Tension.—Some of the specimens tested extended slightly, but very irregularly before failure occurred, others broke suddenly without extending. The pieces tested were turned down for a length of 10 inches to a diameter of ½ inch, and the results of a few of the principal ones are given below.

Experiments made on full sized tension joints, similar to those shown on plates 17 and 18 gave the safe working strength of bolts one inch in diameter as 1·34 tons, and of 1⅛ inch diameter bolts as 1·85 tons in single shear ; in all cases the joints failed by the bending of the bolts and the crushing of the fibres of the timber.

The maximum tensile strength of the best ironbark *E. Paniculata* and *Crebra* is over 11 tons per square inch.

TIMBER.	BREAKING LOAD IN LBS. PER SQUARE INCH. MAXIMUM.	MINIMUM.	NUMBER TESTED.
Ironbark	25,800	10,900	17
Turpentine	23,000	12,500	8
Grey Gum	19,100	16,300	2
Tallowwood ...	21,700	6,800	6
Spotted Gum ...	22,400	10,800	10
Blackbutt	28,000	14,200	10
Grey Box	13,200	6,600	3
Forest Red Gum ...	16,100	8,500	5
Bloodwood	20,200	7,100	6
Mahogany	28,600	14,000	6
Red Box	23,400	20,800	3
Giant Gum	23,100	...	1
Blackwood	19,500	11,800	6
Jarrah	18,000	11,700	4
Western Red Gum ...	22,700	...	1
Blue Gum	27,500	25,300	2
Murray Red Gum ...	8,500	8,000	2
Coachwood	15,600	10,300	4
Black Bean	10,800	7,900	2
Red Cedar	...	...	0

Compression.—Specimens 3 inches square and 12, 24, 48, 72 and 108 inches long were tested, and it was found that when the ratio of length to least dimension was as 4 to 1 and 8 to 1, the specimens failed by crushing of the timber, when 16 to 1 generally by crushing but a few by lateral flexure, when 24 to 1 by crushing in the best hardwoods, by lateral flexure in the others, but when 36 to 1 all failed by lateral flexure.

A few of the principal ones are given below, and the ultimate strength of the best ironbark in compression is 5 tons per square inch.

TIMBER	Ratio of Length to Least Dimension									
	4 to 1		8 to 1		16 to 1		24 to 1		36 to 1	
	MAX.	MIN.	MAX	MIN.	MAX.	MIN.	MAX.	MIN.	MAX	MIN.
Ironbark ...	12,600	8,100	11.600	7,600	11.600	7,900	8.700	6,300	8.300	6,300
Turpentine ...	10,500	6.300	9,400	5.700	8 700	5 600	6,800	4.500	5,400	4,500
Grey Gum ...	10 400	9 200	10 300	10.100	9.600	6.700	7,400		5.100	
Tallowwood ...	10,400	7.300	11.100	5.900	10,300	5.500	6,800	4.500	5,200	4,100
Spotted Gum ...	10,900	6.600	10,000	6,500	10.000	6,400	7.800	5,000	5,300	
Blackbutt ...	10 300	7.300	10,600	5 700	10,600	4.700	8.700	3,500	6,100	5.900
Grey Box ...	10,200	6 900	9.400	6.500	8.800	5.900	6,800	4,700	5,200	3.500
F. Red Gum ...	10,000	5,000	8,800	4,600	8.400	5,100	6 600	3,000	5.000	
Bloodwood ...	11.700	4,800	11,500	4.700	10.500	4,100	7.700	6.300	6,400	3 900
Mahogany ...	10,100	6,800	10,300	4.700	9,900	5,600	8,300	4,800	5.600	
Red Box ...	8.500	7,600	8,600	8.500	8,100	8,000	7.400	7,100		
Giant Gum ...	7 900	7,300	9,100	8.300	7,500	6,300	6.100		4 400	
Blackwood ..	8.300	6,600	8,700	6,900	7.500	6,500	7 200	5,200	4 000	
Jarrah	7 900	5.900	9,400	5.400	7.500	4.600	5,200	4,200	4.500	3,500
W. Red Gum ...	6,200	5,700	5,100	5,000	5.300	5,200	3.500		3,400	
Blue Gum ...	9,100	8,900	10,500	9,000	7.400	7.000	5,500		5,200	
M. Red Gum ...	8.100	7,100	5,900	4.400	6,900	6,000	4,600		3 300	
Coachwood ..	6,600	5 400	6,800	6,400	5,600	4,700	4.200	3,800	3.600	3.300
Black Bean ...	7.400	7.300	6.300	5.900	5.700	5.100	5.500	4.700		
Red Cedar ...	3.200	2.600	3,000	2,800	2.700	2,300	2.000		969	

