increases if the load is allowed to remain for a considerable time. Lauza found that the deflection of a beam was twice as great after six months as when first the load was applied. This increase in the deformation with the time rate is seen in all timber tests whether in tension, compression, or in cross-bending; it is, however, less decided in seasoned than in unseasoned timber. It is usual to record the time rate of testing as the elongation, or shortening, of the most strained fibres expressed in inches per inch per minute.

In all the tests of the large beams a chronograph was arranged to record the time on the autographic stress-strain diagram, and in the compression tests of short and long columns, a clock beating seconds was observed at the time of recording the deformations, so that the time rate was accurately determined. It was necessary in every test to allow sufficient time for the deformations to be accurately determined, and the amount depended upon the size of the test piece and the quality of the timber. The time rate of the extreme fibre extension in the large beams of 10 in. x 10 in. cross-section, varied from 0.000266 to 0.001182 inches per inch per minute, and the average of all tests, 0.000557.

The extensions in this case were determined on the central portions of the beam by means of a Marten's extensometer, and compared with the chronographic record on the recording drum.

The rate of straining the beams 4 in. x 4 in. x 48 in. centres was 0.00238 to 0.00116 inch deflection per minute, averaging 0.00169 inch per minute. In the beams 2 in. x 2 in. x 24 in. centres the deflection was 0.00394 to .009 inch per minute, and the average 0.00589 inch per minute.

On the column of circular cross-section 12 inches long the time rate was 0.00018 to 0.00087, and the average rate was 0.00038 inch per inch per minute. On the square columns 12 inches long, the time rate was 0.000111 to 0.000560, and the average 0.0002836 inch per inch per minute. On the long columns of square cross-section, the shortening was from 0.000302 to 0.000481, and the average of all tests, 0.0003894 inch per inch per minute. On the circular columns of approximately the same length the rate was 0.000414 to 0.000771, and the average 0.000568 inch per inch per minute.

The time rate of the extensions in the tension tests varied from 0.000400 to 0.001054, and the average was 0.000693 inch per inch per minute. The report of tests made in U.S., America, by Professor W. K. Hatt, just published by the International Association for Testing Materials, gives the following time rates of fibre strain expressed in inch per inch per minute:—

Large beams..	0.0007
Small beams	0.0015
Compression parallel to grain, small pieces ..	0.0030
Do do large pieces ..	0.0015

In official tests a speed variation of 56 per cent. is allowed, as it does not affect the results by more than 2 per cent.

SHEARING TESTS.

The difficulty of making accurate tests of the shearing strength of any material is acknowledged by all authorities. It is generally considered more satisfactory to subject test pieces to a shearing stress on one plane only, or "single shear," than to apply the stress on two planes, or in "double shear." The method adopted in this report has been very carefully considered, and Fig. 22 shows clearly the manner of preparing the specimens, and the method of holding them in the machine. In the writer's report published in 1892, "Australian Timbers," the method adopted did not ensure the determination of the true shearing stress, as a bending moment was necessarily developed, although the ultimate shear was confined to one plane only; but the object of these tests was to determine the shearing strength of timbers used as keys in compound timber beams, such as have been used to a considerable extent in railway viaducts in New South Wales. The method used in this early report was admirably suited to the case, and the results obtained, although much in excess of the true shearing resistance, represents accurately the behaviour of timbers when subjected to shearing stress applied in this way. The method adopted by Professor Johnson, and followed by Mr. Julius in his report on Western Australian Timbers, published in

