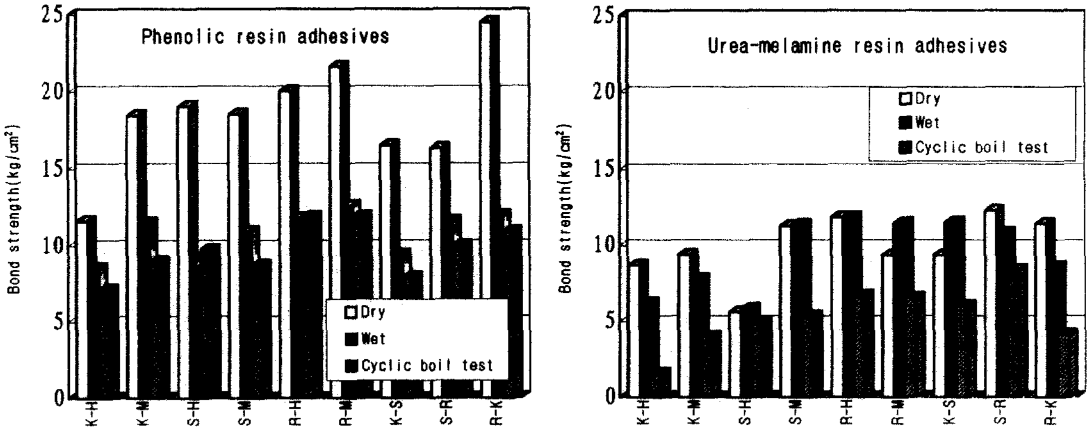


Fig. 4. Bond strength for various types of plywood using unheated veneer.

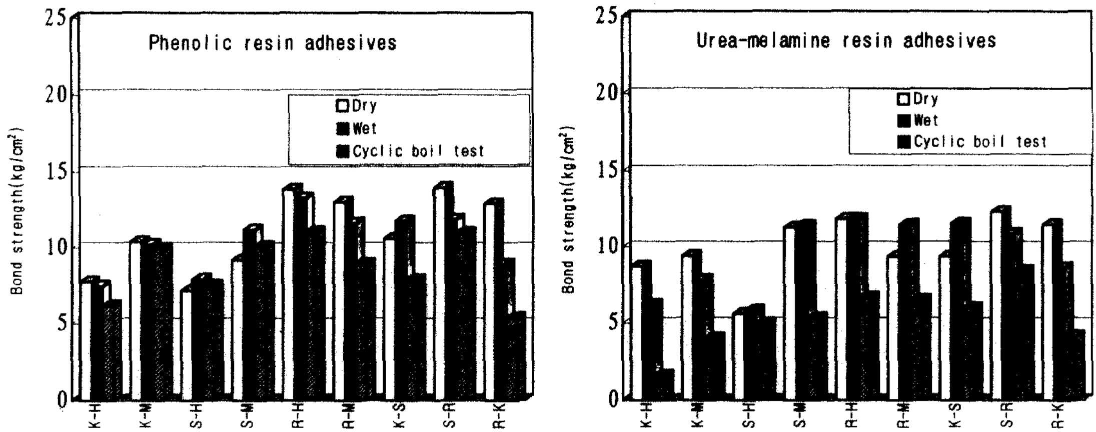


Fig. 5. Bond strength for various types of plywood using heated-pretreatment veneer.

of other species. Faust and Rice(1986) pointed out that shear bond strength were significantly reduced by rough veneer surfaces. There was little difference between plywood of single species and mixed species. The effect of shear bond strength on unheated processing conditions were shown greater values than heated one. Hart(1952) pointed out that a very considerable temperature effect on veneer quality existed. In shear bond strength test, the shear bond strength of plywood glued with phenolic resin adhesives were shown higher values than urea-melamine resin adhesives. The plywood glued with phenolic resin adhesives has exceeded the requirement, 7.5kg/cm^2. But the plywood glued with urea-melamine resin adhesives showed a very bad performance in cyclic boil test. Shear bond strength in various accelerated-aging tests of plywood was shown in earlier work(Koch, 1965; Krahmer, 1992; Terry sellers, 1986).

