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“Strength and Other Properties of Scots Pine.”

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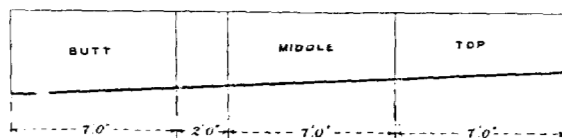
(Abridged.)

THE purpose of this Paper is to record the results of a series of investigations upon the properties of home-grown timber, carried out by the Author, in the laboratory at Robert Gordon's Technical College, Aberdeen, in collaboration with Mr. Alexander Cruickshank, Head of the Building Trades Department there.

The tests were carried out upon sufficiently large specimens to make the results applicable to conditions existing in constructional work.

Three average trees, from each of six selected forests, were cross-cut as soon as possible after felling, in accordance with *Fig. 1*.

Fig. 1.



The butt, middle and top cuts were intended as specimens for cross-breaking, while the 2-foot cut immediately above the butt was reserved for tests of compression and shear; these latter tests have not been carried out up to the present. The trees, cross-cut as described, were, after delivery, measured and numbered, and the 7-foot logs were carefully sawn into test-pieces $5\frac{1}{4}$ inches by $2\frac{5}{8}$ inches; while specimens 3 inches by 3 inches were cut from the 2-foot lengths.

Table I gives particulars of the sources of supply and data relative to the cross breaking of the 7-foot specimens.

In the case of the trees from Nethy Bridge, there were only two

TABLE I.—PARTICULARS OF CROSS-BREAKING SPECIMENS.

Forest.	Tree.	Date of Felling.	Date of Cross Cutting.	Diameter over Bark. Inches.			Date of Sawing.	Number of Specimens.
				Butt.	Middle.	Top.		
Glenmore, Inverness-shire	A	{ 10/3/18	{ 15/3/18	18	13	12	Between 4/4/18 and 8/4/18	47
	B			13½	12	10½		
	C			15½	13½	13		
Fetterneer, Kennay, Aberdeenshire	A	{ 10/3/18	{ 10/3/18	18	14	13½		58
	B			19	14½	13½		
	C			19	14½	14		
Nethy Bridge, Banffshire	A	{ not stated	{	15	14	..		32
	B			13	12	..		
	C			18	13	..		
Alyre Woods, Forres, Morayshire	A	{ 20/3/18	{ 20/3/18	21	17	15½		60
	B			19½	14½	14		
	C			17	13½	12½		
Blackboat, Ballindalloch, Banffshire	A	{ 23/3/18	{ 23/3/18	21	15	14		62
	B			18	13½	13½		
	C			20	14	13½		
Orton, Morayshire	A	{ 26/4/18	{ 26/4/18	20	18½	17	{ 16/5/18	72
	B			18	15	14		
	C			16	12	11½		

Total cross-breaking specimens, 331.

7-foot logs; the top log of one tree being discarded, owing to defects.

PARTICULARS OF FORESTS FROM WHICH THE SPECIMENS WERE DRAWN.

Forest.	Natural or Planted.	Nature of Soil.	Exposure.	Elevation, above Sea-Level.
				Feet.
Glenmore . .	Natural	Light gravel	{ North (Slope of Cairngorms)	{ 1,000-1,200
Fetternear . .	Planted	{ Glacial till overlying granite	{ All directions }	250-400
Nethy Bridge .	Natural	Light gravel	North	800-1,000
Forres . . .	Planted	{ Sandy loam, gravel sub-soil }	North	200-400
Ballindalloch .	Planted	{ Springy shallow loam, sandy sub-soil, clay 2 feet deep, gravel below }	North	800
Tree A . . }				
Tree B . . .	..	Ditto.	West	600
Tree C . . .	..	{ Wet ground with springs ; other con- ditions as above }	South	700
Orton . . .	Planted	Sandy loam	North	200-400