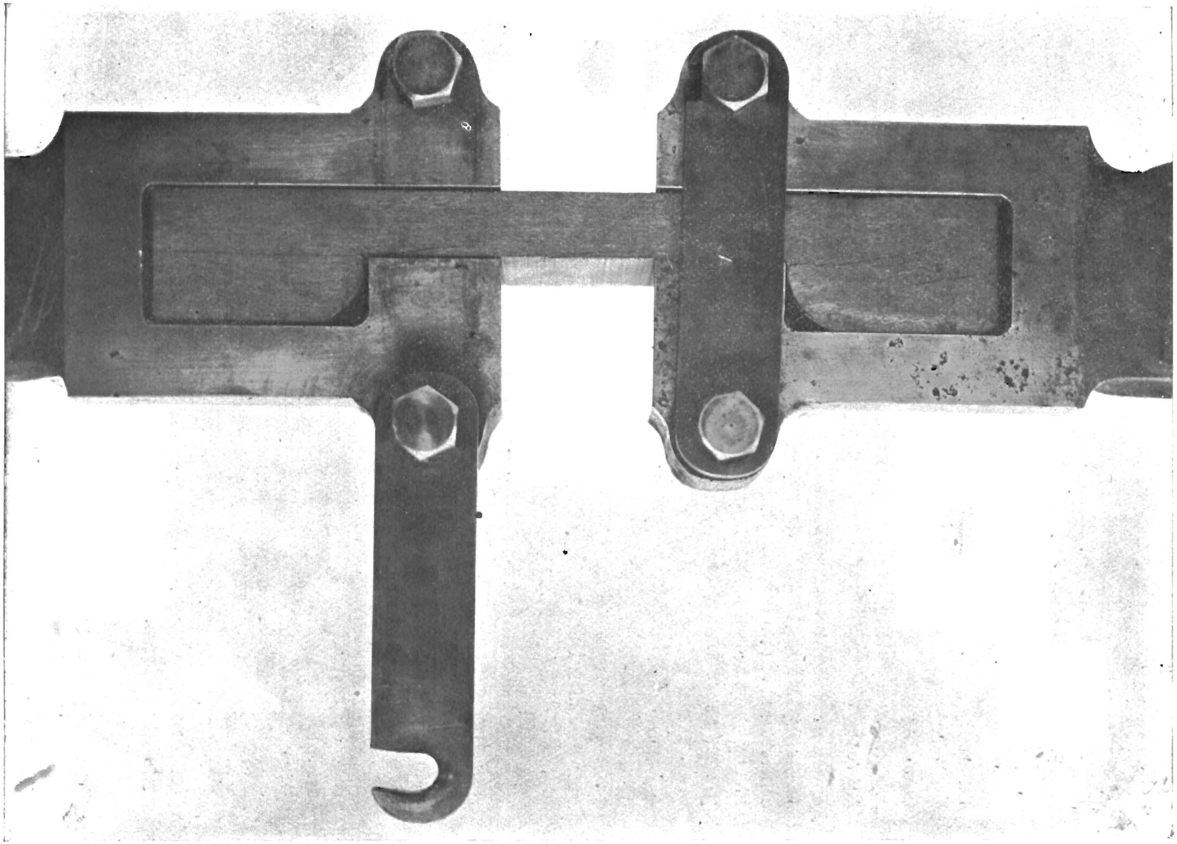


FIG. 22.

1906, in like manner represents the behaviour of timber when tested in double shear, and gives useful data of the shearing strength of timber when used in the manner tested; but it does not give the strength of timber when subjected to a pure shearing stress acting on one plane only, moreover the bending moment is not prevented, although considerably reduced. Many other devices have been used in timber tests, but they are all more or less unsatisfactory, in so far as they express the shearing strength of the timber, although they may serve a useful purpose in so far as they represent the conditions under which timber is used.

The results recorded in Table 6 represent the shearing strength as accurately as possible under the circumstances; the bending moment is very small, and the shear is confined to one plane. If a shearing stress exists on one plane, there will also exist a shearing stress of equal amount on a plane perpendicular to the first plane, and if a shearing stress is applied in a plane tangential to the direction of the annual rings, an equal shearing stress will be developed in a plane normal to the direction of the annual rings, and failure will necessarily occur along that plane where the resistance is least.

In testing beams the horizontal shearing stress along the neutral axis is 50 per cent. greater than the mean shearing stress in the cross-section of the beam, and if the timber was of uniform quality it would always shear along the neutral axis, if it failed by shearing; but timber is not of uniform quality, and the failure occurs along the plane least able to resist the stress developed along that plane. In the tests of large beams recorded in Tables 2 and 3, the presence of gum-veins and other defects determined the selection of the plane of shear in those cases where the beam failed by the horizontal shearing stress, but the intensity of the stress causing the beam to shear is necessarily lower than the true shearing resistance of sound timber of the same kind.

It was originally intended to cut the test pieces so that shearing would take place only tangentially or normally to the direction of the annual rings, but this was not accomplished with all the specimens, and in some cases the plane of shear is more or less inclined to the tangent or normal.

Table 6—New South Wales Timbers. Shearing Tests—New Method

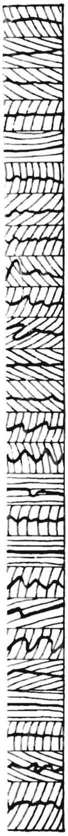
NORTH COAST TIMBERS.

