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PRELAID PARTICLEBOARD FLOORING IN NEW ZEALAND

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ABSTRACT: The prelaying of urea formaldehyde particleboard floors, as a working platform before the erection of the walls, has been practiced in New Zealand for the past 12 years. Approximately 80 percent of all new houses are constructed in this manner. Little is published about the extent of deterioration of particleboard that occurs during the exposure to the weather before houses are closed in. This paper reports the results of changes in physical and mechanical properties of particleboard exposed to the weather for periods of up to 6 months. The changes were measured both before and after the particleboard had been sanded back to a clean surface. After 3 months weathering and subsequent sanding, the particleboard tested met standard criteria for bending strength. Lack of a suitable surface for clear finishing may determine the amount of weathering the flooring can be subjected to before the houses are closed in.

KEY WORDS: wood particleboards, urea formaldehyde resins, floors, prefabrication, weathering, sanding, stiffness, modulus of elasticity, modulus of rupture in bending, surface roughness, durability, building materials

Urea formaldehyde (UF) resins, and particleboards manufactured using these resins are not normally considered moisture resistant and are known to break down when used in moist conditions [*1,2*][2] Particleboard floors in houses can be subjected to high humidities and condensation when there is inadequate sub-floor ventilation or wet ground conditions, and to spillages that occur in the wet areas of houses such as laundries and bathrooms. Despite this, UF particleboard flooring has gained wide acceptance in several countries [*3-6*] presumably through satisfactory performance in practice.

The unusual aspect of the use of UF particleboard flooring in New Zealand is that it is prelaid [*7*]. This paper examines the changes in properties of UF particleboards caused by the weathering and subsequent sanding that occurs

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[2] The italic numbers in brackets refer to the list of references appended to this paper.

when these boards are prelaid. Prelaying involves laying the particleboard onto the floor framing to provide a working platform on which the rest of the house is constructed. The particleboard can be exposed to the weather for several weeks, and in some cases months, before the house is closed in. After the house has been completed the floor is sanded to produce a finish which is acceptable for carpet and other floor coverings, or for clear finishing with a polyurethane varnish. Prelaying has several important benefits. These include: (*a*) a major saving in the time required for floor laying, (*b*) a further saving in the time for the later stages of construction of the house (particularly the timber framing) by the provision of a solid working platform, (*c*) greater safety since it is not necessary to work on open joists, and (*d*) there is reduced waste of materials as offcuts.

Particleboard flooring has been used in New Zealand houses since the early 1960's. In the mid sixties prelaid particleboard flooring was accepted for houses built for or financed by the government. Since then the use of particleboard flooring in new houses has risen to 80 percent [*3,4*].

The suitability of particleboards as flooring materials from a structural viewpoint, has been considered elsewhere [for example, *8* and *9*]. Collins [*9*] has looked at New Zealand-produced particleboards. He mainly considered the boards in their ex-factory state, and mentioned the need for research into the effects of prelaying on the properties of the boards.

Particleboards Examined

The high density flooring grade UF particleboards examined were manufactured by the two particleboard manufacturers in New Zealand. Both companies use mainly Pinus radiata (D.Don) in roundwood or slab form for producing wood flakes. The boards are three-layer boards with small particles in both surface layers and coarse particles in the core. Both brands of particleboard contain a wax additive which is designed to permit the board to be exposed to the weather for a brief period during construction. Although the thickness of the boards from both manufacturers is different, 19 and 20 mm, both brands are manufactured within a density range of 650 to 730 kg/m^3. Pollard [*3*] has discussed the manufacturing process, specification, and formulation of these particleboards in further detail.

Experimental Design and Procedure

Six boards from each manufacturer were used. The boards were selected from different production shifts. Five specimens were cut from each board. One specimen (450 by 75 mm) was retained as a control and the other four (500 by 125 mm) were subjected to various periods of weathering. The specimens were cut so that the long side was perpendicular to the direction of manufacture.

The specimens were selected in random order for weathering. Four specimens were missing from the 60 in the balanced experimental design.