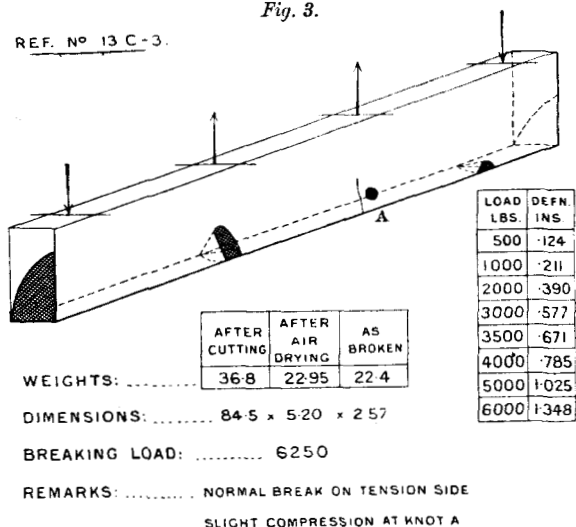
All the trees selected were approximately 100 years old.

Immediately after the logs had been sawn and marked, each specimen was weighed. The specimens were then stacked in a drying-shed which was roofed, but was open on the sides allowing a free current of air to pass through. They were stacked on edge, with an air-space of 1 inch between them, both horizontally and vertically. The specimens were removed to the laboratory on the 10th August, 1918. Thus, the period of seasoning in the open was, in the case of all but the trees from Orton, approximately 4 months; and, of the Orton trees, about 10 weeks. The specimens were re-weighed, on delivery at the laboratory, and stacked in the same manner as that already described.

In view of the long period over which it was necessary to continue the tests, the specimens were broken in no definite order, so that the average time of seasoning in the laboratory might be approximately the same for all trees. This average period was about 5 months. An exception was made in the case of the trees from Orton, which were stored in the laboratory approximately 10 months, with the result that they contained less moisture than

induced was approximately equal to the load. The values of the modulus of elasticity were, therefore, obtained for an increment in stress of about 3,000 lbs. per square inch.

Fig. 3.



A record sheet was kept for each specimen, of which *Fig. 3* is typical. In addition to reference numbers, records were made of:—

- The weights of the specimen at cutting, after air-drying and at breaking.
- The length, breadth and depth of the specimen.
- The breaking-load.
- The nature, and immediate cause of fracture.
- The deflections corresponding to the loads.
- The direction of the annular rings. *Noted on the sketch.*
- The position of knots or other defects. *Noted on the sketch.*

Every effort was made to ensure that the rate of loading would be sensibly the same for all specimens. In order to eliminate errors due to the personal equation, the tests were carried out by the experimenters in person.

Immediately after a specimen was broken, it was cross-cut into three equal parts, and a section, about $\frac{5}{16}$ inch thick, was taken from each end of the central portion. These sections were stored in air-tight boxes, pending the determination of the moisture content, and were thereafter used for the purpose of estimating the

relative proportions of heart and sap woods. After weighing these specimens were placed in an air-bath, through which a free circulation of air was maintained, kept at a temperature of 216° F., by means of a Reichert regulator, for 5 hours, and they were then re-weighed, and the percentage of moisture, based on the dry weight, was calculated. The average of the two results from the two sections of the specimen was taken. Preliminary experiments established that this period of drying gave results which agreed more closely with the absolute moisture content, as determined over much longer periods, than did those from the two sections cut from the same specimen. Fully 40 per cent. of the total sections were subjected to this test, representing about 250 tests. In the case of one tree, all the sections were tested. The closeness of the results appeared to justify average values being taken for the remaining specimens, where only a proportion of the sections belonging to one log were actually dried.

From the weight of the specimen as broken, and the moisture content at this stage, determined as above, the dry weight of the specimen was found from:—

$$\text{Dry weight} = \text{weight as broken} \times \frac{100 - \text{percentage moisture}}{100}.$$

The percentage of moisture at the time of cutting, based on the dry weight, was found from:—

$$\left. \begin{array}{l} \text{Percentage moisture} \\ \text{after cutting} \end{array} \right\} = \frac{\text{weight after cutting} - \text{dry weight}}{\text{dry weight}} \times 100$$

Similarly, the percentage moisture after air-drying was determined from:—

$$\left. \begin{array}{l} \text{Percentage moisture} \\ \text{after air-drying} \end{array} \right\} = \frac{\text{weight after air-drying} - \text{dry weight}}{\text{dry weight}} \times 100$$

The volume of each specimen was found in cubic feet, from its dimensions; and from this, together with the weights as broken and dry, the densities at these two stages were found.