3.2.2 Bending strength

The bending strength or modulus of rupture(MOR) is the most important mechanical property of wood-based materials with respect to their practical application as structural elements. A statistical analysis of distribution(student's *t*-distribution) was performed to assess the effect of log pretreatment conditions (unheated and heated) on bending properties. There was not significant difference between log pretreatment conditions at the 5 percent level. It was meant that log pretreatment conditions in this study did not influence upon bending strength of softwood ply-woods. That is, the pretreatment by hot water softened the surfaces of logs for easier cutting into thin veneer only. The bending strength of plywood of single species showed the difference between sapwood and heartwood for three species(Fig 6 and 7). As expected, MOR of sapwood showed higher values than one of heartwood. MOR of plywood made of radiata pine was present greater than other panels. Also, the statistical analysis

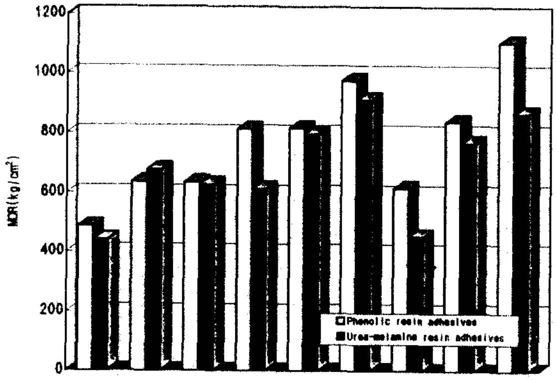


Fig. 6. Bending strength for each panel using unheated-treatment veneer.

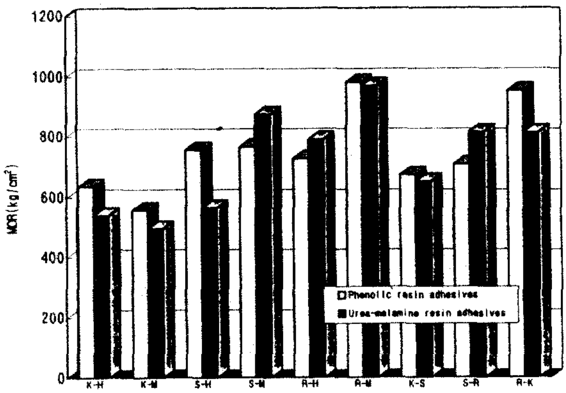


Fig. 7. Bending strength for each panel using heated-pretreatment veneer.

Table 2. Results of shear bonding- and bending test in panels of unheated veneers glued with phenolic resin adhesives.

Species	Thickness (mm)	Part of log	Shear bond strength(kg/cm²) Dry Ave.	S.D.	Wet Ave.	S.D.	Cyclic boil test Ave.	S.D.	Wood failure(%) Dry Ave.	S.D.	Wet Ave.	S.D.	Cyclic boil test Ave.	S.D.	MOR (kg/cm²)
K	5.1	H	11.6	3.3	8.5	3.8	7.1	2.0	85.3	15.1	43.3	26.9	43.8	18.7	442
		M	18.4	4.9	11.5	2.8	8.9	1.9	69.4	16.7	37.5	29.5	38.8	12.7	601
S	4.9	H	19.0	3.2	8.7	1.7	9.7	2.0	76.8	21.2	34.4	31.0	48.8	18.3	529
		M	18.5	3.3	10.9	1.6	8.7	1.5	89.0	13.5	48.8	34.1	36.3	11.1	736
R	5.3	H	20.0	2.7	11.8	1.9	11.9	2.4	80.9	10.4	58.8	25.2	66.3	13.2	818
		M	21.6	7.9	2.6	2.0	11.9	1.4	71.9	33.0	24.6	17.6	58.8	12.7	1023
K-S*1	4.7	M	16.5	3.3	9.4	2.2	7.9	1.8	71.9	17.3	43.8	37.4	35.0	18.0	482
S-R*2	4.9	M	16.3	3.2	11.6	2.4	10.0	2.0	83.8	20.1	35.0	28.7	51.3	17.6	687
R-K*3	5.2	M	24.5	2.9	12.0	1.9	10.9	3.0	60.0	37.1	70.0	31.2	26.3	11.1	1046

Notes : K : Japanese larch, S : Siberian larch, R : Radiata pine, H : Heartwood, M : Sapwood.