After weathering the specimens were conditioned to constant weight (± 1 g) at 20 ± 1°C and 65 ± 5 percent relative humidity and trimmed to 450 by 75 mm. The surface roughness and apparent modulus of elasticity in bending (MOE) of the weathered and control specimens then were measured. The specimens then were given two sandings with MOE measurements being repeated after each sanding. Finally the modulus of rupture (MOR) and internal bond (IB) of the sanded specimens were determined.

Weathering

It was considered that one of the worst conditions experienced by prelaid floors is ponding, where rainwater is retained on the particleboard floor by the continuous bottom plates of the wall. To simulate this condition a timber batten was fixed around the specimens to produce a tray with a 25-mm high curb. To prevent leaks from this tray the joints in the curb were sealed with an oil-based mastic. The tray was filled with water at the commencement of the exposure, any losses by evaporation during the period of exposure being replaced by natural rainfall. Because of the relatively small size of the specimen and its large edge to surface area ratio, not found on full size panels in actual buildings, the edges of the specimen were sealed with an epoxy-coal tar composition. This was done to minimize moisture uptake through the edges and reduce its effect on the section subsequently cut from the specimen.

Specimens from each board then were weathered for periods of 1, 3, and 6 months at the Building Research Association of New Zealand (BRANZ) exposure site approximately 25 km northeast of Wellington, and 6 months at Whangarei, 150 km north of Auckland. Weathering commenced on 20 August 1976 at the Wellington site, and 14 September 1976 at the Whangarei site. Weather conditions are summarized in Table 3.

Sanding

The weathered surfaces of the specimens were sanded on a spindle molder which had been converted to a drum sander; 60 grit carborundum paper was used. The molder bench was set up so that the center of the board was just in contact with the sanding drum. The direction of sanding was parallel to the direction of manufacture of the particleboard. The bench was then raised by 0.5 mm, and the board sanded by several passes under the sanding drum. The removal of 0.5 mm during the first sanding was not sufficient to produce a clean surface on some of the specimens, particularly those which had been weathered for 6 months. In these cases the first sanding was continued until the specimen had a clean surface. During the weathering process some

TABLE 1—*Effect of weathering on thickness and surface roughness of UF flooring grade particleboard.*[a]

Weathering, months		0	1	3	6	6[b]
		BRAND A				
Change of Thickness, mm	unsanded	0.00	0.36	0.84	1.89	2.68
	1 sanding	−0.53	−0.39	0.18	0.67	1.21
	2 sandings	−0.91	−0.88	−0.34	0.16	0.54
Surface Roughness[c]	mm	0.09	0.32	0.43	0.72	. . .
		BRAND B				
Change of Thickness, mm	unsanded	0.00	0.70	1.29	2.43	3.02
	1 sanding	−0.57	−0.08	0.40	1.25	1.89
	2 sandings	−1.15	−0.68	−0.25	0.64	1.16
Surface Roughness[c]	mm	0.07	0.34	0.72	0.82	. . .

[a] All values are means of six results.
[b] Refers to Whangarei; all other weathering at Wellington.
[c] Surface roughness (Fig. 3) is measured before sanding and is assessed according to BS 1143: Part 1: 1972, by averaging differences between the five highest peaks and the five deepest valleys.

boards had distorted. To produce a clean surface over the entire board would have reduced thickness considerably. Therefore only the surface of the central one third of the board was considered although the whole surface was sanded. This central section is most important in bending. The surface of a representative selection of the specimens was assessed by a commercial floor sanding contractor as to its suitability for clear finishing or for covering with a floor covering.

In the second sanding a further estimated 0.5 mm was removed and the appearance reassessed.

Surface Roughness

A surface roughness profile, was traced along a 200-mm line, roughly in the center of each specimen. Tracings were made using a profilemeter. The specimens were clamped to a base plate to eliminate any bowing of the board before surface roughness was measured. The profilemeter was such that the stylus moved in a straight line and did not track around surface irregularities.

Surface roughness was assessed according to the procedure set out in the British Standard Assessment of Surface Texture (BS 1134: Part 1: 1972) in which the differences between the five highest peaks and the five deepest valleys on the trace were averaged.