The proportions of sapwood and heartwood were determined from the sections cut from the specimens in the following manner, the mean of the two results being taken in each case.

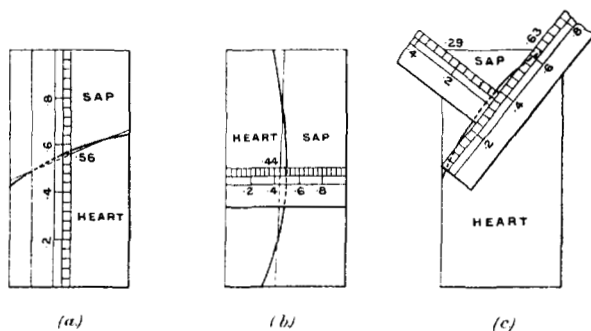
A straight line was drawn across the line of separation between the heartwood and sapwood, by judgment, so that the areas of the resulting figures were equal to the areas of the heart and sapwoods. Where this line lay across the specimen, as in *Fig. 4a*, a line was drawn along the centre of the specimen, as indicated. A scale, the unit length of which was 5.2 inches—the depth of the specimen

—was then applied to this centre line, and the fraction of heartwood read off directly. Thus, in the case illustrated, the fraction of heartwood was 0·56, or 56 per cent. A similar method was adopted where the line of separation emerged from the top and bottom of the specimen, as in *Fig. 4b*, only that the unit length of the scale used was 2·6 inches, this being the breadth of the section.

When the separating line lay as indicated in *Fig. 4c*, running out on two adjacent sides, a perpendicular was dropped to it from the upper corner. The lengths of the separating line and the perpendicular were then measured with the scale whose unit length was the depth of the section. The product of these two dimensions gives the fraction which the sapwood bears to the whole.

The information on the records, together with the results of subsequent determinations and calculations, were tabulated for

Figs. 4.



each of the fifty logs. A typical extract from these records is given in *Fig. 3*, and from these records a summary of the results has been prepared, Table II (p. 384).

By analysis of the notes made regarding the defects and mode of failure, the specimens were divided into two broad classes: (a) Normal specimens, which were either entirely free from defects or, if present, of no material influence on the breaking-strength or modulus of elasticity; and (b) abnormal specimens, wherein the defects present had a decided lowering effect upon the strength and elasticity.

Broadly speaking, "normal" specimens may be regarded as those which did not disclose, before breakage, any inherent defects likely to reduce strength appreciably; while "abnormal" specimens were, for the most part, obviously defective, principally on account of

SPECIMEN OF RECORD. FETERNEAR, TREE B. BUTT.

Serial No.	Reference No.	Dimensions.				Percentage of Moisture as Broken.	Weight (Lbs.).				Percentage of Moisture Calculated on Dry Weight		Density. Lbs. per Cubic Foot.		Breaking Load. Lbs.
		Length. Ins.	Depth. Ins.	Breadth. Ins.	Volume. Cu. Ft.		After Cutting.	After Air-Drying.	As Broken.	Dry.	At Cutting.	After Air-Drying.	As Broken.	Dry.	
31	17 A	84 $\frac{1}{2}$	5.20	2.52	0.646	15.7	37.4	26.95	26.3	22.2	68	21.5	40.7	34.4	9,250
32	B	84 $\frac{1}{2}$	5.21	2.54	0.645	15.3	25.3	23.15	22.75	19.3	31	20.0	35.3	29.9	4,840
33	C	84 $\frac{1}{2}$	5.21	2.60	0.659	17.1	36.25	29.25	28.85	23.9	52	22.2	43.7	36.4	9,540
34	D	84 $\frac{1}{2}$	5.18	2.59	0.655	15.8	31.95	26.9	26.5	22.3	43	20.7	40.5	34.0	8,280
35	E	84 $\frac{1}{2}$	5.24	2.53	0.648	16.5	39.05	28.25	27.7	23.15	69	22.1	42.8	35.8	8,200
36	F	84 $\frac{1}{2}$	5.22	2.52	0.644	15.3	40.8	25.55	25.25	21.4	91	19.4	39.2	33.2	8,800
37	G	84	5.15	2.59	0.648	16.0	44.6	23.35	23.0	19.3	131	21.0	35.5	29.8	9,350

SPECIMEN OF RECORD—continued.