Local Name.	Number and Letter.	Area under Shear.	Number of Days Seasoning	Moisture Percentage.	Total Shearing Load in lbs.	Total Shearing Stress in lbs. per square inch.	Position of Annual Rings and Shear.
Blackbutt	1 D (1)	8.76	693	14.6	6,270	716	
	1 D (2)	8.55	..	14.5	5,570	651	
	1 H (1)	8.70	..	14.2	6,370	732	
Tallow-wood	2 D (1)	8.61	814	14.3	6,950	807	
	2 D (2)	8.70	..	14.4	7,070	813	
	2 H (1)	8.58	..	14.1	6,450	752	
	2 H (2)	8.61	..	15.3	7,100	825	
Grey Gum	3 H (1)	8.73	657	17.1	6,330	725	
	3 H (2)	8.76	..	15.4	8,016	915	
Grey Ironbark	4 D (1)	8.82	674	16.6	6,810	772	
	4 D (2)	8.73	..	16.5	9,870	1,131	
	4 H (1)	8.70	..	16.0	8,040	924	
	4 H (2)	8.82	..	15.5	9,730	1,103	
Blue Gum	6 D (1)	8.76	728	16.2	7,460	852	
	6 D (2)	8.79	..	16.5	7,910	900	
	6 H (1)	8.82	..	14.8	8,310	942	
	6 H (2)	8.79	..	15.0	7,600	865	
Brush Box	7 D (2)	8.64	694	14.8	6,310	730	
	7 H (1)	8.73	.	15.3	8,880	1,014	
	7 H (2)	8.79	..	14.7	7,100	808	
Turpentine	8 D (2)	8.91	674	14.0	6,150	690	
	8 H (1)	8.76	..	14.0	7,610	869	
	8 H (2)	8.76	.	14.5	8,380	957	
Red Mahogany . ..	9 H (1)	8.70	664	15.0	5,100	586	
	9 H (2)	8.67	..	14.4	5,630	649	
White Mahogany ..	10 D (1)	8.76	677	13.8	5,350	611	
	10 D (2)	8.82		15.2	5,020	569	
	10 H (1)	8.70	..	16.0	5,120	589	
	10 H (2)	8.79	..	15.6	3,990	459	
Colonial Teak	11 D (1)	8.76	911	12.7	7,000	799	
	11 D (2)	8.64	..	12.9	7,570	876	
	11 D (3)	8.67	..	13.4	7,580	874	
	11 H (2)	8.79	..	12.8	8,310	945	

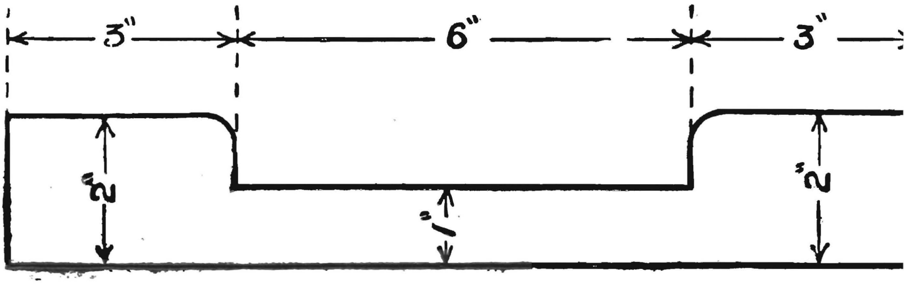
Table 6 *(continued)*—New South Wales Timbers. Shearing Tests—N Method.

SOUTH COAST TIMBERS.

Local Name.	Number and Letter.	Area under Shear.	Number of Days Seasoning	Moisture Percentage.	Total Shearing Load in lbs.	Total Shearing Stress in lbs. per square inch.	Position o Annual Rin and Shear
Grey Box..	12 D (2)	8.64	473	16.6	8,220	951	
	12 H (1)	8.55	..	16.1	7,720	903	
	12 H (2)	8.55	..	16.9	8,620	1,008	
	12 H (3)	8.73	..	16.7	6,940	795	
Woollybutt	13 D (1)	8.37	491	17.0	7,820	837	
	13 D (2)	8.73	..	16.2	7,130	817	
	13 H (1)	8.76	..	15.4	7,450	850	
	13 H (2)	8.61	..	16.5	7,380	857	
Spotted Gum	14 D (1)	8.58	521	17.2	8,350	973	
	14 D (2)	8.67	..	18.1	9,150	1,055	
	14 H (1)	8 61	.	16.4	8,230	956	
	14 H (2)	8.61	..	16.3	7,560	878	
Turpentine	15 D (1)	8.61	448	14.4	6.590	765	
	15 D (2)	8.49	..	15.3	6,920	815	
	15 H (2)	8.73	..	14.7	7,190	824	
Black Butt	16 D (1)	8.43	490	16.2	6,960	944	
	16 D (2)	8.64	..	16.4	5,100	591	
	16 H (1)	8.64	..	14.4	7,220	836	
	16 H (2)	8.64	..	14.6	6,160	713	
Mountain Ash	17 D (1)	8.67	472	14.5	7,220	833	
	17 D (2)	8.76	..	15.1	6,760	772	
	17 H (1)	8.67	..	14.8	6,450	744	
Stringybark..	18 D (1)	8.34	456	15.8	5,840	700	
	18 D (2)	8.55	..	15.8	4,990	584	
	18 H (1)	8.49	..	14.7	6,350	748	
	18 H (2)	8.64	..	14.3	6,070	703	



Size of test pieces: Length, 3 inches. Breadth, approx. 2·9 inches.



In the case of all the best pieces recorded in Table 6, the failure occurred in the plane of shear, whatever its position relatively to the plane of the annual rings.

The Table 6 of results show that the timber was well seasoned, and yet the results are lower than those obtained by the method adopted in the series of tests published in 1892. This is due mainly to the fact that in this series the bending moment was practically zero.