Shearing.—The specimens were 6 inches long, 4 inches wide, 2 inches thick, and in every case the shear took place along the grain, though the apparatus was always arranged to develop shear across the grain.

TIMBER.	Shearing Load in lbs. per square inch. MAXIMUM.	MINIMUM.	NUMBER TESTED.
Ironbark	2,450	1,450	18
Turpentine	2,150	1,250	8
Grey Gum	2,150	1,900	2
Tallowwood ...	2,200	1,100	8
Spotted Gum ...	2,550	1,500	9
Blackbutt	2,300	1,650	9
Grey Box	2,500	1,900	4
Forest Red Gum ...	2,300	1,800	6
Bloodwood	2,650	1,450	6
Mahogany	2,150	1,550	6
Red Box	2,450	1,650	4
Giant Gum	1,450	1,400	2
Blackwood	2,750	2,000	4
Jarrah	1,950	1,800	4
Western Red Gum ...	1,600	1,500	2
Blue Gum	2,050	1,900	2
Murray Red Gum ...	1,650	1,350	2
Coachwood	2,050	1,850	4
Black Bean	2,650	2,300	2
Cedar...	1,500	1,450	2

Comparative Strength of Ironbark and Iron.—With the best ironbark the ultimate tensile strength is 11 tons, and the compressive 5 tons per square inch, with wrought iron the ultimate tensile strength is 22 tons per square inch, and the compressive 17 tons.

Tension.—In tension 22 square inches of ironbark are as strong as 11 square inches of iron, and 264 cubic inches of ironbark are as strong as 132 cubic inches of iron. 264 cubic inches ironbark at 75 lbs. per cubic foot weigh 11·5 lbs. 132 cubic inches iron at 485 lbs. per cubic foot weigh 37·0 lbs., so for equal strength the comparative weight of ironbark and iron is as 11·5 is to 37·0, or as 1 is to 3·2.

Taking iron at £24 per ton, and ironbark at 5s. per cubic foot, allowing 30 cubic feet to 1 ton.

Cost of 1 ton of Ironbark is £7 10s.

Cost of 3·2 tons of iron is £76 16s.

Compression.—In compression 17 square inches of ironbark are as strong as 5 square inches of iron, and 204 cubic inches of ironbark as strong as 60 cubic inches of iron. So for equal strength the comparative weight of ironbark and iron is as 8·8 lbs. is to 16·8 lbs., or as 1 is to 1·9.

Cost of 1 ton of ironbark is £7 10s.

Cost of 1·9 tons of iron is £45 12s.

As an offset, however, the factor of safety in timber is generally double that in iron, the timber also decays and has to be replaced, and the material provided above what is actually required, is always much greater in a timber than in an iron structure.

APPLICATION OF TIMBER TO THE DESIGN OF VARIOUS WORKS.

Temporary Works.—Timber is largely used in all Engineering works when being constructed, though none may be required in the finished work. An enormous quantity is consumed annually in this way, as mining and shoring props, scaffolding for the erection of buildings, bridges and similar works, and in manifold other ways. Economy is considered, and the timber allowed to carry much greater loads than otherwise, and, as it is only temporary work, all kinds of hard and soft woods are employed.

