LAMINATED OR SOLID NEW ZEALAND DOUGLAS FIR SCAFFOLD PLANKS AND THE STANDARD SPECIFICATION FOR THEM

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ABSTRACT

From the results of bending tests of glued laminated planks of New Zealand Douglas fir (**Pseudotsuga menziesii** (Mirb.) Franco) and solid planks of both New Zealand and imported Douglas fir, a breaking load criterion of 1050 lbf (4.67 kN) under a standardised laboratory test procedure is proposed for scaffold planks of Special Class (NZSS 1426: NZSI 1965). A single cross-section size of 10 x 2 in. (254 × 51 mm) nominal is considered rational for all scaffold planks. Other suggestions for improving the current Standard relate to the allowable defect and wood quality requirements for solid planks of Douglas fir.

A manufacturing specification for laminated planks which passed the criterion in "acceptance tests" is appended for the guidance of those considering alternatives to kahikatea (**Podocarpus dacrydioides** A. Rich.) and imported Douglas fir for Special Class planks, in terms of the Standard. Binding the ends of this class of plank is mandatory.

Information basic to mechanical stress grading of planks, an attractive alternative to visual grading, is also given.

INTRODUCTION

The current New Zealand standard specification (NZSI, 1965) for scaffold planks (NZSS 1426) defines two classes of plank of one-piece solid timber. They are *Special Class,* suitable for use on long single spans under "light duty" loading, and *Standard Class,* suitable for use on short span fully decked platforms under "heavy duty" loading. New Zealand-grown Oregon, i.e., Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco), is among the timbers specified for planks of Standard Class. The only two timbers specified for planks of Special Class are kahikatea and North American-grown Douglas fir, but New Zealand-grown Douglas fir can be considered for this class in terms of Clause 4.2, which requires planks of alternative timbers to be not inferior in strength and suitability to selected planks of North American material.

Glued laminated planks are provided for in Part 3, "Alternative Scaffold Planks" as follows:

Glued laminated planks built up from suitable timbers may be accepted if:

(a) Quality control at place of manufacture is known to be at least equal to a recognised standard and is confirmed by tests.

(b) The glue used is in accordance with the requirements of BS 1204 (NZSS 1155) relating to exterior service (NZSI, 1960).

(c) The actual dimensions are such as to ensure an adequate over-all factor of safety comparable with that of an equivalent solid timber plank.

Thus, lamination in accordance with the New Zealand standard recommendation for glued laminated timber construction (NZSR 34: *see* SANZ, 1968), under the certification scheme of the New Zealand Timber Research and Development Association (Johnston, 1970), will produce planks which meet requirements (a) and (b), but for (c) answers will be needed to the questions: What is an "equivalent solid plank"? and what is an "adequate over-all factor of safety"? and, perhaps even, what are "suitable timbers"?

This was the situation which faced the Forest Research Institute and the Commercial Division of the New Zealand Forest Service when the Labour Department asked them to investigate laminated scaffolding planks which would augment solid planks made from imported timber, and make greater use of New Zealand resources. This paper reports what has been achieved by laminating New Zealand-grown Douglas fir; it indicates possible answers to the questions posed above, and draws attention to some matters, relating to the specification and use of solid planks, that have arisen in the course of this work. Appendix 1 presents a specification for laminated planks and Appendix 2 some information on a mechanical means of sorting planks for scaffolding use.

INVESTIGATIONS

Manufacturing trials and strength tests have been made with three species of New Zealand-grown timbers, viz, Douglas fir for its reputation as a suitable species and its current (though limited) acceptability for solid planks; European larch (*Larix decidua* Mill.) for its similarities to Douglas fir, and radiata pine (*Pinus radiata* D. Don) for its widespread abundance and ease of processing. A total of 120 solid and laminated planks of several types have been tested to destruction in bending, most being of Douglas fir; timber from North America was used in 14 tests, and from Kaingaroa Forest in 54 tests.

The standard of plank sought in laminating has been Special Class throughout these tests to meet the greater need of this class, and perhaps, to justify the expense of remanufacturing. Douglas fir, although not readily available everywhere in New Zealand is, on most other counts, considered to be the best species for the purpose.

Within the limits of what is acceptable in use, the width and thickness of laminated planks are defined by the most convenient and economical method of manufacture. Thickness is thus a minimum of $1\frac{3}{4}$ in. (44.4 mm), and width a multiple of $\frac{3}{4}$ or $1\frac{5}{8}$ in. (19.0 or 41.3 mm), or of 13/16 or $1\frac{3}{4}$ in. (20.6 or 44.4 mm), depending on the nominal thickness of the stock and the dressing required. (Rather than fabricate plank by plank it is preferable to laminate a balk and convert it to vertically laminated planks by deep cutting with a thin bandsaw. The rough-sawn surface required on both wide faces may be obtained by sawing between the planks set back to back.)