*1 Japanese larch(face and back veneer) and Siberian larch(core veneer).

*2 Siberian larch(face and back veneer) and Radiata pine(core veneer).

*3 Radiata pine(face and back veneer) and Japanese larch(core veneer).

Table 3. Results of shear bonding- and bending test in panels of unheated-pretreatment veneers glued with urea-melamine resin adhesives.

Species	Thickness (mm)	Part of log	Shear bond strength(kg/cm²) Dry Ave.	Dry S.D.	Wet Ave.	Wet S.D.	Cyclic boil test Ave.	Cyclic boil test S.D.	Wood failure(%) Dry Ave.	Dry S.D.	Wet Ave.	Wet S.D.	Cyclic boil test Ave.	Cyclic boil test S.D.	MOR (kg/cm²)
K	5.4	H	9.4	1.3	7.7	3.5	1.7	1.3	83.8	21.8	34.4	23.1	22.5	13.2	440
		M	13.0	2.7	6.2	0.8	6.2	0.8	77.5	27.3	44.4	33.5	63.1	30.7	676
S	5.2	H	13.3	1.0	12.2	2.6	7.3	1.4	82.5	13.0	65.0	21.2	30.3	24.4	627
		M	15.2	1.7	9.3	1.4	6.1	0.6	88.8	29.8	45.0	34.6	76.9	40.1	612
R	5.4	H	16.1	2.6	12.1	2.4	8.1	1.9	46.3	32.4	69.4	14.2	20.6	11.3	795
		M	18.3	3.1	10.0	5.5	9.1	1.7	67.5	17.1	53.1	26.3	43.8	37.6	912
K-S[a]	5.3	M	10.6	2.9	8.7	2.5	5.1	0.9	88.8	16.2	70.6	38.9	45.0	34.6	453
S-R[b]	4.8	M	13.5	2.9	10.1	3.0	6.9	1.0	60.6	40.0	48.1	42.5	32.5	30.6	776
R-K[c]	5.3	M	19.5	2.9	13.6	4.1	6.4	2.0	48.8	34.3	58.1	34.6	26.3	17.5	867

Notes : K: Japanese larch, S: Siberian larch, R: Radiata pine, H: Heartwood, M: Sapwood.
*1 Japanese larch(face and back veneer) and Siberian larch(core veneer).
*2 Siberian larch(face and back veneer) and Radiata pine(core veneer).
*3 Radiata pine(face and back veneer) and Japanese larch(core veneer).

Table 4. Results of shear bonding- and bending test in panels of unheated-pretreatment veneers glued with phenolic resin adhesives.

Species	Thickness (mm)	Part of log	Shear bond strength(kg/cm²) Dry Ave.	Dry S.D.	Wet Ave.	Wet S.D.	Cyclic boil test Ave.	Cyclic boil test S.D.	Wood failure(%) Dry Ave.	Dry S.D.	Wet Ave.	Wet S.D.	Cyclic boil test Ave.	Cyclic boil test S.D.	MOR (kg/cm²)
K	5.1	H	7.66	2.52	7.42	1.50	6.14	2.07	94	8.77	86	27.09	76	26.25	635
		M	10.36	1.71	10.17	3.58	9.88	1.11	85	18.89	65	31.05	73	30.59	557
S	5.3	H	7.13	2.62	7.86	2.69	7.44	2.15	89	10.11	78	22.04	89	14.08	755
		M	9.14	3.86	11.17	2.29	10.07	1.41	57	32.37	83	17.31	73	26.85	764
R	5.2	H	13.87	4.04	13.31	2.31	11.03	1.95	93	6.63	72	35.02	87	17.31	727
		M	13.03	3.03	11.65	1.25	8.91	1.74	92	8.84	71	35.20	81	33.96	981
K-S[a]	5.3	M	10.60	3.61	11.77	1.99	7.82	2.24	81	18.02	56	39.23	68	33.05	673
S-R[b]	5.2	M	13.97	3.14	11.88	2.82	10.99	2.14	61	42.63	87	15.34	79	28.34	708
R-K[c]	5.0	M	12.93	3.71	8.87	2.33	5.36	4.30	71	29.00	91	17.27	84	34.30	953