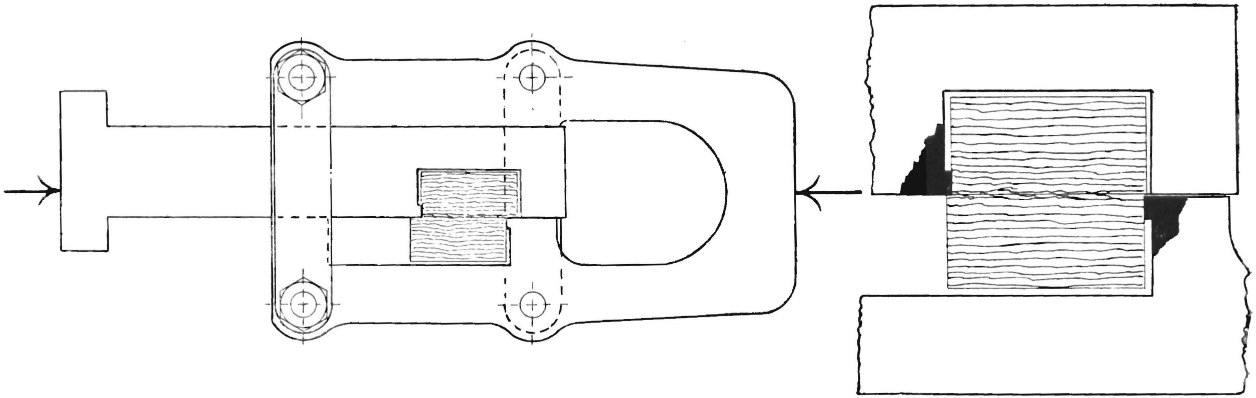
In order to obtain some further information on this subject, the apparatus used in the 1892 series has been modified so that the bending moment is considerably reduced, as the parts pressing on the timber were only $\frac{1}{2}$ inch wide, so that the lever arm of the moment is only $\frac{1}{2}$ inch. The apparatus used in this case is shown in Fig. 23, and Table 7 gives the results.

The results recorded in Table 7 are higher than those on Table 6, yet the influence of the small bending moment does not, in the writer's opinion, account for this difference, although it may have contributed to it.

Figs. 24 and 25 represent the appearance of the blocks after testing by shearing. In Fig. 24, the right-hand piece is Woollybutt, and the left-hand piece Grey Box In Fig. 25 both blocks are Colonial Teak.

TORSION TESTS.

The stress at the surface of a specimen subjected to a stress of pure torsion is a shearing stress, and it was considered desirable to obtain the results of testing specimens in torsion for the purpose of comparing them with the results obtained by the two methods of testing for direct shear. There is no bending moment in this case to complicate the shear, but the failure is due to the stress developed at the outside surface, and is somewhat analogous to the normal-failure of a beam subjected to bending, which also is due to the stress developed at the extreme fibres. The assumptions made in deriving the equations expressing the moments of resistance in both torsion and bending do not apply, even approximately, after the elastic limit (limit of proportionality between the stresses and strains) has been exceeded. If d denotes the diameter of a shaft subjected



Enlarged View of Jaws.

FIG. 23.

Table 7.—New South Wales Timbers. Shearing Tests.

Local Name.	Direction of Shear. A with grain B against	Number of Tests.	Moisture Percentage. Average.	Shearing Stress. lbs. per square inch. Average.	Number of Days Seasoning.
NORTH COAST TIMBERS.					
Blackbutt	A	3	15.7	1,693	1,213
	B	3	15.8	1,520	1,213
Tallow-Wood	A	5	15.0	1,530	1,331
	B	5	14.8	1,488	1,330
Grey Gum	A	10	15.8	1,788	1,175
	B	10	16.2	1,680	1,176
Grey Ironbark	A	10	16.7	1,957	1,192
	B	10	16.8	1,833	1,192
Blue Gum	A	10	16.2	1,533	1,181
	B	10	15.6	1,430	1,183
Turpentine	A	10	17.4	1,637	1,190
	B	10	17.0	1,517	1,191
Red Mahogany	A	10	15.9	1,597	1,181
	B	10	15.2	1,516	1,183
White Mahogany	A	7	15.8	1,480	1,195
	B	7	15.8	1,381	1,196
Colonial Teak	A	10	13.2	1,483	1,423
	B	10	13.2	1,411	1,423
SOUTH COAST TIMBERS.					
Grey Box	A	10	16.1	1,871	986
	B	10	15.8	1,611	985
Woollybutt	A	10	16.4	1,667	1,003
	B	10	16.9	1,545	1,004
Spotted Gum	A	10	15.5	1,644	1,033
	B	10	14.8	1,568	1,035
Turpentine	A	10	16.5	1,688	961
	B	10	16.7	1,510	960
Blackbutt	A	10	16.6	1,596	1,003
	B	10	17.0	1,474	1,004
Stringybark	A	10	16.1	1,655	969
	B	10	16.1	1,454	968

Number of Tests, 10 in each case.

Test pieces, 4in. cube.

FIG. 24.