Initially it was deduced from the grade requirements for solid planks of imported Douglas fir, and basic strength properties, that the minimum breaking *load* of an acceptable plank would, in laboratory tests, be some three to four times the maximum work load of 350 lbf (1.56kN) described in NZSS 1426 (NZSI, 1965). With the cross-section known, the acceptable minimum breaking *stress* depends on how the work load would be applied in practice, and this in turn influences the expression of the "factor of safety".

For testing, the planks were freely supported on the customary spans for "light duty" loading given by the scaffolder's rule of "one foot per inch of width". In early tests a single concentrated load was applied at mid-span, but in the standardised procedure adopted later equal concentrated loads were applied 1 ft (305 mm) to each side of the mid-span line (Fig. 1). This arrangement is considered to be a realistic but nevertheless conservative simulation of the most severe disposal of the Regulation workload in normal use, described in Appendix A of the Standard as "two men with light tools". It also assists study of the effect of defects in planks. The different methods of loading were not expected to appreciably influence the breaking stresses obtained, and no distinction is made between them in the tabulated results.

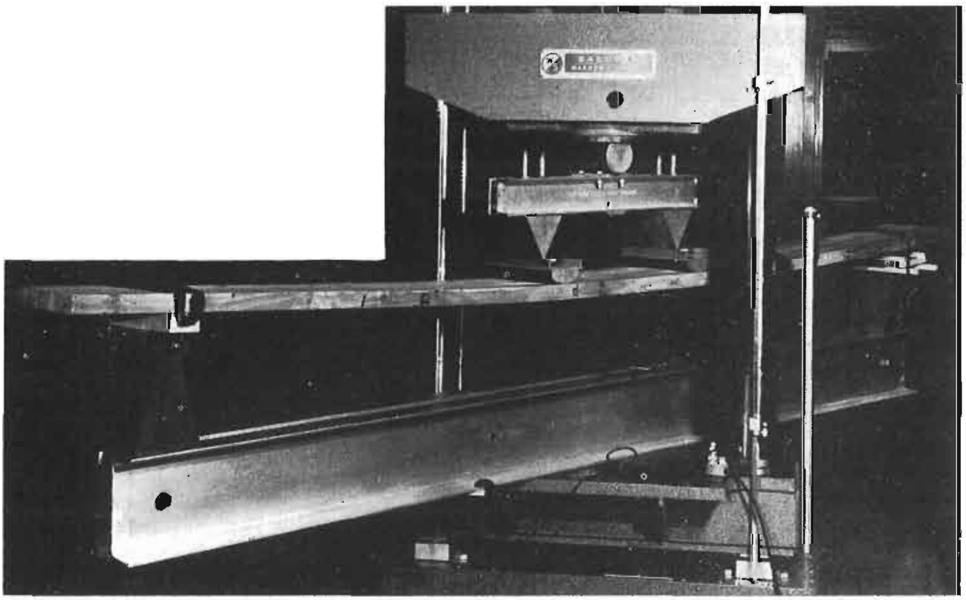

FIG. 1—Standardised bending test for planks. Two equal concentrated loads are applied, 305 mm each side of the mid-span line.

The modulus of elasticity of all specimens was determined on the in-use span, either under the one- or the two-point concentrated loading. In addition, for about half of the planks, it was determined by centrally loading each wide face on a span of 3 ft (914 mm) to obtain stiffness ratings in a manner corresponding to the functioning of a particular device, the "Microstress" grading machine (Anon., 1964).

Complete descriptions of all types of planks tested and full details of results obtained are not warranted in this paper. Table 1 gives brief descriptions of the

TABLE 1—Summary of bending test results for solid and laminated Douglas fir scaffold planks.

Metric equivalents have not been included in the table but may be calculated with the following factors that have been used for the metric equivalents shown (at first mention) throughout the text: length, 1 in. = 0.025 4 m (mm used when value <1 m); density, 1 lb/ft^3 = 16.018 5 kg/m^3; load, 1 lbf = 4.448 22 N (kN when $>$1000N); stress, 1 lbf/in.^{2} = 6894.76 Pa (N/m^2) (MPa when $>10^6$; GPa when $>10^9$).