Minor Works.—Timber is extensively used in such works as fencing, gates, platforms, buffer stops, box and log drains, culverts, flood openings, &c. Split and rough timber is mostly used, and the sizes determined by experience. The timber generally used is the local hardwood, and in this class of work many timbers have lasted over 40 years. For gates and similar work, the lighter and readily worked pines and softwoods are used.

Sleepers.—Railway sleepers are another important use. They are exposed to all kinds of weather, and must be elastic, strong, and durable. Ironbark, jarrah, Murray red gum, and grey gum are the best, though bloodwood, sugar gum, mahogany, blue gum, and other hard woods are employed.

Plain Beam Bridges.—The high and low level bridges, as erected in New South Wales, with slight modification of detail, are the same all the world over. In the low level bridges the girders and piles are spaced closer together, owing to the extra strain on them in flood time. The timbers preferred in N.S.W. are ironbark for the girders, and tallowwood for the decking; whilst in other colonies jarrah, red, grey and spotted gums, box, mahogany, stringybark, bloodwood, etc., are extensively used.

Strutted and Compound Beams.—For road bridges 35 feet, for narrow-gauge raiiways 26 feet, and broad-guage railways 15 feet, are about the maximum spans used for a single girder. If longer spans are required, strutted or compound beams are adopted. Strutted beams are not a good form, as they put a bending stress on the piers. Compound beams consist of two or more simple beams bolted and keyed together, to act like a large girder of the same section. They are calculated for bending, but the design of the keys and bolts, to take up the horizontal and vertical shear, is the chief feature. In the old type of road bridge the keys and bolts both vary, but in the later designs the keys are proportioned to take up the horizontal shear, and the bolts made of one size throughout, viz., 1¼ inches diameter. Several 50 feet spans have been erected, with bolts of a uniform size, and answer all requirements. They are lighter in ironwork, cheaper, and the labour and the number of tools for boring are reduced to a minimum. In the 24 feet railway spans, the keys are proportioned to take up the shear, and are put in diagonallv, so that the whole face bears on one girder, and gives the maximum of bearing with the minimum of cutting, whereas with a key let equally into the two girders, only half the key bears on one girder. These diagonal keys are made in three pieces, and are kept from falling out when slack by spikes, and are easily tightened by driving up the centre key. The bolts are not proportioned to take up the vertical shear, but are in two sizes, ⅞ inch diameter through two, and 1⅛ inch diameter through three timbers. In one 24 ft. span there are three girders, the two outside ones bolted and keyed together, but, as it would be awkward to drive up the keys in the centre girder, they are omitted.

Trusses and Arches.—The truss and arch are called into use for economy and engineering reasons, when the span exceeds 50 feet. A Howe truss 60 feet span has lately been adopted by the Railway

Construction Branch in New South Wales, and a minimum of metal work, consistent witk good design, is used. For road bridges the spans vary from 70 to 150 feet, and are of the Howe type. In New South Wales ironbark is used in the construction of these trusses.

Piers.—Timber (both round and squared) is extensively used in piers. In earth, piles are driven to give them sufficient bearing power, or are silled at the surface of the ground or a few feet below, and sometimes the timber sill is encased in concrete. In rock they are planted or lewised. When planted, a hole is excavated in the rock a foot or two deep, about the same size as the pile, and grouted with mortar after the pile is placed in position. When lewised, the excavated hole is larger and deeper, the piles are tightened by wedges, and all spaces filled with cement grout. Often the piles are encased with concrete for a few feet at the bottom, and rest on the surface of the rock.

Wood-Paving.—The first wood-paving in Sydney was opened for traffic in August, 1880, and was laid in King-street, between George and Pitt-streets. The blocks, 9 inches x 6 inches x 3 inches were laid on 6 inches of concrete, and kept 1 inch apart by 2 inch x 1 inch timber strips, and the rest of the joint filled with tar and sand. The timbers experimented on were red, blue, and spotted gum, blackbutt, mahogany, turpentine, brush box, pine and cedar.