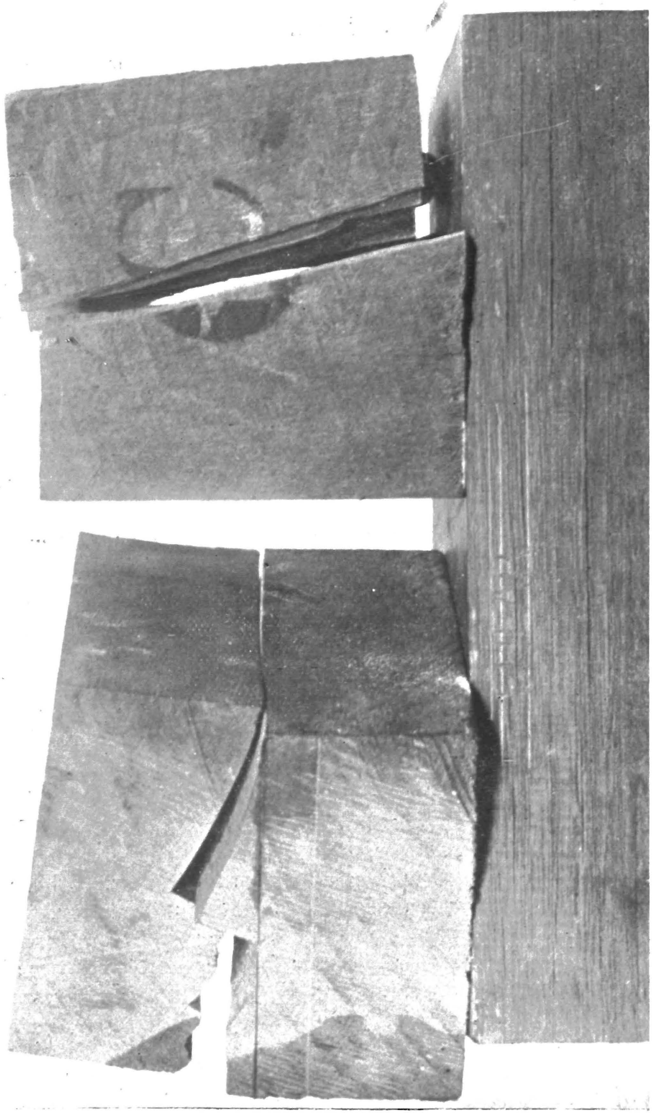


FIG. 25.

to torsion, the moment of resistance may be shown to be:—

$$T = 0.196 d^3 \sigma_s$$

where T denotes the twisting moment and σ_s the shearing stress at the surface only, when this stress is within the elastic limit of the material.

Again, in regard to bending, the moment of resistance may be shown to be:—

$$M = 0.098 d^3 \sigma$$

where M denotes the bending moment, and σ the extreme fibre stress only, when this stress is within the elastic limit of the material.

If σ_s in torsion, and σ in bending are each calculated from the results of tests in which T and M produce fracture, then

$$\sigma_s = \frac{T}{0.196 d^3}$$

and

$$\sigma = \frac{M}{0.098 d^3}$$

do not express the stress at the surface or extreme fibre, and the expressions are in each case empirical.

σ is termed the "modulus of rupture" in bending or transverse tests, and exceeds the strength of the material which would produce failure if applied directly to a piece of similar material, so that the stress was distributed uniformly over the area of the cross-section, as in the tension tests of a piece of timber or steel, or the compression tests of short prisms.

In like manner, σ_s is not the shearing strength of the material, and the results obtained by torsion, although developing a pure shear, cannot be compared with those of direct shear, and will in all cases be higher. The relative shearing resistances of various timbers, however, tested in this manner by torsion, probably are more accurate than those obtained by direct shear, in consequence of the absence of a bending moment. But the absolute values recorded in the Plate VI. are only the stresses at the outer skin at failure.

The modulus of rupture recorded in the strength tests of beams, and the value of σ_s in torsion tests are useful constants of strength, but their exact meaning should be clearly understood.

Fig. 26 shows a test piece fixed in the torsion testing machine with the extensometer attached to the specimen for recording the small twists which occur within the elastic limit of the material, also an autographic stress-strain apparatus recording the loads and deformations from zero load up to the point of fracture.

Fig. 27 shows the extensometer more clearly.

Fig. 28 shows some of the specimens after testing, indicating the various modes of fracture. The moisture percentages indicate the dryness of the timbers at the time of testing, which is accounted for by the number of days seasoning.

The method of obtaining the figures in some of the columns in Plate VI., may need some explanation.

Maximum Twisting Moment, T.—This is the moment causing fracture in the testing machine expressed in inch pounds.

For Blackbutt, 1D, T = 1,440 inch pounds.

For Tallow-wood, 2D, T = 1,880 inch pounds.