Plank Type No.	Brief Description	No. Tested	Visual Class*	Breaking Load† lbf	Maximum and Minimum Values of: Modulus of Elasticity, Full Span 10^6 lbf/in.^{2}	3-ft Span 10^6 lbf/in.^{2}	Density at Test* lb/ft^3	Moisture Content %
1	Solid 9 x 2 in. Recut for size and Class from 12 x 2 in. ex imported balks of "Select. Merch."	6	"Special"	1,380–2,175	1.63–2.29	1.52–2.13	30.9–35.2	14–16
		8	"Standard"	1,100–1,925	1.29–2.05	1.28–?	26.9–34.0	14–16
2	Solid 9 x 2 in. Random sample recut from 10 x 2 in. and 9 x 3 in. available dry New Zealand stock.	3	"Special"	1,880–2,290	1.73–2.03	...	32.4–33.0	14–16
		4	"Standard"	850–2,480	1.17–2.28	...	27.1–36.2	14–16
		6	"other"	875–1,635	1.12–1.61	...	28.1–32.2	14–16
3	Horizontally laminated 8 x 1 in. stock. Pith excluded, otherwise ungraded. Paired at random, bark-side faces together.	3	"Special"	990–1,660	1.32–1.63	...	28.5–32.3	14–16
		4	"Standard"	1,030–1,215	1.24–1.41	...	27.0–29.5	14–16
		4	"Other"	790–1,105	1.25–1.39	...	27.6–30.6	14–16
4	Vertically laminated 8 x 2 in. ungraded stock. Two balks of 5 pieces, outer ones chosen to give a range of edge knots in planks.	2	"Standard"	1,155, 1,205	1.47, 1.33	1.37, ?	28.8, 30.5	13–18
		6	"Other"	655–1,610	1.26–1.76	1.16–1.64	29.6–32.3	13–18
5	T. and G. battens, nominally 2 x 2 in., from wide ungraded stock, in groups of 6 not deliberately shuffled.	3	"Standard"	910–1,015	1.18–1.39	1.13–1.48	27.9–28.6	12–13
		3	"Other"	825–1,250	0.98–1.54	1.08–1.46	28.2–29.8	12–13
6	Vertically laminated 8 x 1 in. ungraded stock. Two balks of 11 pieces, outer ones chosen to give "Minimum" marginal face knots in planks.	2	"Standard"	1,285, 1,545	1.46, 1.50	...	29.4, 30.4	16–18
		6	"Other"	1,000–1,335	1.22–1.68	?–1.68	28.5–30.0	13–18
7	Vertically laminated 4 x 1 in. To specification of Appendix 1. Two balks of 12 pieces and two of 14 pieces.	4	"Standard"	1,345–1,650	1.46–1.74	1.37–1.56	29.2–30.0	14–16
		2	"Standard" – dry	...	...	1.40, 1.28	29.4, 29.3	14–16
			soaked 24 hr	1,235, 1,315	1.56, 1.42	...	30.2, 29.9	§
		2	"Other"‡	1,350–1,560	1.68, 1.62	1.40, 1.47	28.9, 29.9	14–16

* For defects alone (in critical region only, in some cases) by rules of NZSS 1426:1965 for Special (imported) and Standard Class (NZ) planks. Few planks of NZ material met the requirements for Special Class in respect of both defects and wood quality. For Special Class the Standard specifies density not less than 32 lb/ft^3 at 15% moisture content.

† Applied 1 ft either side of centre of 9 ft span, on plank sections of $8\frac{1}{2}$ x $1\frac{7}{8}$ in. for solid, $8\frac{1}{2}$ x $1\frac{3}{4}$ in. for horizontally laminated, and 9 x $1\frac{3}{4}$ in. for vertically laminated.

‡ Down-graded for "excessive" edge knot only.

§ Outer $\frac{1}{4}$ in., 23%

construction of the planks, and the ranges of physical and mechanical properties in sufficient detail to support the discussion and conclusions which follow. In the table, groups of planks are identified by Type numbers, and for ready appreciation the breaking stresses resulting from the tests are presented in terms of breaking loads. The cross-sectional sizes varied somewhat from plank to plank and from type to type. For uniform comparison, breaking loads have been calculated for appropriate minimum sections of solid planks $8\frac{1}{2} \times 1\frac{7}{8}$ in. (216 × 47.6 mm); horizontally laminated $8\frac{1}{2} \times 1\frac{3}{4}$ in. (216 × 44.4 mm); and vertically laminated $9 \times 1\frac{3}{4}$ in. (229 × 44.4 mm). Further, the load is assumed to be applied as in the two-point test loading arrangement described above, and on a common span of 9 ft (2.74 m).

The subdividing of each group according to "Visual classes" will be referred to in the next section.

DISCUSSION AND CONCLUSIONS

Solid Planks

Type 1 (imported) planks which were Special Class in terms of the Standard, had an average breaking load of 1850 lbf (8.23kN) with a standard deviation of 279 lbf (1.24 kN); the weakest had a breaking load of 1380 lbf (6.14 kN). The equivalent single central load is 1073 lbf (4.77 kN) which is 3.1 times the workload of 350 lbf (1.56 kN).

While a precise statistical estimate of minimum breaking load cannot be expected from the relatively small number of tests, a figure as low as 915 lbf (4.07kN) is not impossible. This is 2.6 times the workload.

It is concluded that a factor of 3.0 times the workload, i.e., a breaking load of 1050 lbf (4.67 kN) is a suitable criterion of adequacy for Special Class planks when tested by loading at two points as in the standardised procedure. Table 2 shows the number of planks of each type that had breaking loads greater than, and less than 1050 lbf without regard to Visual Class.