Notes : K: Japanese larch, S: Siberian larch, R: Radiata pine, H: Heartwood, M: Sapwood.
*1 Japanese larch(face and back veneer) and Siberian larch(core veneer).
*2 Siberian larch(face and back veneer) and Radiata pine(core veneer).
*3 Radiata pine(face and back veneer) and Japanese larch(core veneer).

was performed to assess the effect of adhesives. There was no difference between MOR values by adhesives. Higher bending strength appeared in radiata pine than other species.

3.2.3 Wood failure

In general, greater wood failure was found for shear specimens pulled 'closed' than those pulled 'open' (Perry, 1968). However, this is not in agreement with other results for Japanese

Table 5. Results of shear bonding and bending test in panels of heated-pretreatment veneers glued with urea-melamine resin adhesives.

Species	Thickness (mm)	Part of log	Shear bond strength(kg/cm^2) Dry		Wet		Cyclic boil test		Wood failure(%) Dry		Wet		Cyclic boil test		MOR (kg/cm^2)
			Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	Ave.	S.D.	
K	5.3	H	8.69	1.12	6.19	0.70	1.57	1.12	77	20.51	26	39.89	5	14.14	538
		M	9.37	2.69	7.78	2.14	4.00	1.40	61	28.11	33	31.16	31	39.80	494
S	5.3	H	5.62	2.27	5.80	3.07	4.95	1.11	94	8.63	73	33.91	36	15.22	565
		M	11.28	3.18	11.39	2.98	5.34	1.67	80	16.90	68	40.00	16	32.92	874
R	5.4	H	11.85	1.12	11.85	2.02	6.65	0.64	66	32.04	39	38.80	13	25.63	790
		M	9.33	3.93	11.47	1.74	6.50	1.14	71	28.13	26	19.35	0	0.00	969
K-S[a]	5.4	M	9.33	2.91	11.54	1.76	5.98	0.77	73	15.67	45	20.87	16	32.27	653
S-R[b]	5.3	M	12.32	1.67	10.85	2.21	8.40	1.94	57	41.18	64	35.55	11	17.06	814
R-K[c]	5.4	M	11.45	2.13	8.59	2.45	4.15	0.98	65	22.24	76	34.27	1	3.54	812

Notes : K : Japanese larch, S : Siberian larch, R : Radiata pine, H : Heartwood, M : Sapwood.
*1 Japanese larch(face and back veneer) and Siberian larch(core veneer),
*2 Siberian larch(face and back veneer) and Radiata pine(core veneer),
*3 Radiata pine(face and back veneer) and Japanese larch(core veneer).

