TIMBER TRUSS BRIDGE
MAINTENANCE HANDBOOK

DEPARTMENT OF MAIN ROADS NEW SOUTH WALES

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FOREWORD

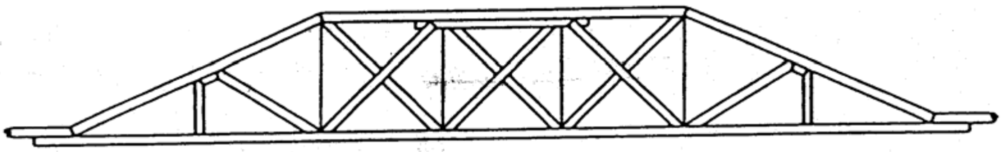
This handbook is directed to those members of the Department's staff who are responsible for the maintenance of timber truss bridges. It augments the Department's Manual No 6 – Bridge Maintenance – and its preparation followed a decision of the Bridge Engineering Committee of NAASRA to exclude timber truss bridges from the NAASRA publication "Bridge Maintenance Practice" as timber truss bridges are virtually unique to New South Wales. There are few, if any, remaining in service in other States.

Because of the historical importance of the timber truss bridges a section of the handbook is devoted to their early development. The reader will appreciate not only the tremendous part these bridges played in the expansion of the State road system but also the ingenuity of the early Bridge Engineers such as W C Bennett, J A McDonald, P Allan, E M De Burgh and H H Dare in designing and refining the trusses.

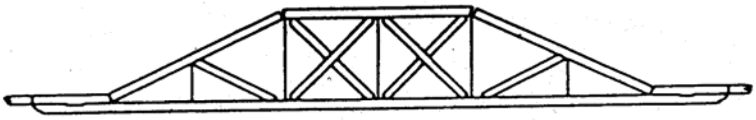
The Department acknowledges the permission of the Ryde Historical Society to publish the photograph of the opening of the De Burgh's bridge and of the Institution of Civil Engineers, London to publish the table of the properties of timbers taken from a paper by H H Dare in Processing of 1903-4. Assistance in the preparation of the handbook has been obtained from Dr Don Fraser of the University of New South Wales on the historical side and from Mr Harry Trueman, Consulting Engineer, on the technical side. Mr Vince O'Grady and Mr John Muirhead, Consulting Engineer, were responsible for the final editing and compilation.

Chief Engineer (Bridges)

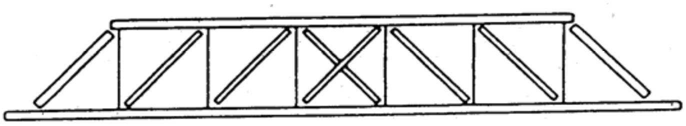
February 1987



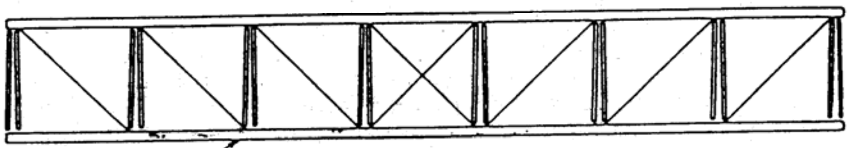
OLD PUBLIC WORKS DEPARTMENT TYPE 1860-1886



McDONALD 1886 - 1893

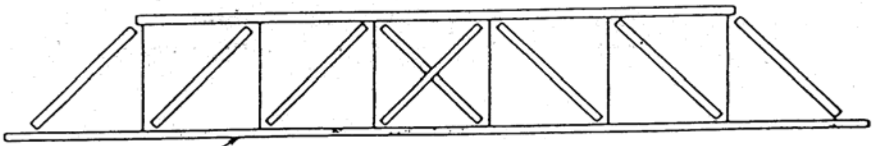


ALLAN 1893 - 1929



Steel bottom chord

DE BURGH 1899 - 1905



Steel bottom chord

DARE 1903 - 1936

OUTLINES OF TIMBER TRUSS TYPES FOR BRIDGES CONSTRUCTED
1860 - 1936

TIMBER TRUSS BRIDGE MAINTENANCE HANDBOOK

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SECTION 1 HISTORY

1.1 THE FIRST SIXTY YEARS.

Records which have come down to us would suggest that the first timber truss road bridge in New South Wales was that constructed over the Belubula River at Carcoar in 1856.