TABLE 2—Classification of seven types of test plank according to breaking load

	Plank types*						
	1	2	3	4	5	6	7
Number with breaking load greater than 1050 lbf	14	10	8	6	1	7	8
Number with breaking load less than 1050 lbf	0	3	3	2	5	1	0
Total number	14	13	11	8	6	8	8

* See Table 1 for type constructions.

Under this criterion New Zealand-grown Douglas fir can yield solid planks (Type 2) of acceptable strength, but as Table 1 shows, visual grading by the rules for imported material (NZSI, 1965) is unsatisfactory; they also may be somewhat unsatisfactory for grading imported material. If the criterion of 1050 lbf is acceptable, there is evidently a need to devise visual grading rules appropriate to New Zealand material should it be added to timbers specified for Special Class planks. Machine grading (*see* Appendix 2) is a possible alternative.

Horizontally Laminated Planks

About 75% of Type 3 planks (Table 1) had a breaking load of not less than 1050 lbf. Their width could be increased from 8½ in. to 9½ in. (216 to 241 mm) with some advantage, but this construction is not considered to be reliable without grading the stock to requirements similar to those appropriate to solid planks. That effort may well be better directed to selecting the cheaper solid planks.

Vertically Laminated Planks from Wide Stock

In Table 1, classification of planks of Types 4, 5, and 6 by the rules of the Standard is not intended to imply the rules are appropriate to these types; they are used to indicate relative merit as determined visually. Judged against the breaking load criterion of 1050 lbf the use of wide stock, whether 2 in. (51 mm) or 1 in. (25 mm) thick, would not be sufficiently reliable unless it were graded.

The relatively low weight and low strength of some planks which contained a preponderance of lower density wood from near the centre of the tree indicates wood density is a factor additional to size and placement of knots in selecting timber for planks.

Use of tongue-and-groove battens (Type 5) facilitates assembly plank by plank, which is helpful when specialised plant is not available, but spreading the glue properly is more difficult.

Type 6 planks made from 1-in. stock showed better promise for this method of manufacture.

Vertically Laminated Planks from Graded 4 × 1 in. (102 × 25 mm) Stock

Planks of Type 7 were made because 4 × 1 in. is cut mainly from the denser outer zone of the tree; its relatively low cost offsets that of additional gluing compared with thicker stock; and it is a slow-moving line which is readily available where Douglas fir is milled.

Because knot size on the wide faces of planks would be limited to lamina thickness, ¾ - 13/16 in. (19.0 × 20.6 mm), it was decided to limit knots on the wide faces of the stock to ¾ in. (19 mm), i.e., "20 percent of section", width being taken as 3¾ in. (95.2 mm), thus making it slightly superior to No. 2 Laminating Grade (NZSR 34: *see* SANZ, 1968) in this respect.

All of eight test planks surpassed the breaking load of 1050 lbf, including two that had been submerged in water for 24 hr. These two planks confirm the expectation that seasoned Douglas fir is not easily rewetted and is not seriously reduced in strength and stiffness by rewetting, one reason being that wetting causes wood to swell, and the resultant increase of cross-section tends to offset the reductions of basic properties effected by an increase in moisture content. Conversely, lack of seasoning can apply to solid planks, but these have a minimum section somewhat greater than has a seasoned plank, to allow for shrinkage. Thus, the net effect of seasoning is some gain in strength, but, with Douglas fir, little or no gain in stiffness. Tests of seasoned planks, therefore, may over-estimate the strength of unseasoned ones, but not to a serious

however, "good housekeeping" to stack unseasoned or wetted planks with fillets between
dry or not, and wetting in use is normally confined mainly to the upper face. It is, however, "good housekeeping" to stack unseasoned or wetted planks with fillets between them.

With the minimum cross-section, 9 × $1\frac{3}{4}$ in., the average breaking load of Type 7 planks was 4.1 times the workload, and 98% of these planks can be expected to have a breaking load not less than 3.0 times the workload under normal service conditions.

A specification (Appendix A) has been written for planks of Type 7 as a guide to potential manufacturers, users, and safety officials who may be considering laminated planks as an alternative to Special Class planks of kahikatea (*Podocarpus dacrydioides* A. Rich.) or imported Douglas fir in terms of NZSS 1426 Part 3 (NZSI, 1965).

Some Matters Arising from the Investigation

Planks in Use

In view of the test results obtained, no limitation has been set on the sale and use of planks made to the specification of Appendix A. To test whether or not they are a good answer to the problem of an adequate supply of planks and have the required qualities, a number have been specially marked and placed with known users as an in-use trial, by courtesy of the Labour Department. Many others are also in service, and there is evidently a tendency to use them for the less exacting purposes of the Standard Class, or as "just planks". There is nothing against this, but more appropriate types could be developed if the expense of laminating were justified, and it may be unwise to discourage such developments. However, the writer considers that the present specification must be regarded as essentially for Special Class planks, and any substantial relaxation of it risks discrediting glue-laminated planks of this class.