Mechanical Properties

The MOE, MOR, and IB were measured according to the procedures set out in the British Standard Tests for Wood Chipboards and other Particleboards (BS 1181: Part 2: 1969) with the following exceptions. The length of the 19 mm thick specimen was 450 mm instead of 425 mm, but the slight increase in overhang over the supports was not considered critical. The MOR was determined on the 75-mm wide MOE specimens at a span of 300 mm, this span being the maximum that the testing machine would accept. The specimens were conditioned at 65 ± 5 percent relative humidity and 20 ± 1°C. The MOR, and IB were measured on a tensometer with an accuracy of ±2 percent over the range in which the readings were made.

$$\text{MOE} = \frac{9.81ML^3}{4bd^3\Delta}\ \text{MPa}$$

where

L = span,
b = width,
d = mean thickness of the specimen measured at mid span,

Δ = deflection of the board (all measured in mm), and
M = mass used, kg.

$$\text{MOR} = \frac{3WL}{2bd^2}\,\text{MPa}$$

where W is the ultimate failing load, N.

Results and Discussion

The results are summarized in Tables 1 and 2 and Figs. 1 to 4. In Table 2 MOE and MOR are expressed as *relative* values calculated using d measured before weathering and sanding, and *actual* values calculated using d measured at the time of testing. The actual values represent the change in the moduli of the material. These changes result from a combination of changes in stiffness or strength, and changes in the thickness of the material caused by swelling or sanding, or both. The relative values of MOE and MOR while they do not represent intrinsic properties, are directly proportional to the stiffnesses and bending strengths respectively of the boards as changes in thickness are not included in their calculation. Thus using the relative values, it is possible to assess the effects of weathering and sanding on the mechanical performance of the boards in service as flooring.

Using a missing data approach, to allow for the four missing samples, the analysis of variance on the results showed that the change in properties with weathering illustrated in Figs. 1 to 4 are real effects ($P < 0.01$).

Effects of Weathering

The ponding conditions used in this project were expected to represent the worst conditions experienced by prelaid floors. The design of the trays was such that ponding over all the specimen was encouraged. In practice ponding should be avoided by good building practices [7]. Ponding will only occur where water is trapped on the floor by continuous bottom plates, or where the floor is not completely level. In addition any ponded water should be swept off daily before construction restarts. Actual MOE, MOR and IB all decrease with weathering (Fig. 1) indicating as expected that the particleboard does deteriorate during the prelaying period. After one month of weathering IB had not decreased by any significant amount, indicating that at this stage the core of the boards had not deteriorated. However after further weathering IB dropped by a larger amount than actual MOE and MOR indicating that the core layer of the board was degrading to a greater extent than surface layers. It can be seen that exposure at the Whangarei site with its hotter conditions produces greater deterioration than exposure at Wellington. Increasing deterioration of UF particleboard is known to occur with

TABLE 2—*Summary of results of the effect of weathering on the mechanical properties of UF flooring grade particleboard.*[a]

Weathering, months		Brand A 0	Brand A 1	Brand A 3	Brand A 6	Brand A 6[b]	Brand B 0	Brand B 1	Brand B 3	Brand B 6	Brand B 6[b]	Standard Deviation[c]
MOE[d] (relative)	unsanded	3650	3360	2960	2620	2230	4720	4430	4080	3830	3450	
	1 sanding	3380	3150	2930	2470	2110	4410	4040	3870	3620	3240	128
	2 sandings	3020	2790	2640	2310	1920	3790	3550	3490	3320	3040	
MOE[e] (actual)	unsanded	3650	3150	2590	2000	1510	4720	4040	3450	2790	2360	
	1 sanding	3700	3320	2830	2240	1750	4800	4120	3700	3100	2580	194
	2 sandings	3550	3180	2770	2260	1760	4500	3970	3680	3100	2690	
MOR[d] (relative)		22.0	21.1	19.3	17.1	13.6	28.7	27.5	26.1	24.6	21.3	1.63
MOR[e] (actual)		24.6	23.0	19.9	17.0	12.9	32.3	29.6	27.0	23.5	19.7	2.28
Internal bond		0.647	0.622	0.442	0.232	0.122	0.673	0.665	0.494	0.397	0.353	0.093

[a] All values are in MPa, (1 MPa = 145 psi) and are means of six results.
[b] Refers to Whangarei; all other weathering was at Wellington.
[c] Standard deviations are calculated from the error mean square of analyses of variance on the results. These values can be used for determining confidence limits for comparing differences between factors except for differences between brands. Degrees of freedom are 136 (MOE) and 36 (IB and MOR).
[d] These values are calculated using the thicknesses of the specimens before weathering and sanding.
[e] These values are calculated from the thicknesses of the specimens at testing.