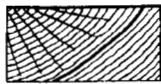
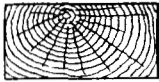
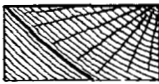
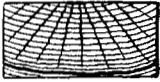
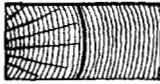
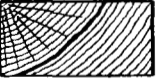
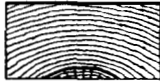




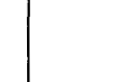


Serial No.	Refer- ence No.	Modulus of Section.	Breaking Stress, lbs. per sq. in.	Deflection Between 500 and 3,500 lbs. lbs.	Moment of Inertia.	Modulus of Elasticity, 1,000 lbs. per sq. in.	Percentage of Sap- wood.	Percentage of Heart- wood.	Details of Grain.		Remarks on Fracture
											
31	17 A	11.35	9,780	0.348	29.51	1,936	41	59			Normal fracture in tension
32	B	11.49	5,050	0.601	29.93	1,106	0	100			Break along heart-shake
33	C	11.76	9,740	0.355	30.63	1,828	23	77			Normal fracture in tension, pre- ceded by slight compression
34	D	11.58	8,530	0.365	29.99	1,817	9	91			Normal fracture in tension, with failure in compression
35	E	11.57	8,510	0.437	30.31	1,501	48	52			Normal fracture in tension, with slight horizontal shear
36	F	11.44	9,225	0.372	29.85	1,790	61	39			Normal failure in tension
37	G	11.44	9,800	Not taken			93	7			Normal failure in tension

TABLE II.—SUMMARY OF RESULTS.

Forest.	Trees.	Weight of Specimen. Lbs.			Moisture Per Cent. Calculated on Dry Specimen.			Density. Lbs. Per Cu. Ft.		Maximum Stress. Lbs. per Sq. In.		Modulus of Elasticity. 1,000 Lbs. per Sq. In.		
		After Cutting Drying.	As Broken	Dry.	After Cutting Drying.	As Broken	Dry.	Normal Specimens.	All Specimens.	Normal Specimens.	All Specimens.			
Glenmore Fetter- near . Nethy Bridge Altyre- Forres Ballind- Alloch Orton .	Average of the Top, Middle and Butt specimen of three trees.	..	23.2	22.8	19.4	..	19.25	15.5	35.15	29.65	8,120 (29)	7,380 (44)	1,236 (28)	1,196 (40)
		..	22.0	21.7	18.3	..	20.5	15.7	32.8	27.2	8,050 (35)	7,420 (48)	1,374 (31)	1,315 (41)
		..	23.3	22.2	19.4	..	20.25	15.5	35.8	30.3	7,990 (12)	6,775 (27)	1,221 (12)	1,177 (27)
		..	22.85	21.75	19.0	..	20.5	15.75	35.25	29.7	8,830 (31)	7,690 (54)	1,374 (38)	1,384 (53)
		..	21.65	21.35	18.0	..	20.6	15.76	33.1	27.8	7,170 (38)	6,690 (51)	1,305 (37)	1,267 (47)
		..	25.55	24.8	21.6	..	18.25	12.83	37.7	33.55	9,070 (34)	8,060 (48)	1,671 (34)	1,581 (48)

NOTE.—The breaking stresses and moduli of elasticity have been tabulated under two heads: "normal" and "all specimens"; the figures within the brackets give the numbers of specimens failing under each head.

large knots at or near the edges or the centre of length of the beam.

The weights of the specimens immediately after cutting, even from one log, varied greatly, ranging from 44·6 to 20·2 lbs. This large range is chiefly attributable to variations in the proportion of sapwood: but it is also due to the fact that the dry density of the timber showed considerable variations. Notwithstanding this, the weights and moisture contents of the specimens, after air-drying, came in very close agreement; thus, while the percentage of moisture at cutting, calculated upon the dry weights, varied from 180 to 22·6 per cent., the moisture content after air-drying in the two specimens under consideration fell respectively to 20·7 and 20·8 per cent.