Binding of Ends

During up to 10 months' use some planks have developed end splits. Some of these splits have found and followed a glueline as an inevitable result of normal grain deviations, but all splits have started in the wood. Splitting has usually, if not invariably, been associated with failure to prepare the ends before use, indicating that the planks must be treated as Special Class in this respect also. The Standard requires the ends to be secured against splitting, but does not say with whom the obligation lies. At present, the preferred measures against splitting are both cross-bolting and chamfering of corners.

Plank Sizes

Laminated planks are currently being made either 10 ft 6 in. (3.20 m) long × 9 in. (229 mm) minimum width, or 12 ft (3.66 m) long × $10\frac{1}{2}$ in. (267 mm) minimum width, both of minimum thickness $1\frac{3}{4}$ in. (44.4 mm) with moisture content at manufacture about 14%. Some users have expressed a preference for $10\frac{1}{2}$-in.-wide planks for "Special Class (single span) platforms", which follows a recent trend in scaffolding practice.

Rationalising plank size has been considered, and a measure of informal agreement reached that a nominal width of 10 in. (254 mm) would be suitable for all planks. For solid planks, this width is more readily procurable than is 9 in. (229 mm). It is doubtful whether all planks could be, or need be of one class, i.e., of identical length, thickness, and grade, as well as width. When allowable overhang is considered, a length of 10 ft 6 in. is appropriate to individual planks or platforms on single spans of 8 ft 6 in. to 10 ft, but lengths in multiples of 4 ft (1.22 m) may continue to be needed for conventional platforms, i.e., Standard Class, planks.

Although Standard Class planks may be as thin as $1\frac{1}{2}$ in. (38 mm) when supports are spaced at 4 ft, it is unlikely that New Zealand-grown Douglas fir less than 2 in. (51 mm) thick is ever used in this way. For either thickness, the strength (grade) needed for this Class is low relative to Special Class. For efficient use of timber in this circumstance, if grade is fixed, thickness should vary, or vice versa. From all points of view, varying the grade is preferable.

Therefore, a single nominal section size of 10 × 2 in. (254 × 51 mm) is advocated. Accordingly, a single rationalised size for Special Class laminated planks may well be given by the constructions:

12 nominal 4 × 1 in. boards dressed to 13/16 in. = 2 planks of $9\frac{3}{4} \times 1\frac{3}{4}$ in.
or 13 nominal 4 × 1 in. boards dressed to $\frac{3}{4}$ in. = 2 planks of $9\frac{3}{4} \times 1\frac{3}{4}$ in.

For either plank an appropriate length would be 10 ft 6 in.

Solid Planks

It is appropriate to comment on the requirements of the Standard for solid planks of Douglas fir. For Special Class planks as defined in NZSS 1426 (NZSI, 1965), these points arise:

(1) The aggregate of face knots in any 9-in. (229 mm) length could read "2 in. (51 mm)" and not "1 in. (25 mm)". This is supported by established principles of grading for strength (ASTM, 1968) and is reinforced by the present tests.
(2) The edge clearance of one diameter for face knots may be unduly restrictive.
(3) Limiting edge knots to $\frac{1}{2}$ in. (12.7 mm) may also be unduly restrictive, and combination of edge and face knots is not clearly dealt with.
(4) Prohibiting even minor knots that are intersected by an arris can downgrade many planks of adequate strength.
(5) Again in keeping with established grading principles for single-span members (ASTM, 1968), edge knots and marginal face knots could be permitted to increase substantially in size between the third-points and the adjacent ends.
(6) Even if technically justifiable, it is not practicable to give effect to the quality requirement that "Douglas fir of a density not less than 32 lb/ft^3 (513 kg/m^3) at 15 percent moisture content shall not be used."

Attention to these six points may increase the yield of Special Class planks of New Zealand-grown Douglas fir, perhaps sufficiently to justify its inclusion in the Standard.

Standard Class planks are rightly graded as members continuous over two or more spans, but the following points are noted:

(a) Limiting edge knots to $\frac{1}{2}$ in. (12.7 mm) is certainly unduly restrictive. Their spacing and combination with face knots are not clearly dealt with.
(b) The measurement of knots that are intersected by an arris is not adequately illustrated, and it is considered that a distinction should be made between those that originate within the plank (arris knot) and those that do not (corner knot).

The greatest improvement in recovery of either class of planks from New Zealand-grown Douglas fir would probably result from relaxing the permitted size of edge knots to some degree.

If the nominal section size of 10 × 2 in. advocated above were adopted for both classes, it would certainly be appropriate to review the requirements for Standard Class, which are based on a nominal width of 8 in. (203 mm).