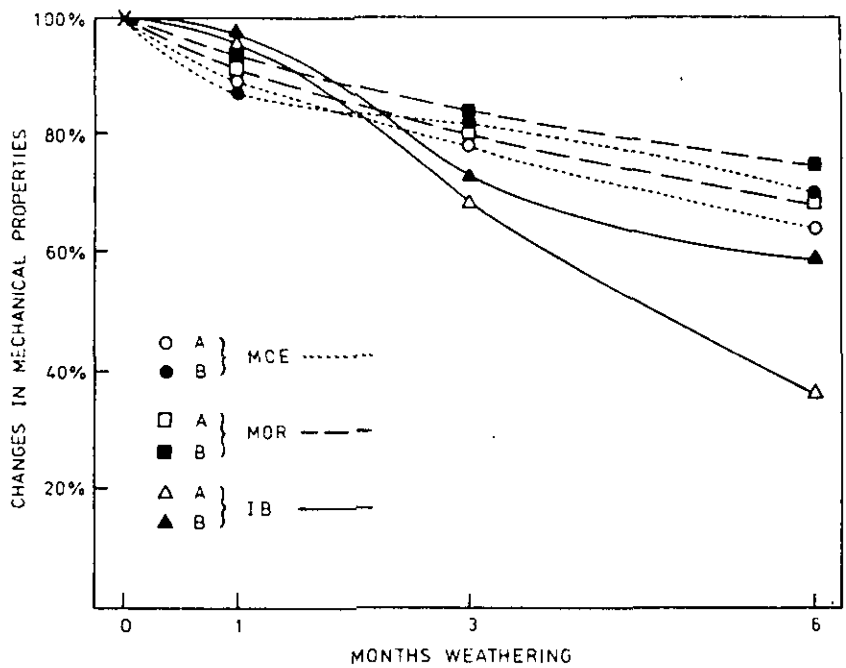

FIG. 1—*Changes in properties with weathering (MOE and MOR are actual values measured after two sandings).*

increasing temperature [*2*]. This result indicated that with the relatively high rainfalls and humidities that occurred in this project (Table 3) temperature is likely to be the factor that controls the rate of deterioration.

Effects of Sanding

The first sanding of the weathered boards led to an increase in the actual MOE. This indicated that relatively loose material was being removed from the surface of the board. The decrease in actual MOE which accompanied the second sanding indicated this sanding was removing from the surface sound material of greater strength than the core of the board. The trends with relative MOE (Fig. 2) confirmed this effect. The expected decrease which occurred because material was being removed from the board, was less pronounced with the first sanding of the weathered boards than with the second sanding, as mainly unsound material was removed by this first sanding.

Surface Conditions

Surface roughness of the specimens increased from less than 0.1 mm before weathering to just under 1 mm after 6 months weathering (Table 1 and Fig. 3). After the first sanding all the specimens were considered by the floor sanding contractor to have a suitable surface for overlaying with a floor covering, but only the unweathered and 1-month specimens were suitable for clear finishing. After the second sanding the surfaces of most of the 6-month specimens were still not good enough for clear finishing, even although more than the measured surface roughness (see Table 1) had been removed from the surface by the two sandings. During the sanding process wood particles were being plucked from the surface, presumably due to a deterioration of the bonding between surface particles caused by weathering. The same effect was also noticeable, although to a lesser extent, on some of the 3-month specimens.

This effect may have been partly attributable to the nature of the sanding process, and might not be so pronounced in practice. Even so its occurrence does indicate that the surface condition of the board, if it is to be clear finished, may be a limiting factor to the length or severity of weathering that the boards can be exposed to satisfactorily.

Compliance with Particleboard Standards

In the absence of any rigorous analysis which enables prediction of requirements for MOE, MOR, and IB for flooring, it was considered appropriate to compare the properties of the specimens of particleboard, before and after weathering and sanding, with the criteria for flooring grade particleboards in various standard specifications.