The specimens from Orton, which were air-dried for 10 weeks only, while ranging in moistures from 115 to 19·2 per cent. at the time of cutting, contained only 20·6 and 16·8 per cent. of moisture, respectively, after this air-drying process was completed. It is clear, therefore, that a relatively short period of seasoning in the open, provided the timber is protected from rain, serves to reduce the moisture content to a low figure.

Further seasoning in the laboratory, the mean temperature of which may be taken as 55° F., for an average period of 4 months, reduced the moisture content to a fairly uniform value; the maximum and minimum percentages being then 17·1 and 14·4 per cent. respectively, with an average of 15·65 per cent. The Orton specimens were stored in the laboratory for 10 months, after which time the average moisture was 12·83 per cent., the maximum and minimum being 13·6 and 12·0 respectively. There was good reason for believing that the rate of loss of moisture was exceedingly slow at the end of this period.

The density of the timber at the time of breaking is of interest only in so far as it indicates the weight of a cubic foot of well-seasoned pine. The maximum and minimum of all the specimens were 46·4 and 24·8 lbs. per cubic foot respectively, with an over-all average of 35 lbs. The dry density varied considerably—from 40·0 to 23·0 lbs. per cubic foot—with an average of 30 lbs.

In reviewing the results of the tests, it is to be remembered that the trees were not specially selected, but that average samples of the product of the forest were obtained.

Complete records were kept as to the causes of premature failure of the specimens, where such occurred. Table III gives the immediate causes and mode of failure.

TABLE III.

Cause, or Mode, of Failure.	Normal.	Abnormal.	Total.
Tension side only	152	..	152
„ with compression	9	..	9
„ with shear	3	2	5
Compression only	1	..	1
Horizontal shear only	1	..	1
Shear along heartshake . . . . .	..	2	2
Tension, hastened by grain running out at knot	5	24	29
Fracture hastened by knots otherwise than by tension	7	20	27
Tension, with suggestion of horizontal shear .	1	1	2
Cross-breaking through knots . . . . .	..	44	44
Total	179	93	272

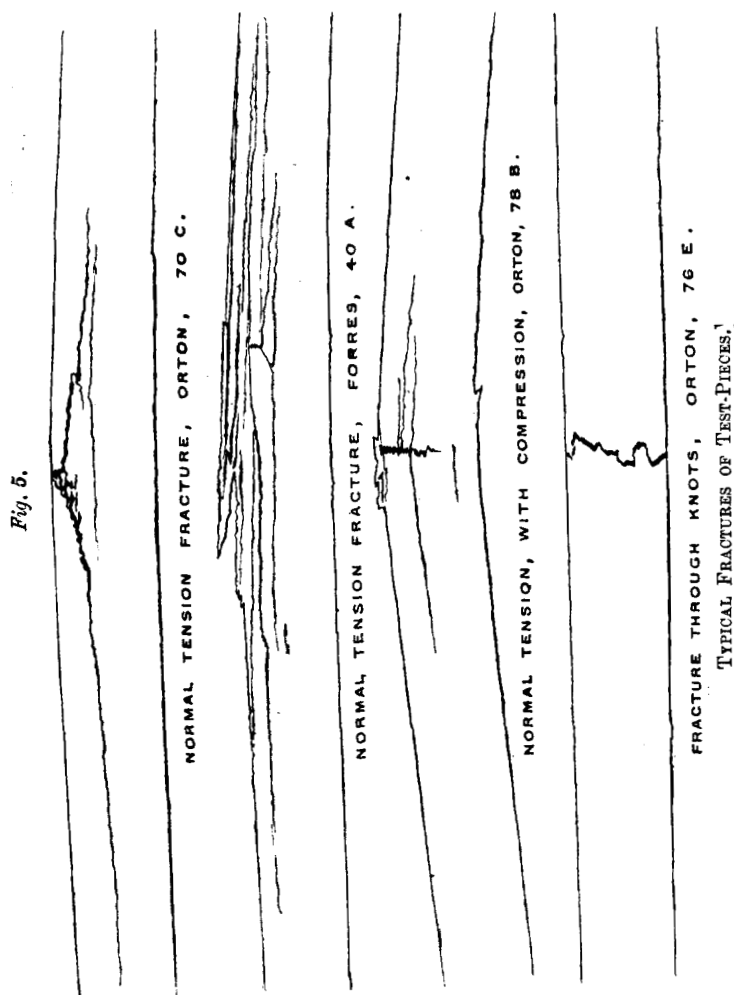
It will be seen that the specimens generally failed, except where defects were present, on the tension side; the strength apparently being less in tension than in compression in normal timber.