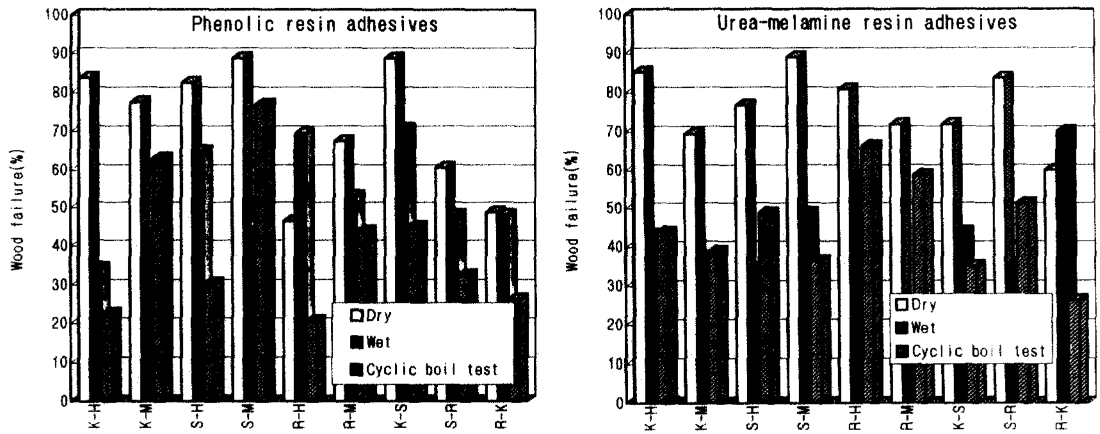


Fig. 8. Percentage of wood failure after shear bond test in plywood fabricated with unheated veneer.

larch, Siberian larch and radiata pine which show that specimens pulled 'open' yielded not greater wood failure than those pulled 'closed'. The effect of adhesives on wood failure at the three types of bond strength test is shown in Table 2 to 5, and Fig. 8 and 9. The woodfailure in this study were averaged with values pulled 'closed' and those pulled 'open'. Higher percent wood failure were exerted with phenolic resin adhesives than with urea-melamine resin adhesives. The effect of species on wood failure in plywood was also observed. In the plywood of single species, Radiata pine showed higher wood failure than any other species. There was the higher wood failure using Japanese larch as face and back veneers and Radiata pine as core veneers than other plywoods in the plywood of mixed species. The effect of log pre-

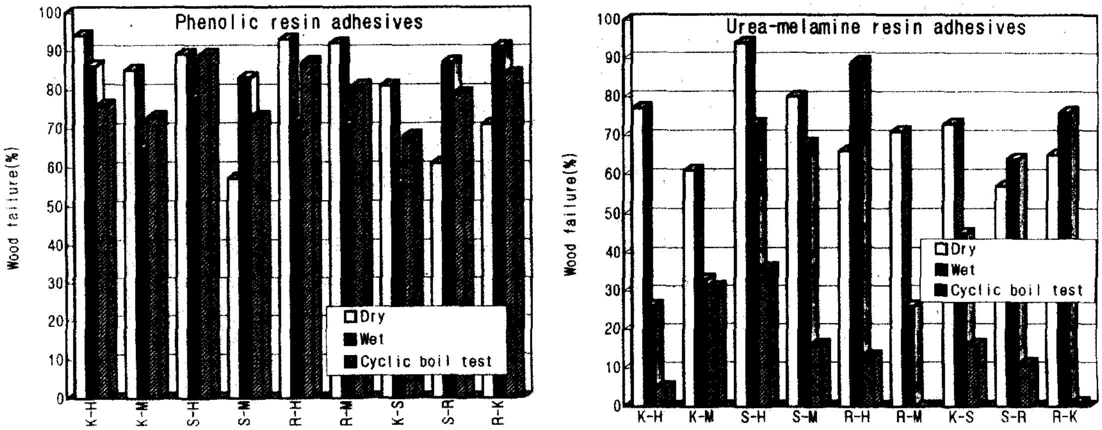


Fig. 9. Percentage of wood failure after shear bond test in plywood fabricated with heated-pretreatment veneer.

treatment conditions on wood failure showed higher percentage in plywood using heated-pretreatment veneers than unheated veneers except for cyclic boil test.

4. CONCLUSION

The possibility to use Japanese larch, Siberian larch and Radiata pine as raw materials of softwood plywood was investigated in this study.

The results of the study were summarized as follows :

1. The lathe check of veneers rarely influenced on the shear bond strength and bending strength of plywood.
2. There was a difference in bending strength between sapwood and heartwood but wasn' ta difference between log heated- and unheated pretreatment. MOR of plywood made of Radiata pine was present greater than other panels.
3. The plywood used with phenolic resin adhesives satisfied the bond strength of structuralplywood requirement(7.5kg/cm^2).
4. In the plywood of single species, Radiata pine showed higher wood failure than anyother species. There was the higher wood failure using Japanese larch as face and back veneers and Radiata pine as core veneers than other plywoods in the plywood of mixed species.

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