Maximum Shear Stress, σ_s.— The real meaning of σ_s has already been explained; it has been calculated in the following manner:—

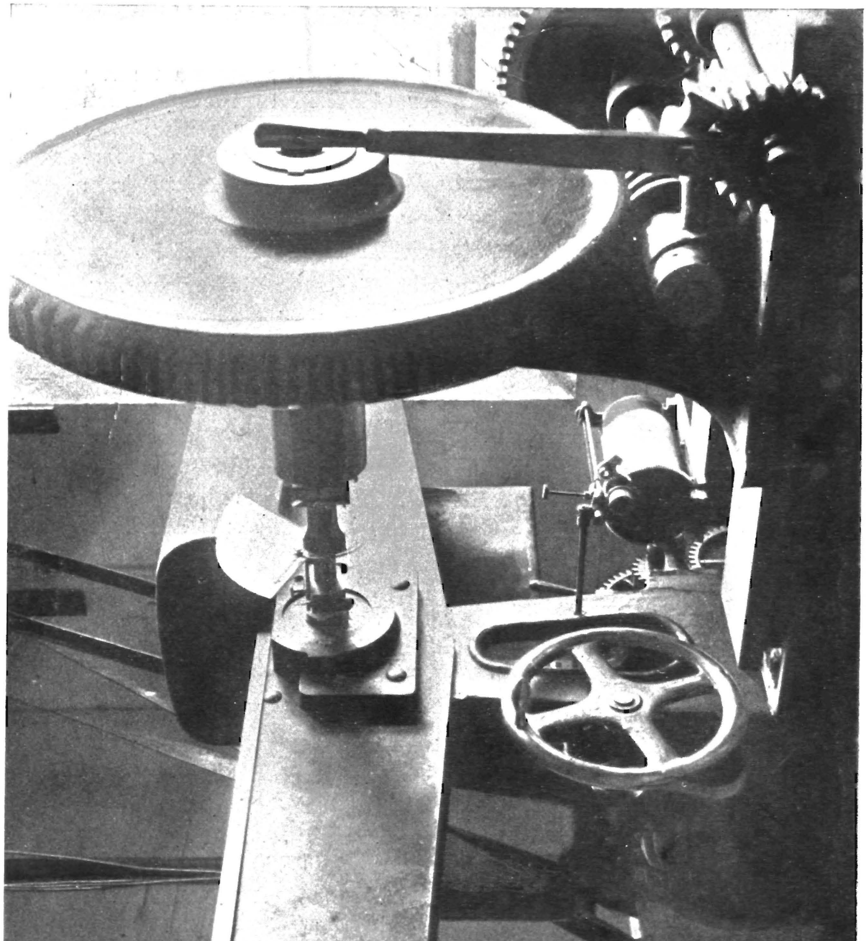
$\sigma_s = \dfrac{T}{0.196 d^3}$ For Blackbutt, 1D, $\sigma_s = \dfrac{1{,}440}{0{\cdot}196 \times 3{\cdot}375} = 2{\cdot}180$lb. per square inch.

For Tallow-wood, 2D, $\sigma_s = \dfrac{1{,}800}{0{\cdot}196 \times 375} = 2{,}720$ lb. per square inch.

Coefficient of Rigidity, C.—This quantity, like the coefficient of elasticity, is the ratio of the stress to the corresponding strain, within the elastic limit of the material.

The stress in this case is the shearing stress, σ at the surface of the cylindrical test piece.

The strain is the angular displacement of two cross-sections perpendicular to the axis of the test piece, one of