ACNOWLEDGMENTS

Development of laminated planks was instigated by Mr E. E. Hendricksen, previously Chief Safety Engineer, Labour Department, and was sustained by the unfailing interest and enthusiasm of Mr A. Hall, Safety Inspector, Rotorua. Mr C. Tritt, Waipa Sawmill, New Zealand Forest Service, made the proposal to use 4 × 1 in. Douglas fir stock, which led to a satisfactory conclusion. Manufacturing trials were made by Lloyds (Rotorua) Ltd, and Waipa Sawmill in collaboration with the writer; bending tests were made by technical staff at the Forest Research Institute.

APPENDIX 1

SPECIFICATION FOR GLUED LAMINATED SCAFFOLD PLANKS OF NEW ZEALAND-GROWN DOUGLAS FIR*

BASIS

This specification is based on the results of 68 strength tests of Douglas fir planks comprising solid and laminated planks of New Zealand material and solid planks of imported material.

PURPOSE

The purpose is to enable manufacture of planks of a definite standard. The standard sought is that of a Special Class plank (NZSS 1426: NZSI, 1965).

REQUIREMENTS

1. Size and Construction

Any of the following may be required as indicated by strength requirements, spacing of supports, and the method of manufacture:

Finished length	10 ft 6 in.	10 ft 6 in.	12 ft
Minimum thickness	1¾ in.	1¾ in.	1¾ in.
Minimum width	9 in.	9¾ in.	10½ in.

2. Laminating Stock

Grade and Dimensions

Nominal 4 × 1 in. New Zealand Douglas fir

Knot ratio: not exceeding 20% of section (¾ in. on wide face)

General slope of grain: not exceeding 1 : 14

Crossgrain (As defined in National Grading Rules, NZSS 169 (NZSI, 1962): not permitted

Preservative Treatment

No provision is made for preservative treatment of laminating stock or finished planks of Douglas fir.

Note: Treatment is not called for on the grounds that untreated sapwood is permitted in Standard Class planks of solid timber (NZSI, 1965) and the only approved universal preservatives for this species are pentachlorophenate in oil, and creosote.

the metric equivalents shown in the main body of the text, see the heading to Table 1.

3. Lay-up

Whether assembled as 4 × 1 in. for ripping after gluing, or as 2 × 1 in., the stock shall be arranged to meet the following requirements:

* From Hellawell, 1970. Imperial units have been retained; for the factors used to calculate the metric equivalents shown in the main body of the text, see the heading to Table 1

The better pieces shall be placed first and last in the assembly.

Pith centre may be present in not more than one piece in planks of 9 in. width, and in not more than two pieces in wider planks.

Within the central third of the overall length of finished planks, not more than two face knots, or two edge knots, or one face and one edge knot of maximum size (¾ in.), or the equivalent in aggregate, shall occur in any length equal to the width.

Between the third points and the adjacent ends, knots may increase in proportion to distance from the third points to a maximum of twice the limit specified for the mid-third.

4. Jointing

Side Jointing

The faces to be joined shall be dressed. Joints such as the reversible tongue and groove may be used to align battens when gluing plank by plank provided they are fully bonded in all parts.

End Jointing

End jointed laminae are not permitted.

Note: The performance of laminated planks containing end joints has not been studied.

5. Assembly

In general, the laminating procedure shall be in accordance with NZSR 34, "Glued Laminated Timber Construction", and shall be subject to quality control (e.g., in accordance with the industry standard for the quality of glued laminated timber established by the New Zealand Timber Development Association). In particular, stock with a reasonably uniform moisture content not exceeding 16% is appropriate, and the class of glue required is Class WBP/Group GF (NZSS 1155: NZSI, 1966).

6. Finishing

Faces

Both wide faces shall present a sawn surface or be otherwise roughened to a similar degree.

Edge corners

If required by the purchaser, these corners shall be chamfered ⅛ × ⅛ in. or rounded to 3/16 in. radius approximately.

End corners

If required by the purchaser, these corners shall be removed by chamfering 1¼ × 1¼ in. approximately.

Binding

When required by the purchaser, securing of the ends against splitting shall be by ¼ in. diameter galvanised iron stitch bolts.

Note: Taken together, the last two requirements above exceed the minimum requirements of NZSS 1426 (NZSI, 1965), but both measures are justified to enhance the service life of planks.

MARKING (FOR USE IN NEW ZEALAND)

NZSS 1426 (NZSI, 1965), Clause 10.2, requires each end of a Special Class plank to be painted for approximately 6 in. (with the owner's colour) and to be marked in solid letters "A1" on each face near each end. As it does not state with whom the obligations lie, they shall be subject to agreement between the producer and the purchaser.