The specimens were too long in relation to their depth to cause failure to occur by shear. Where compression occurred, it was usually in close proximity to a knot. Failure in tension was accompanied by shear on a vertical, or approximately vertical, plane in five specimens. In three of these the shear took place over a support. Two apparently sound specimens sheared horizontally on the plane of union between the heart- and sapwoods; while in one other, in which, strangely enough, the annular rings were vertical, failure was caused by horizontal shear only.

It was found that in no less than twenty-nine specimens the strength was reduced, in some by a considerable amount, by the grain being deflected outwards by the presence of a knot, in many cases of small size, on the tension side. This result suggests that this defect is an important consideration in the selection of timber which is to be subjected to considerable bending moment. Nearly one-sixth of the pieces failed through knots; while, in addition, a considerable number were laid aside before testing, on account of a similar defect. This points to the necessity for improved silviculture so as to procure the production of clean timber. Examples of typical fractures are shown in *Fig. 5*.

As was to be expected the breaking-stresses, even in specimens from one log, varied very considerably, especially when those having

obvious defects were included. Table IV gives a summary of the principal breaking-stresses in pounds per square inch.



It will be seen that the average stresses for the trees from the several forests do not vary very greatly. When it is remembered that under "normal" specimens are included only those which would, on examination, be accepted for first-class constructional work, the average breaking-stress for all the trees, of 8,200 lbs. per

TABLE IV.

	Normal Specimens.		All Specimens.		Number of Normal Specimens to All Specimens, Per Cent.
	Number.	Stress.	Number.	Stress.	
Maximum of all . . . . .	..	12,600	..	12,600	..
Minimum of all . . . . .	..	5,075	..	2,870	..
<i>Average of three trees.</i>					
Orton ¹	34	9,070	48	8,060	71·0
Forres	31	8,830	54	7,690	57·5
Glenmore	29	8,120	44	7,380	66·0
Fetternear	35	8,050	48	7,420	73·0
Nethy Bridge.	12	7,990	27	6,770	44·5
Ballindalloch	38	7,170	51	6,690	74·5
	179		272		
Average of all, lbs. per sq. in.	..	8,200	..	7,380	..
Average of all, cwts. per sq. in.	..	73·2	..	65·8	..

¹ It is to be remembered that the specimens from Orton were, at the time of breaking, drier than the others, see page 377.

square inch, and even the minimum of 7,170 lbs. per square inch, compares favourably with those usually given for foreign timbers of the same class, based on specimens of considerable size.