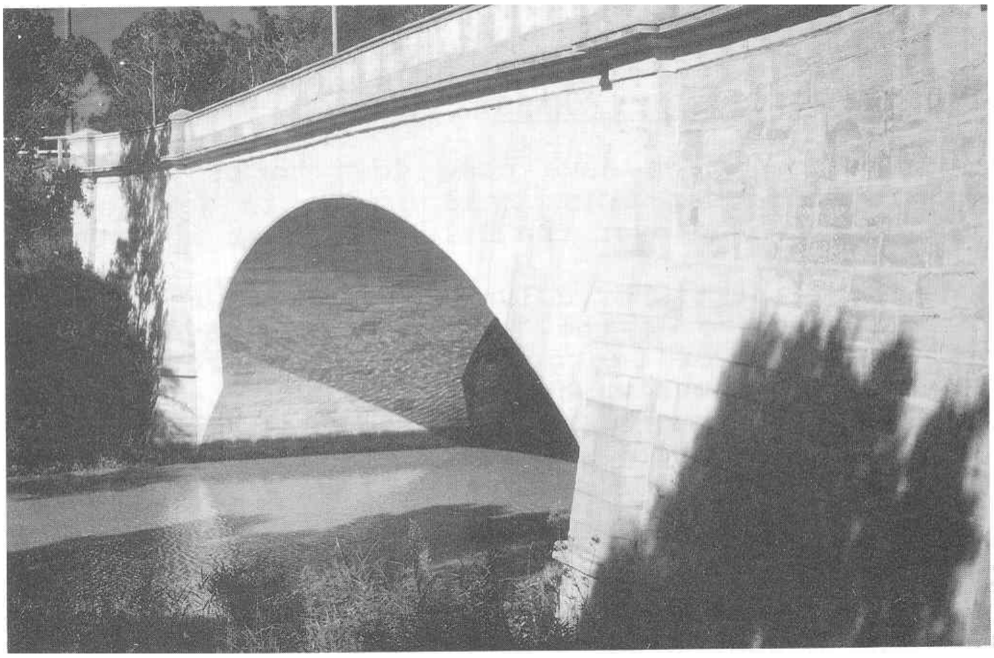
The first timber culvert or bridge was constructed in 1788. This was over the Tank Stream in Sydney, near the present crossing of George and Bridge Streets. It was not long before it was washed away and had to be replaced. Many more bridges were built over the next sixty years, but most of these were lost because they were inadequately built or maintained, or were carried away by floods.

The oldest surviving bridges in New South Wales are some of the masonry arches designed by David Lennox and built under his supervision between 1833 and 1840. His first bridge was the modest stone arch at Mitchell's Pass, Lapstone built in 1833.

"Lennox Bridge, Mitchell's Pass, Lapstone. Oldest bridge in New South Wales"

In 1981-82 it became necessary to replace the load-bearing interior of this bridge in cement concrete, but the exposed facade is original.

In 1836, Lennox completed his largest and best work in New South Wales, Lansdowne Bridge over Prospect Creek, near Cabramatta. This graceful semi-elliptical stone arch of 33.5m (110 feet) span still carries road traffic for the Hume Highway.