APPENDIX 2

MECHANICAL STRESS GRADING AND SCAFFOLD PLANKS

Performance of solid planks in strength tests and their visual class (Table 1) lack agreement, and, while the rules used (NZSS 1426: NZSI, 1965) do not necessarily apply to laminated planks, agreement for these is also poor. This anomaly raises interest in other methods of sorting for load carrying capacity.

Machines are now available which utilise the actual properties of timbers for sorting. Stiffness is measured in terms of the amount of bending under a given load, and strength or safe working load is obtained from a numerical relationship between the two properties. This relationship is predetermined by statistical analysis of numerous laboratory tests in bending, of the species concerned. Generally, such relationships are expressed in terms of the basic properties of modulus of elasticity, E (relating to stiffness), and modulus of rupture or breaking stress, f (relating to strength), and are straight lines with an equation of the form $f = bE + a$. They express the change in the dependent variable, f, that accompanies a given change in the independent variable, E, and are called linear regression equations.

Machines based on this principle of measuring stiffness to determine strength in bending are used primarily for grading structural timber, and are also being applied to selecting planks for scaffolding in Australia (Anon., 1966), South Africa (Müller, 1969), and England (Curry, 1965). The operation is commonly known as mechanical, or machine stress grading.

Notwithstanding the general nature of the principle, if a reliable basis for a particular application is to be obtained, the bending test conditions must correspond to the way the timber is to be used, viz, its dimensions, state of seasoning, and manner of loading, as well as to the design of the machine (Muller, 1968).

Two relationships obtained from the present tests are shown in Figs. 2 and 3.

Of the 66 dry planks for which E was measured on the in-use span, 34 were tested by loading at two points, and 32 by central loading. There was a significant difference between the regression lines for these two groups. Central loading is more convenient in practice, and the line for this is presented in Fig. 2.

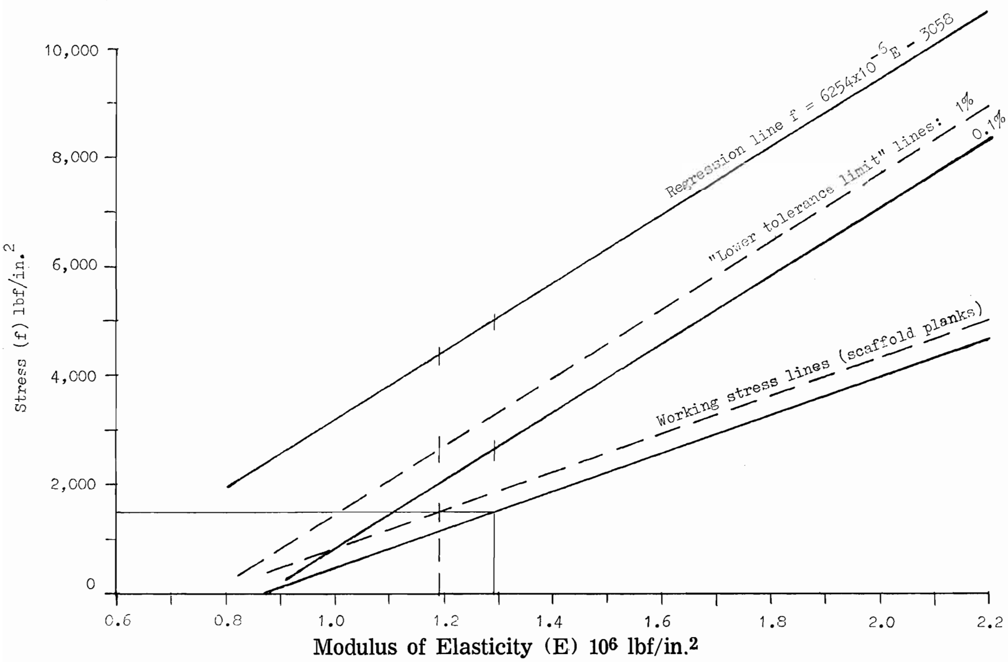

FIG. 2—Relationships between breaking stress or working stress and modulus of elasticity of dry Douglas fir scaffold planks when modulus of elasticity is determined by central loading on in-use span.

For 30 planks, E was also measured on a span of 3 ft (914 mm) by a central load applied close to where they eventually broke under 2-point loading on the in-use span. The relationship of these planks is shown in Fig. 3.