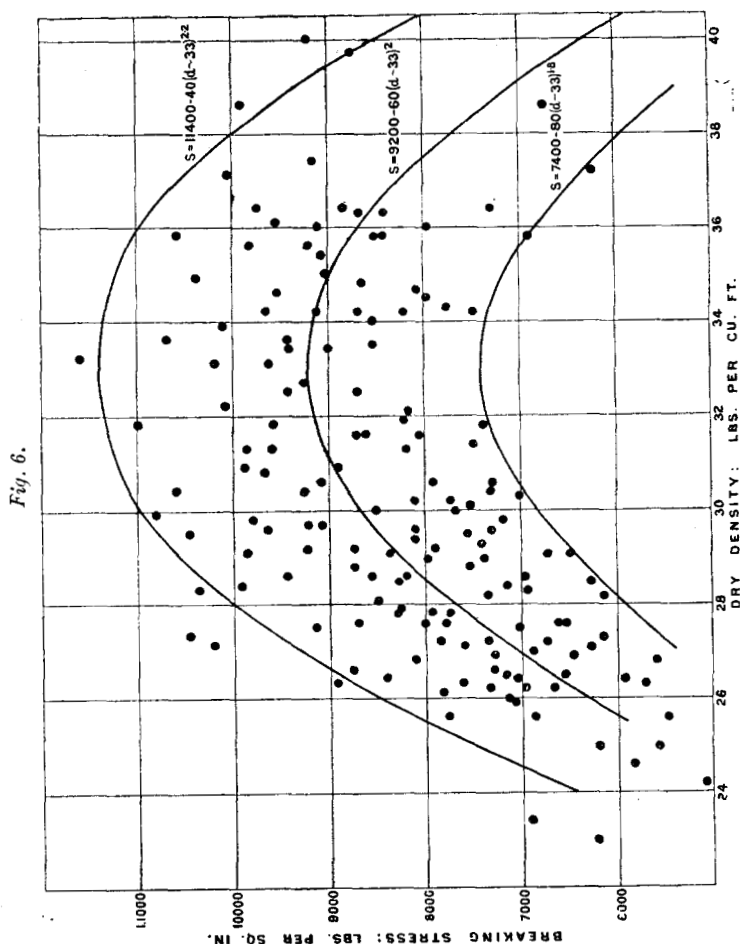
It is not unusual to allow for foreign pine of good quality, which would fall under the category of "normal" as used in the classification here adopted, a working-stress of 9 cwt. per square inch. This stress allows, in the case of the "normal" specimens under review, a dead-load factor of safety of over 8 on the average of all trees; and of over 7 under the worst conditions. For the average of "all" specimens the factor of safety with a stress of 9 cwt. per square inch is 7·3.

A careful examination of the results failed to disclose the existence of any definite relation between strength and the direction of the annular rings; nor did it support, although it did not refute, the opinion generally held that certain portions of the tree are stronger than others.

In some trees the specimens cut from the butt were the strongest; in others, the middle section, while in some cases the greatest strength was developed in those cut from the top of the tree,

Again, and contrary to expectation, there appears to be no definite relation between the breaking-stress and the percentage of sapwood, at least in well-seasoned timber.

When the breaking stresses of all the normal specimens are



plotted against their dry densities, the result suggests the existence of a best dry density, on either side of which the strength of the timber shows a falling off (*Fig. 6*). This ideal dry density appears to be in the region of 33 lbs. per cubic foot.

The breaking stress was plotted against the dry density, and a mean curve, and also two envelopes, were drawn.

If S denotes the breaking stress, in lbs. per square inch,
 d „ „ dry density, in lbs. per cubic foot,

then, for the mean curve,

$$S = 9,200 - 60 (d \sim 33)^2,$$

while the upper and lower envelopes are given by :—

$$S = 11,400 - 40 (d \sim 33)^{2.2}$$

and $S = 7,400 - 80 (d \sim 33)^{1.8}.$

It will be observed that the dry density varied through a considerable range—from 40 to 23 lbs. per cubic foot.

The short grain, and the dust given off at breaking suggested, in some of the fractured specimens, over-maturity; in the majority, the dry density exceeded 33 lbs. per cubic foot. In one specimen, where there was decided evidence of decay, the dry density was 37.2 lbs. per cubic foot. From these observations, there is reason to suggest that, after reaching a certain dry density, probably about 33 lbs. per cubic foot, the resisting power of the timber to cross-breaking becomes reduced.

As was to be expected, the strength of the timber was found to augment with increase in the modulus of elasticity. An examination of the notes relating to the fractures of certain specimens indicates that, while the specimens had been characterized as normal, the breaking load had fallen below the true normal value by reason of knots near to the tension edge which had caused the grain to run out, but such defect does not affect the modulus of elasticity to the same extent.

If S denotes the breaking stress, in lbs. per square inch,
 and E „ „ modulus of elasticity, in lbs. per square inch,
 the mean line in a graph of breaking stress and modulus of elasticity gives:

$$E = 170 S,$$

while the upper and lower envelopes represent :—

$$E = 215 S$$

and $E = 130 S$ respectively.