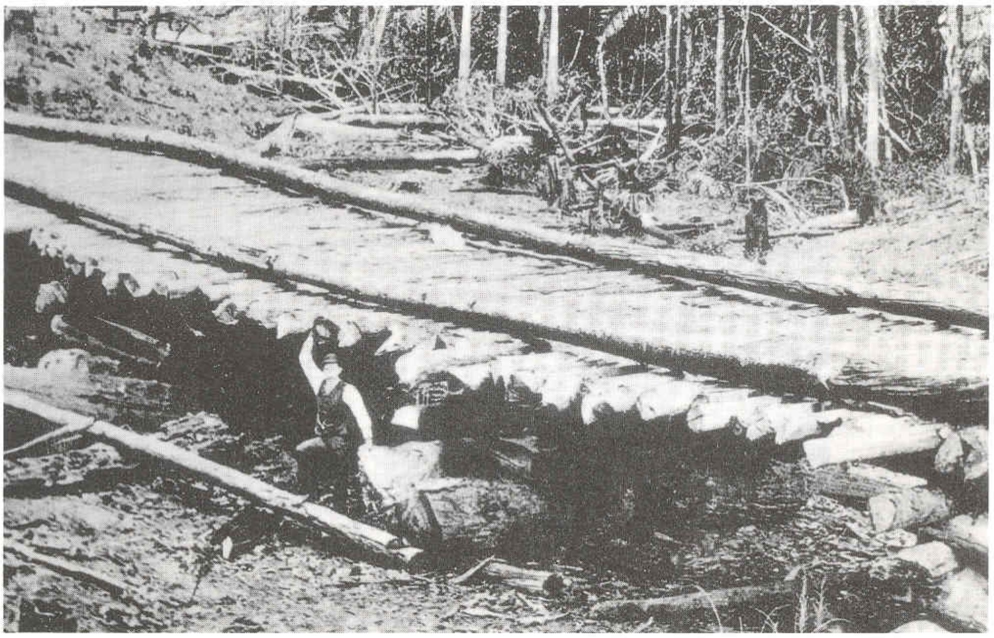


"Lansdowne Bridge, over Prospect Ck, Hume Highway near Liverpool."

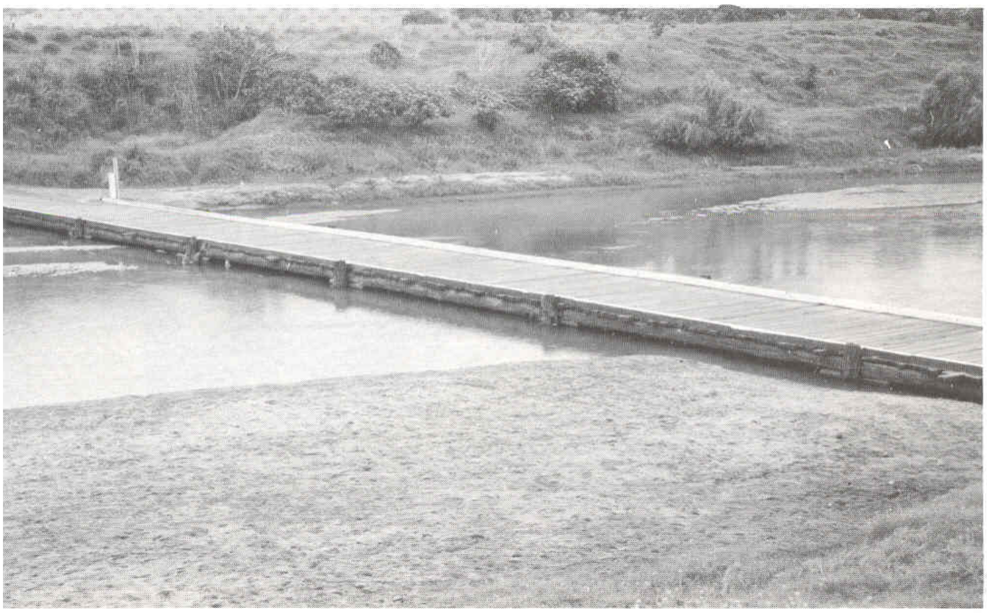
Three years later, he completed a bridge of similar propositions over the Parramatta River at Parramatta which today forms the downstream strip of a much widened Church Street. Other surviving Lennox bridges are the 1840 brick arches over Duck Creek, Granville (just west of the Carlingford railway line), the 1839 stone arch over Towrang Creek on the Old Southern Road to Goulburn and a little further on, two narrow stone culvers. All these works were built cheaply because suitable stone was relatively close by and they were mostly built by convict labour.

"Stone culvert at Towrang, near Goulburn, on Mitchell's old route of the Hume Highway."

Unfortunately Lennox's bridges were but shining exceptions in the otherwise dismal conditions of roads and bridges at the time. Some stone arch bridges had been built by others, but none have survived. Timber bridges were, of course, also built. Some were primitive log bridges, called corduroy bridges made from heavy longitudinal logs with cross-logs. It was customary to cover the deck with a layer of road material to improve the ride. Better quality timber beam bridges were also built but they were low-level crossings and suffered from the ravages of floods and the tonnes of debris so typically carried down Australian rivers in flood. Overall, satisfactory bridges were few and far between.



“An early Timber Corduroy Bridge.”



"Low level Timber Bridge."