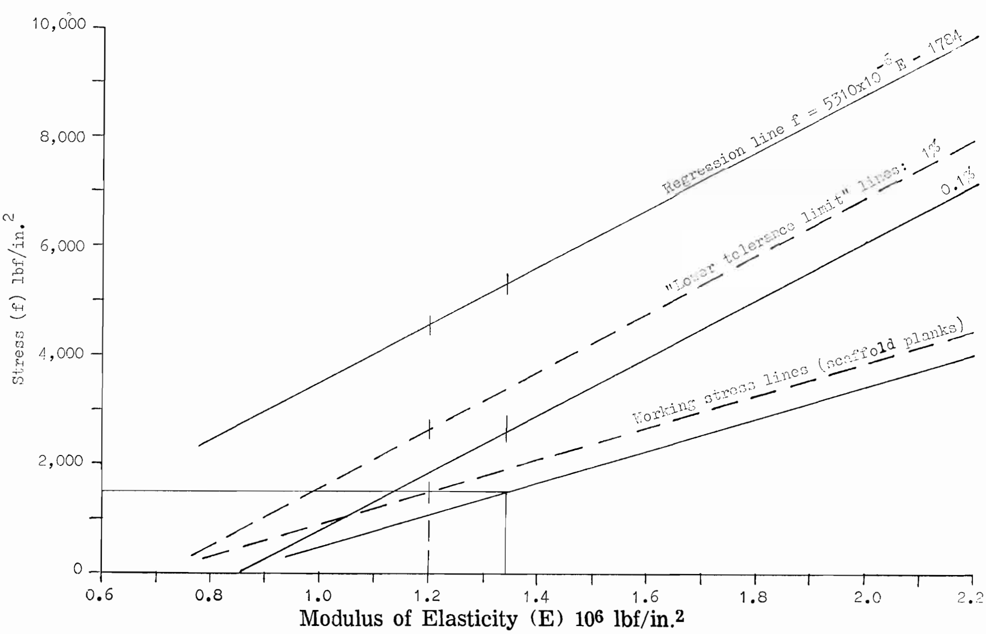

FIG. 3—Relationships between breaking stress or working stress and modulus of elasticity of dry Douglas fir scaffold planks when modulus of elasticity is determined by central loading on 914 mm.

Each of these relationships may be used to grade seasoned timber for scaffold planks of typical dimensions, either with a commercial machine that operates on a 3-ft span (Fig. 3), or with a simpler device such as that described by the Division of Forest Products, CSIRO, Melbourne (Anon., 1968-9), operating on the long span (Fig. 2) or the short span (Fig. 3).

For "tailor-made" laminated planks, e.g., to the specification in Appendix 1, routine machine grading is considered unnecessary, but the method could be used to advantage for acceptance testing and quality control.

A "safe working stress" approach is customarily used to determine E-criteria for grading by means of a regression relationship. Thus, in accordance with established timber engineering practice:

1. The f-values below which not more than 1% (or any other desired proportion) of pieces may be expected to fall are calculated from the test results, giving the lower tolerance limits (Figs. 2 and 3) as straight-line approximations, the usual procedure in this application*.
2. Reduction factors are applied to lower tolerance limits to adjust from test loading

* It is considered prudent to confirm that such approximations are justified. In the present example they result in an over-estimate of not more than 2.1% in the working stress ascribed to the planks, which is considered acceptable.

of short duration to live loading of longer duration ($0.56 \times 1.25 = 0.7$), and as an allowance for workmanship factors (0.8).

These steps give the working stress lines shown on the figures.

Solid seasoned planks of specified minimum section $8\frac{1}{2} \times 1\frac{7}{8}$ in., under the allowable working load of 350 lbf applied at two points, experience a maximum working stress of 1475 lbf/in.^{2} (10.2 M Pa), indicated by horizontal lines on the figures. The corresponding modulus of elasticity values shown by the vertical lines are 1.19×10^6 lbf/in.^{2} (8.20 G Pa) (Fig. 2) and 1.20×10^6 lbf/in.^{2} (8.27 G Pa) (Fig. 3) when based on the 1% lower tolerance limits, or 1.29×10^6 (8.89) and 1.34×10^6 (9.24) when based on the 0.1% limit.

These represent E-criteria for grading, i.e., the level at which the machine or other device is set for sorting. It so happens that in this instance the average breaking stresses predicted from the two regression lines by the lower criterion are about equal, and almost exactly three times the maximum working stress of 1475 lbf/in.^{2}. This is true when not more than 1% of planks may be expected to have less than the required working stress. For higher, more exacting criteria, giving, for example, not more than 0.1% "defectives", the proportion of planks graded "in" will, of course, be lower. That is, the choice of lower tolerance limits for machine grading involves striking a balance between safety and efficiency (Miller, 1964).

Grading trials to assess efficiency have not been made, but it could well be that an optimum tolerance limit lies between the levels which are presented above, to bring out the considerations involved in this alternative to visual grading.

The "minimum" breaking stresses predicted from the lower tolerance limits by the E-criteria are considerably less than the static strength test criterion advanced in the main paper—about 2600 lbf/in.^{2} (17.9 M Pa) as against $1475 \times 3 = 4425$ lbf/in.^{2} (30.5 M Pa). Such a comparison is not justified because the breaking stress criterion is for acceptability on the basis of tests of a limited sample of planks produced to any given specification, whereas with machine grading every plank is, in effect, tested.

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