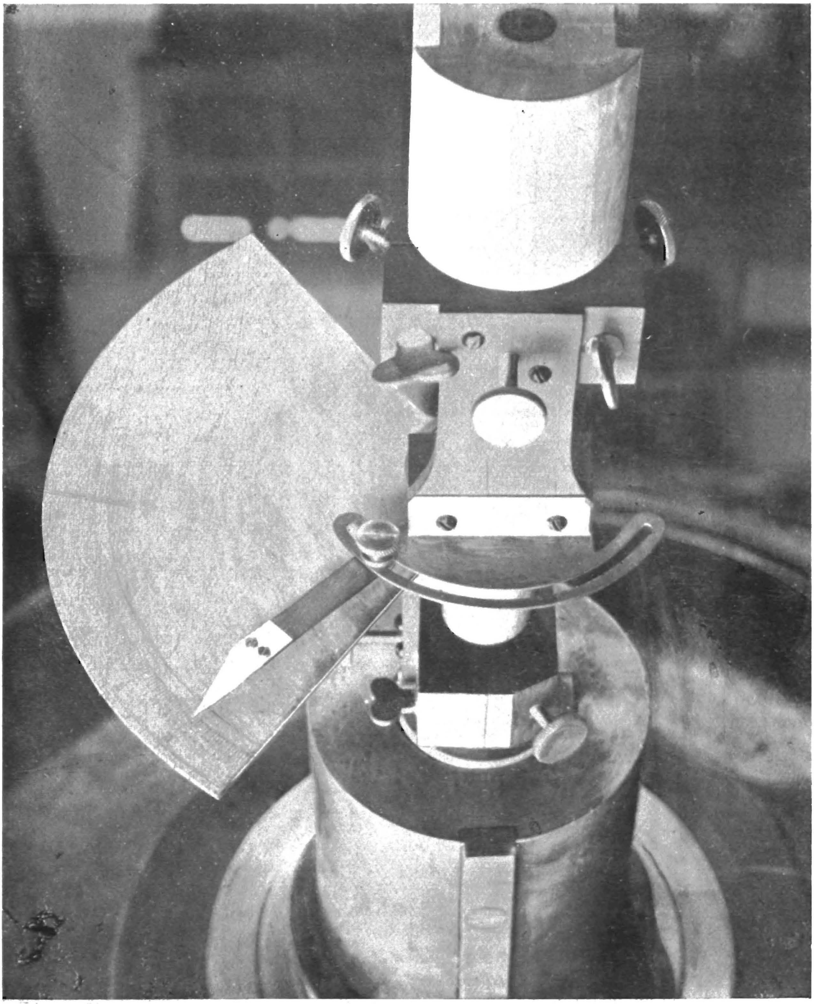


FIG. 27.

FIG. 28.

which is considered fixed relatively to the other. If we denote the angle on the surface by ϕ, and the distance between the cross-sections parallel to the axis of the cylinder by unity, the coefficient of rigidity denoted by C is:—

$$C = \frac{\sigma}{\phi}$$

If dx denote the distance between the cross-sections and $d\theta$ the angle subtended at the centre, then $\phi dx = r d\theta$, where r denotes the radius.

If i denote the angle of torsion per unit of length:—

$$i = \frac{d\theta}{dx} = \frac{\phi}{r} = \frac{\sigma}{Cr}$$

It can be shown that:—

$$T = \frac{\pi}{2}\frac{r^3}{}\sigma = 0.196\, d^3\sigma$$

$$\therefore\ i = \frac{2T}{\pi C r^4} \text{ and } C = \frac{2T}{\pi i r^4} = \frac{32T}{\pi i d^4}$$

If θ = the total angle between the two cross-sections of the test piece at l distance apart:—

$$C = \frac{32Tl}{\pi\theta d^4}, \text{ where } \theta = \text{the angle in radians.}$$

Let θ^1 = angle of twist in radians per 100 inch pounds, then:—

$$C = \frac{32 \times 100 \times 8}{\pi(1{\cdot}5)^4} \times \frac{1}{\theta^1}$$

If θ^0 is expressed in degrees, then:—

$$C = \frac{32 \times 100 \times 8}{\pi(1.5)^4} \times \frac{180}{\pi} \times \frac{1}{\theta^0} = 0.92 \times 10^5 \times \frac{1}{\theta^0}$$

In the case of Blackbutt, 1D, the angle in degrees observed by means of the extensometer attached to the test piece for two cross-sections spaced 8 inches apart was 0.689 per 100 inch pounds, then:—

$$C = 0{\cdot}92 \times 10^5 \times \frac{1}{0{\cdot}689} = 1.34 \times 10^5 \text{ pounds per square inch.}$$

Resilience of Torsion.—The resilience of torsion is the work expended in producing elastic strains in torsion. It can be shown that this resilience may be expressed thus:—

$$\text{Resilience} = \frac{16T^2 l}{\pi C d^4} = 8.05 \frac{T^2}{C}$$

where T denotes the twisting moment at the elastic limit of the material.

HARDNESS TESTS.

An investigation has been carried out by Mr. G. E. Cowdery, B.E., under the supervision of the writer, with a view to ascertaining not only the comparative hardness of the different timbers under test, but also to compare the different methods of arriving at the hardness. Also a comparison is made showing the hardness of the three planes relative to the directions of fibre and annual rings. Thus there are three investigations to consider. In the first method used, namely, "cross-compression," or the sleeper test, no experiments were made in a direction parallel to the fibre, as this would be difficult and almost useless from a practical standpoint. In the "Brinell-Ball test" and the "cone pressure test" methods the hardness along the direction of the fibre was taken, not because it might be of much practical values, but because it would exhaust the possibilities of the test and lead to at least a negative if not to a positive conclusion.

The full details of these tests, however, cannot be dealt with in this paper. But the table given, No. 8, is a summary of the results obtained. As the hardness perpendicular to the annual rings is the test of greatest practical importance, the last column in the table gives the relative orders of hardness from the three methods combined in that direction.

SAND-BLAST TESTS OF NEW SOUTH WALES TIMBERS.

These tests were carried out by Mr. J. MacD. Royle, B.E., under the supervision of the writer, with a view to obtaining the relative values of timbers for wood blocking, flooring, and similar purposes.

It is very difficult to get a suitable test for these properties of materials; but of all tests so far devised, the sand-

Table 8.—Summary of Hardness Tests.