The standard specifications chosen were as follows:

1. The present New Zealand Standard for Resin Bonded Wood Particle

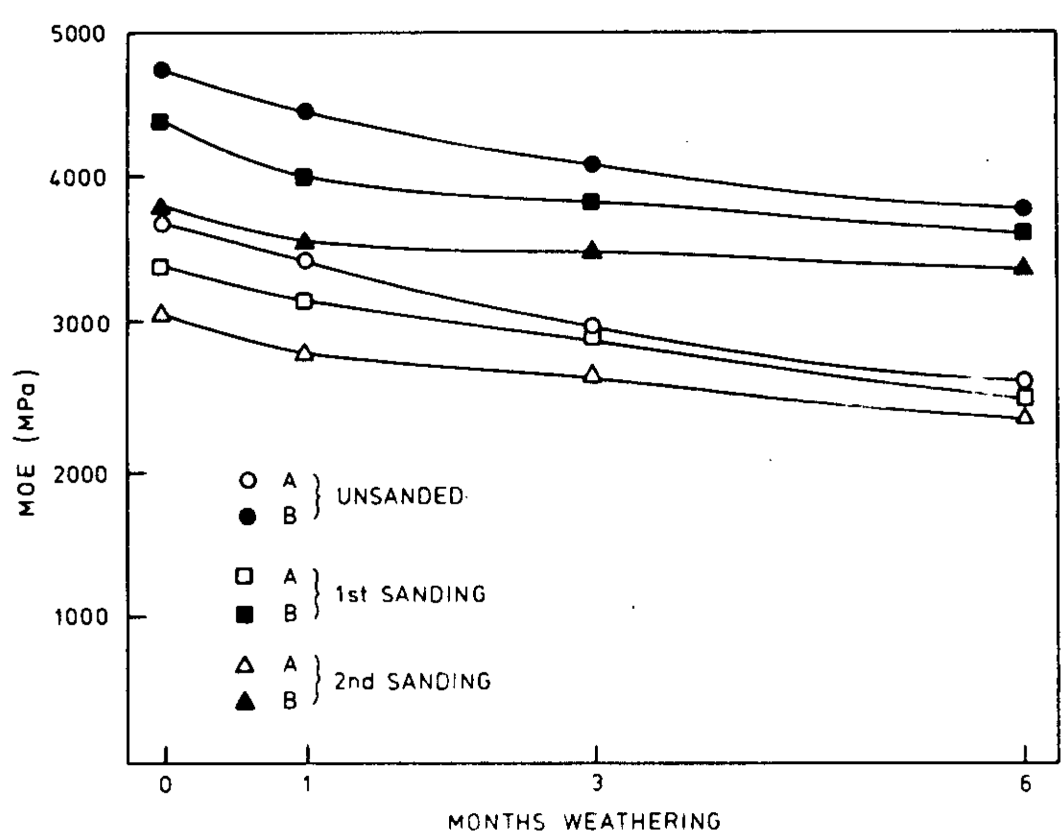

FIG. 2—*The effect of sanding and weathering on relative MOE.*

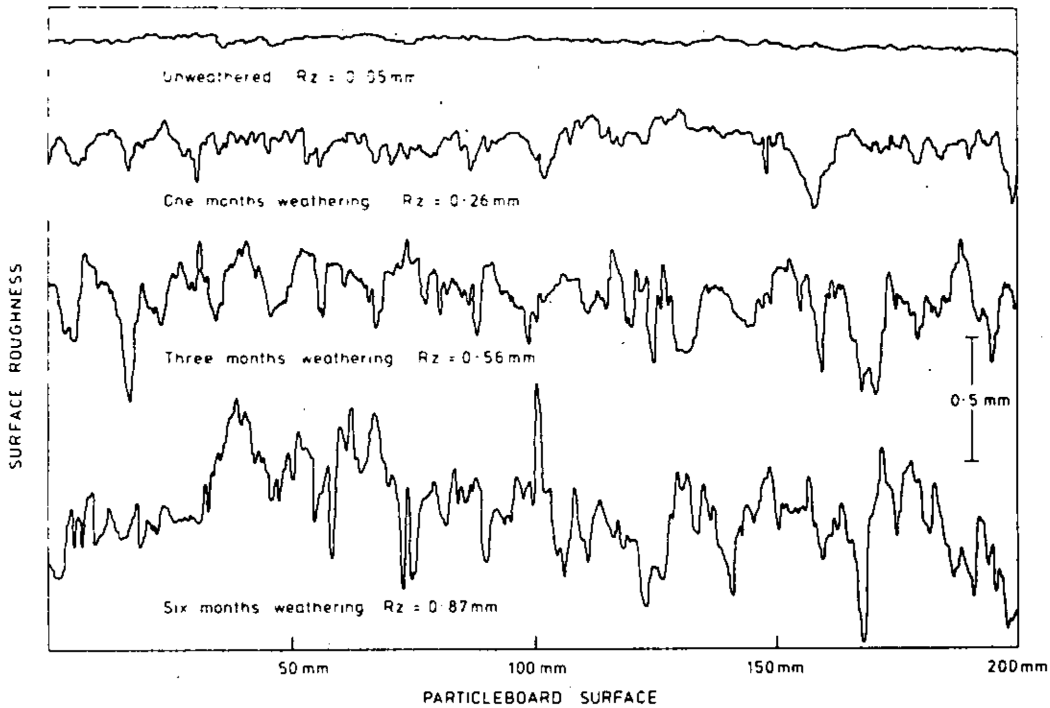

FIG. 3—*Changes in surface roughness with weathering.*

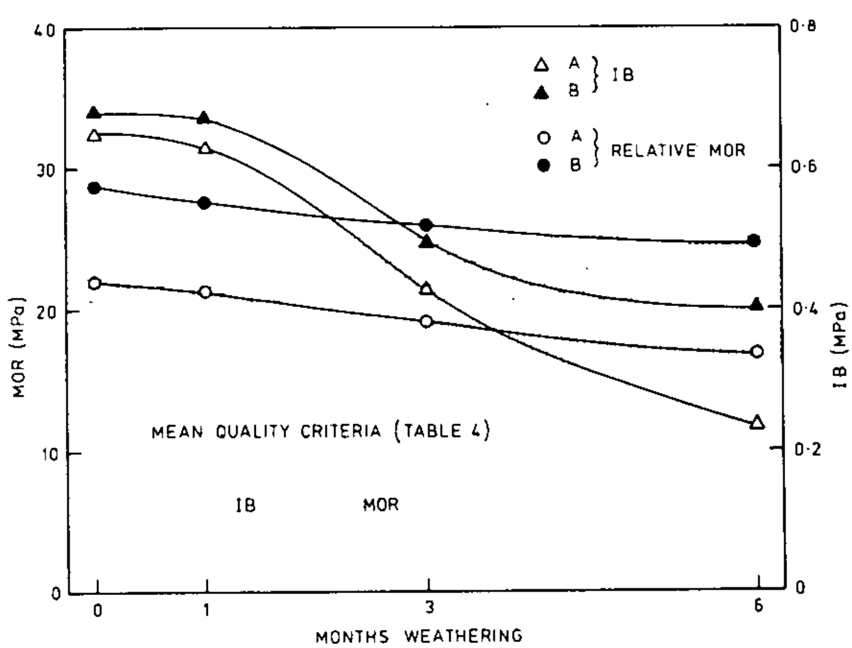

FIG. 4—*The effect of weathering on relative MOR and IB.*

Board (NZS 3608: 1975) which is based on the British Standard for Resin Bonded Wood Chipboard (BS 2694: Part 2: 1970).

2. A new British Standard for Wood Chipboard Including Methods of Test (BS 76/12154DC) which was at the public draft for comment stage when the tests were conducted.

3. The criteria laid down for moisture resistant Flooring Grade Particleboard Class 1 in the Australian Standard for Flat Pressed Particle Board (AS 1859-1976).

4. The U.S. Commercial Standard for Mat-Formed Wood Particleboard (CS 236-66) for Nonmoisture Resistant Boards (Class IB2).