The blocks wore very much, and rounded at the edges. Under these circumstances (1 inch joint) blackbutt wore at the rate of 1-26th inch per annum, turpentine 1-17th inch, red and blue gum about 1-10th inch, and mahogany 1-8th inch, and for durability and wear these timbers proved most suitable.

The joints were reduced from 1 inch to $\frac{1}{2}$ inch x $\frac{3}{8}$ inch. The spaces between the blocks were filled with tarred screenings, battens, concrete, and in the latter case wrought iron studs were used to maintain the joint. Owing to the expansion of the blocks across the roadway, it was found necessary to leave a space along the kerbs, which was afterwards filled with puddled clay.

The tendency to reduce the distance between the blocks resulted in laying the blocks close together on grades less than 1 in 30, and with $\frac{1}{4}$-inch spaces, filled with bare battens, on grades steeper than 1 in 30. The steepest grade paved is 1 in 13, and that only for a short distance. On wet days the blocks are sprinkled with sand, to give horses a better foothold; otherwise the blocks are not unduly slippery, and when laid with close joints, or with $\frac{1}{4}$-inch spaces, are almost noiseless, easily cleaned and maintained. The wider jointed pavements, though affording a better foothold, are unduly noisy and more difficult to clean.

Wood-paving is now laid in a bed of concrete 6 inches to 9 inches thick, floated to give a uniform surface and convexity, which varies from 1 in 40 to 1 in 80. The blocks are laid close-jointed when the grade is less than 1 in 30, and with $\frac{1}{4}$-inch joints when steeper than this. An expansion joint, $1\frac{1}{2}$ inch or 2 inches wide, is left along the kerbs, and is filled in with clay puddle, mastic asphalt, tar, and cork, or similar elastic mixtures. The timbers preferred are blackbutt, tallowwood, and mahogany, though red and blue gum and turpentine are also used. The blocks are sawn 9 inches x 6 inches x 3 inches. Three rows are laid longitudinally along the kerb to form the gutter, the others are laid transversely or diagonally across the street, the rows breaking joint with one another, and after ten or twelve rows are laid, the blocks are driven up tight. The blocks are coated with tar, or some preservative oil before laying, and, when laid, the surface is thoroughly coated with hot tar, and sprinkled with coarse sand and small gravel, which is well swept until all the interstices at the sides and ends of the blocks are watertight. When so laid, the rate of wear of blackbutt, tallowwood, and blue gum is about 1-50th inch per annum; the average number of vehicles of all descriptions was 186 per hour; the roadway was 40 feet wide.

The cost of wood-paving has gradually decreased from 25s. to 15s. per superficial yard, which is about its present value, the blocks costing about £6 per 1000 for supply and delivery. Some of the older pavements with wide joints have been taken up, the blocks re-cut and re-laid at a cost, including repairs to floating, of 2s. $4\frac{1}{2}$d. per superficial yard.

The life of wood-paving with wide joints has proved to be not less than 16 years; but with close joints, where the rate of wear is so much less, if thoroughly sound timber is used, may prove three times this. Jarrah, karri, red gum, tallowwood, blackbutt, mahogany, turpentine, red and blue gum have proved suitable, whilst bloodwood, ti-tree, and woollybutt appear useful, but have hitherto been untried.

Wharves—Timber is used extensively in building wharves and jetties. Ironbark is much used in New South Wales for this class of work, though jarrah, forest mahogany, and turpentine are very suitable, as they are strong and resist marine borers.

Ship and Boat Building.—The hardwood timbers are especially useful, as a heavy timber below the line of flotation is an advantage. Strength and durability are requisite, which most of the hardwoods possess. Tallowwood, though an excellent decking, is not much used in New South Wales for ship-building, as it does not hold oakum well. For curved shapes, as boat-knees, ti tree, mangrove, mahogany, honeysuckle, and water gum are useful, whilst jarrah and she-pine make good sheathing, as they resist marine borers. Blueberry ash makes good oars, and cedar pine and many of the fancy timbers are useful for interior decorative work.