Name.	Number.	Moisture percentage.	Cross Compression, Across Rings. Lb. per square inch.	Cross Compression, Along Rings. Lb. per square inch.	Brinell Ball Test. Hardness Numbers. Across Rings.	Brinell Ball Test. Hardness Numbers. Along Rings.	Brinell Ball Test. Hardness Numbers. Along Fibre.	Cone Pressure Test. Hardness Numbers. Across Rings.	Cone Pressure Test. Hardness Numbers. Along Rings.	Cone Pressure Test. Hardness Numbers. Along Fibre.	Relative Order of Hardness from 3 Methods Combined.
North Coast—											
Blackbutt	1	16.0	2,350 L.	1,925 L.	3.90 L.	3.80 L.	6.90 M.	5.4 L.	4.5 L.	7.1 L.	16
Tallow-wood	2	16.0	2,575 M.	2,150 M.	4.65 H.	4.85 H.	6.80 L.	6.6 H.	5.4 M.	6.6 L.	7
Grey Gum	3	17.5	3,250 V.H.	2,750 V.H.	5.40 V.H.	5.85 V.H.	8.85 V.H.	8.5 V.H.	7.0 V.H.	10.0 V.H.	1
Grey Ironbark ...	4	16.5	3,025 V.H.	2,500 V.H.	5.75 V.H.	6.75 V.H.	9.55 V.H.	8.0 V.H.	7.4 V.H.	9.7 V.H.	2
Blue Gum	6	15.0	2,150 L.	1,950 L.	4.55 H.	3.95 M.	7.10 H.	5.4 L.	5.2 L.	7.1 L.	11
Brush Box	7	16.5	2,875 H.	2,200 H.	4.40 H.	4.20 M.	6.65 L.	6.8 H.	6.4 H.	8.0 M.	6
Turpentine	8	16.5	3,100 V.H.	2,875 V.H.	5.15 V.H.	5.30 V.H.	9.00 V.H.	8.0 V.H.	7.4 V.H.	9.7 V.H.	3
Red Mahogany ..	9	17.0	2,525 M.	2,150 M.	4.00 M.	4.35 H.	6.85 L.	5.2 L.	5.5 M.	7.4 M.	13
White Mahogany .	10	18.5	2,750 M.	1,975 L.	4.40 H.	4.80 H.	8.20 H.	6.4 M.	6.2 M.	7.8 M.	8
Colonial Teak	11	14.0	2,975 H.	2,425 H.	3.80 L.	3.55 L.	6.85 L.	5.0 L.	5.5 M.	7.1 L.	14
South Coast—											
Grey Box	12	17.0	3,125 V.H.	2,650 V.H.	3.95 M.	3.80 L.	7.00 H.	7.4 H.	7.4 V.H.	8.8 H.	5
Woollybutt	13	18.0	2,650 M.	2,200 H.	4.35 M.	4.45 H.	7.40 H.	6.8 H.	6.4 H.	9.1 H.	9
Spotted Gum	14	17.0	2,825 H.	2,225 H.	4.30 M.	3.70 L.	7.00 H.	5.9 M.	6.4 H.	7.4 M.	10
Turpentine	15	18.5	2,300 L.	1,750 L.	3.85 L.	4.25 M.	6.90 M.	5.5 M.	4.9 L.	8.8 H.	17
Blackbutt	16	15.0	2,500 M.	2,100 M.	4.30 M.	4.05 M.	7.90 H.	4.9 L.	5.5 M.	8.5 H.	15
Mountain Ash ...	17	14.0	3,125 V.H.	2,375 H.	4.80 V.H.	4.80 H.	6.90 M.	7.8 V.H.	6.6 H.	10.0 V.H.	4
White Stringybark	18	17.0	2,350 L.	2,075 M.	3.90 L.	3.45 L.	5.60 L.	6.1 M.	5.0 L.	7.1 L.	12

V.H., very hard; H., hard; M., medium; L., Low.

blast method appears to be the best, as the material in this method is actually worn away by abrasion.

It is possible to block, for instance, different parts of tne same street with different timbers; but experiments like these would necessarily last several years, in order to obtain results of any value, as far as the resistance to wear of the various timbers is concerned, and even then it would be most difficult to say that the different kinds of timbers had been subjected to the same conditions.

Description of the Apparatus.

A diagrammatic view of the sand-blast apparatus is shown in Fig. 29.

The apparatus consists essentially of a nozzle, through which sand can be propelled at a high velocity by means of a jet of steam.

This is carried out in the following manner:—

Steam from the boiler (not shown) enters the cylinder *a* at *b* (Fig. 29). Part of this steam flows straight to *c*, where it exhausts to the atmosphere through a nozzle, thus causing a partial vacuum around *c*. The remainder flows up through a valve at *d*, tray *e*, and nozzle *f*, to the expanding nozzle *g*, where it gets completely dried and superheated. The sand is contained in the reservoir ∞, from which it trickles down through the opening *i*, and nozzle *j* on to the tray *e*.

The jet of steam rushing with high velocity through *e* causes a partial vacuum, so that the sand which has fallen on *e* enters through the small aperture *k*, and is caught up by the jet of steam which carries it upwards and projects it against the specimen *l*.

After impact with *l*, the heavier portions of the sand fall downwards into *h*, from which it may be removed from time to time.

The exhaust jet *c* already mentioned produces a partial vacuum, and in the manner indicated by the arrows, causes the exhaust steam and dust in chamber *m* to rush down through *n* into *o* and *q* from which it escapes to the atmosphere at *r*.

By means of *r*, we can shut off the jet of steam and sand from the specimen.