Substituting the above value of S in the appropriate equations,

the relation between the modulus of elasticity and the dry density, for the mean value, is given by :—

$$E = 170 S = 156,400 - 10,200 (d \sim 33)^2,$$

and, for the upper and lower envelopes, by :—

$$E = 215 S = 2,451,000 - 8,600 (d \sim 33)^{2.2}$$

and

$$E = 130 S = 962,000 - 10,400 (d \sim 33)^{1.8}.$$

The modulus of elasticity is affected, as has been seen, by the dry density, and also by the extent and disposition of knots and other defects. The extent of this variation is shown below :—

TABLE V.—VALUES OF MODULUS OF ELASTICITY.

	Elasticity in 1,000 Lbs. per Square Inch.		Breaking Stress in Lbs. per Square Inch. Normal Specimens.
	Normal Specimens.	All Specimens.	
Maximum of all	2,085	2,085	..
Minimum of all	741	741	..
<i>Average of three trees.</i>			
Orton	1,671	1,581	9,070
Forres	1,374	1,384	8,830
Fetternear	1,374	1,315	8,050
Ballindalloch	1,305	1,267	7,170
Glenmore	1,236	1,196	8,120
Nethy Bridge	1,221	1,177	7,990

The general upward tendency of the breaking stresses for normal specimens with the value of E is seen above.

In the majority of instances curves of deflection against breaking load, which latter is directly proportional to the maximum stress, if the slight variations in the dimensions of the sections are neglected, have the slight upward curvature generally characteristic of timber, while in some, and particularly in the specimens from Glenmore, the lines are straight, up to a load of 5,000 lbs., which corresponds to a stress of about 5,250 lbs. per square inch.

The percentage of moisture in the heartwood varies from 37 to 16, with an average of 27; while that in the sapwood lies between 162 and 106, the average being 130. If x is the fraction of sapwood, a specimen from the average tree conforms to:—

Percentage of moisture, as cut = $27 + 103 x$.

Notwithstanding the fact that many of the specimens upon which the foregoing tests were carried out were stored for nearly a year after felling, no case of blueing occurred, though a number of specimens which were placed in the open immediately after air-drying, give evidence of the development of blueing.

It is generally understood that the blueing of Scots pine is caused by a fungus (*Ceratostoma piliferum*) with which the tree has been infected; there is also reason to believe that the rate of propagation of these fungi, and the extent of blueing consequent therefrom, is more rapid in cases where the timber has not been air-dried under conditions which protect it from the direct action of the weather, than is the case when the timber is exposed to the weather only after air-drying has been resorted to.

The Author is of opinion that, if the moisture-content of the timber is reduced by air-drying under protection from the weather, no appreciable blueing will occur, even if the timber is subsequently exposed to the weather for a short period, as, for example, during the construction of buildings.

CONCLUSIONS.

The conclusions which may be arrived at from the investigations described can be summarized briefly as under:—

(1) The cross-breaking strength and the elasticity of the timber reach a maximum when the dry density is in the region of 33 lbs. per cubic foot.

(2) The cross-breaking strength is proportional to the modulus of elasticity.

(3) The cross-breaking strength appears to bear no definite relation to the inclination of the annular rings to the neutral axis of the beam, to the closeness of the annular rings, or to the distance from the butt of the portion of the tree from which the specimen has been cut.

(4) The cross-breaking fibre stress for selected or "normal" specimens averages 8,200 lbs. per square inch, and for all specimens, 7,380 lbs. per square inch. Allowing a safe fibre stress of 9 cwt. per square inch these figures correspond to factors of safety of 8.1

and 7.3 respectively. The factor of safety in the case of the average specimen from the weakest tree, based on the above-mentioned safe fibre stress, is 7.1. The cross-breaking strength of Scots pine, therefore, compares very favourably with that of foreign timber of the same class.

(5) After air-drying for a period of 4 months the moisture content of both heart and sapwood is in the region of 20 per cent. Further seasoning, under protection from the weather, for a period of 5 months, reduces the moisture content to 15 per cent.

(6) If ordinary precautions are taken to protect the timber from the direct action of the weather during seasoning, blueing will not occur unless the material is subsequently exposed, for a considerable period, to rain.

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The Paper is accompanied by three photographs and eight drawings, from some of which the Figures in the text have been prepared.