The methods of testing particleboards varies in the standards and consequently the results will vary from our test method. Where the variations due to these test methods are considered to be small, the strength criteria of the standards are quoted in Table 4, and compared with the strength properties of the particleboards after weathering in Fig. 4. It can be seen that the particleboards from both manufacturers tested after 3 months weathering still meet all the standard requirements for bending strength (Fig. 4). The boards from Manufacturer B are considerably above these standard levels, even after 6 months weathering.

After 3 months the values for IB lie between the requirements of AS 1859-1976, BS 76/121554DC, and of CS 236-66 (Fig. 4). McNatt [*10*] has shown

TABLE 3—*Weather parameters during particleboard flooring exposure trials.*[a]

	Temperature, °C			Rainfall				
Month	Average	Highest, max	Lowest, min	Total, mm	Days ≥0.1 mm	Days ≤1.0 mm	Average RH%	Ground Frosts, days
			WELLINGTON—FROM 20 AUGUST 1976					
1	9.9	17.9	2.8	154.9	20	16	79	6
2	11.7	18.6	3.2	93.3	19	14	78	1
3	12.9	20.5	2.6	64.0	15	7	70	0
4	15.6	23.0	5.4	119.0	18	12	81	0
5	15.2	23.6	5.6	170.9	19	11	79	0
6	16.5	24.2	7.9	87.4	10	6	80	0
			WHANGAREI—FROM 13 SEPTEMBER 1976					
1	14.1	22.5	2.5	95.4	16	12	76	1
2	14.7	23.8	3.8	265.5	20	18	79	0
3	17.1	26.3	5.4	96.9	13	13	82	0
4	17.5	25.2	8.8	106.4	13	11	86	0
5	18.4	28.0	9.0	22.8	6	5	81	0
6	19.7	28.5	12.1	14.4	5	2	83	0

[a] Weather parameters are summarized from the daily climatological records of the New Zealand Meteorological Service for the weather recording stations nearest each exposure site. Readings were taken at 0900 h NZST.

TABLE 4—*Summary of mean quality criteria given in standards.*[a]

Standard		Use	MOR	IB
AS1859-1976	I	prelaid moisture resistant flooring	16	0.50
BS 76/12154DC	II	internal flooring	17	0.50
BS 76/12154DC	III	prelaid moisture resistant flooring	19	0.50
CS 236-66	1B2	internal	16.6	0.41

[a] All values in megapascals (1 MPa = 145 psi).

that IB correlates with interlaminar shear strength. A lack of interlaminar shear strength would be significant if the material was to be used in a highly stressed diaphragm; this does not apply in normal domestic housing. Lack of interlaminar shear may also affect the bending strength, but the high MOE values indicate that at least up to 3 months, internal bonds are still high enough to avoid interlaminar shear affecting the bending strength. This indication is reinforced by the experimental observation that only one specimen failed by interlaminar shear in the modulus of rupture test. This specimen had been weathered for 6 months.

Present New Zealand recommendations [7] limit the weathering period for UF particleboard flooring to 2 months. The above results indicate that the UF particleboards tested had satisfactory stiffness and bending strength for use as flooring, after exposure to weather for 3 months. Particleboard flooring may be subjected to more severe (particularly hotter) periods of weathering, which would lead to a greater rate of deterioration. The present 2 month maximum is therfore reasonable and should be maintained.

Conclusions

After 3 months' weathering at Wellington and subsequent sanding, both brands of UF flooring grade particleboard tested met standard criteria for MOR. The properties of one brand were considerably above these criteria.

After weathering for periods of 6 months, the MOR of one brand fell below standard criteria.

Internal bonds deteriorated to a greater extent with weathering than did MOE and MOR.

If the boards are to have a clear finish, surface deterioration may determine the maximum acceptable weathering period.

Weathering at Whangarei, which has a warmer climate than Wellington, produced a greater deterioration in properties than weathering at Wellington.

Acknowledgments

This project is part of a joint study being carried out by BRANZ and the Forest Research Institute (FRI), into the performance of flooring grade particleboard. BRANZ acknowledges the cooperation of Fletcher Wood Panels, New Zealand Particle Board Ltd; Keith Hay Homes Whangarei and All Floor Services. The authors wish to thank M. J. Collins of FRI and the BRANZ staff who have participated in the project, in particular I. C. Hope, D. J. Glover, B. M. Shaw, and E. R. Wilson.

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