House Building.—All kinds of hardwood are used for the sleepers, joists, studs, wall-plates, and verandah posts, and pine and other soft woods for the flooring, lining, ceiling boards, and all inside timber, not exposed to the weather. Cedar and red bean, used for doors, skirtings, staircases, etc.

Carriage Building.—For passenger carriages and tram cars, cedar and Huon pine is used for contrast in the panelling and decorative work, kauri pine for the flooring and ceiling. Blackwood, spotted gum, blue gum, swamp mahogany, blackbutt and tallow wood are used for the under-frames of carriages and trucks, whilst kauri and other pines are used for the sides and upper portions.

SPECIAL USES.

The special uses of the best timbers are given below :—

Wood-paving.—Blackbutt, tallowwood, jarrah, Murray red gum, turpentine, forest mahogany, and blue gum *(saligna)*, are first-class timbers. Blue gum *(globulus)*, stringybark, messmate, giant gum, spotted gum, give fair results ; whilst bloodwood, white and swamp mahogany, ti-tree and woollybutt, appear suitable, but are untried timbers.

Railway Sleepers.—Ironbark, jarrah, grey gum, Murray red gum, bastard box, and bloodwood are first-class timbers ; whilst blue gum, forest red gum, sugar gum, and many others, have proved durable.

Girders and Beams.—Ironbark, turpentine, grey gum, Murray red gum, red and white mahogany, grey, red and yellow box, jarrah, karri, blue gums, tallowwood, blackbutt.

Piles.—Ironbark, jarrah, turpentine, forest or red mahogany.

Fencing and Rough Work.—All varieties of hardwood.

Flooring and Decking.—Tallowwood, blackbutt, forest mahogany, white mahogany, Murray red gum, jarrah, blue gum, beech, the various pines, sassafras, etc.

Palings and Shingles.—Stringybark, mountain ash, giant gum, messmate, blue gum, forest oak, manna gum, grey gum, forest mahogany, pine, brigalow, etc.

Shipbuilding.—Ironbark, jarrah, blue gum (*globulus*), tuart, Murray red gum, for beams ; kauri and beech, for flooring ; red and yellow cedar, red bean, rosewood, black bean, etc., for interior decorative work.

Boat Building.—Ti-tree, mahogany, water gum, bastard box, honeysuckle for knees ; cedar and she pine for the sides.

Railway Carriage Building.—Blackwood, spotted gum, coachwood, blue gum (*globulus*), tallowwood, blackbutt, jarrah, red gum for the under frames; kauri, colonial pine, beech, &c., for the flooring; cedar, Huon pine and various figured timbers for interior work.

Wheelwrights' Work.—Coachwood, spotted gum, mountain ash, blue gum and every variety of hardwood are used for frames, spokes, naves, &c.; cedar, brown beech, colonial pine for interior work.

Coopers' Work.—Silky oak, blackwood, blackbutt, red ash, Moreton Bay ash, she oak, coachwood, rosewood, beef wood.

Furniture and Decorative Work.—Jarrah, forest mahogany, brush box, spotted gum, she oak, red and yellow cedar, red bean, black bean, tulipwood, rosewood, onionwood, Bunya, Huon, colonial, kauri and cypress pines, yellowwood, domba, poona spar, beech, silky oak, red ash, honeysuckle, waratah, &c.

Wide Flitches.—Kauri, tuart, jarrah, blue gum (*globulus*), stringy-bark, messmate, mountain ash, cedar, kauri.

Timbers which Resist White Ant.—Jarrah, forest mahogany, sugar gum, bastard box, bloodwood, Huon, cypress and she pines.

Timbers which Resist Marine Borers—Jarrah, turpentine, iron-bark, forest mahogany, tallowwood, ti-tree, she pine.