Most rivers were crossed at a ford with all its attendant difficulties and dangers. The approaches could be steep and the bed of the river could be rough and ever changing, thereby giving the bullock teams and the teamsters a torrid time going down and up again. When the river was high or in flood, delays could extend from days to weeks and in desperation some teams took the risk of crossing. There was much damage to goods and there could be heavy losses duet to drowned stock.

The travelling public fared no better. Controlling the lightweight top-heavy coaches down slippery riverbanks could be a tricky manoeuvre and if unsuccessful the passengers could suffer anything from discomfort to death.

"Easing a coach down a river bank."

The tidal coastal rivers and the inland rivers with reasonably permanent water were crossed by punts and ferries but these were not the answer either. Their limited capacities and slow passage caused congestion and long delays, and the operators used their monopolies to charge high tolls.

"Echuca to Moama punt on Murray River c1860."

Some enterprising people saw the floating or pontoon bridge as a suitable solution. One was built as early as 1802 by Andrew Thompson to cross South Creek, Windsor. With many repairs or replacements, this pontoon bridge was operated as a toll bridge for the next twelve years, until the Government built a replacement timber beam bridge.

"Hopwood's Pontoon Bridge on the Murray River from Echuca to Moama c1860."

So this was the unsatisfactory state of affairs with respect to bridges in the first half of the nineteenth century in colonial New South Wales. There followed in the 1850's a succession of significant events, social, political, economic and technical, that were as important to the general history of New South Wales as they were to its systems of land transport. Of the technical changes, the developments in bridge engineering were to be decisive.

1.2 THE EIGHTEEN FIFTIES.

Table 1 lists the events of the 1850's that most influenced the types of bridges used in New South Wales over the next forty years.

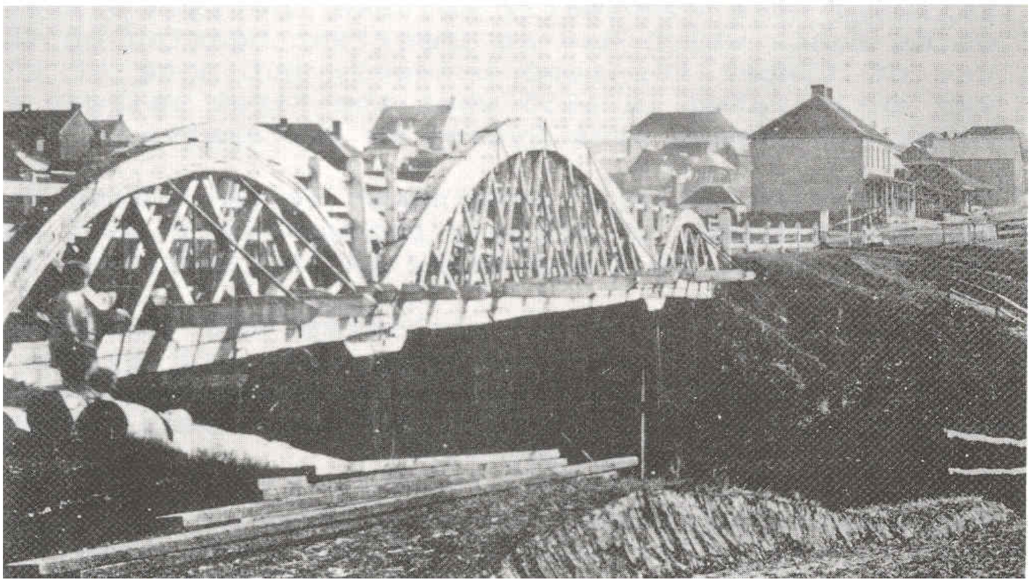
TABLE 1

Significant Events of the 1850's.

DATE	EVENT
Early 1850's	End of convict transportation to New South Wales.
1851 May 10	Discovery of gold publicly announced.
1852 June 21	First laminated timber arch bridge over Wallis Creek, Maitland.
1853 Feb. – Aug.	Paddle steamer "Mary Ann" completed a return journey on the Murray River.
1855 July – Sept. 26	N.S.W. granted responsible government. Railway opened from Redfern to Granville.
1856 Jan.	First timber truss bridge, over Belubula River, Carcoar.
May	Opening of first N.S.W. Parliament, Donaldson's Ministry.
1857 March 30	Railway opened from Civic, Newcastle to East Maitland.
	Swing span bridge completed to Glebe Island. First report of Captain Martindale.
1858	Second report by Captain Martindale.
1859	Third report by Captain Martindale. Swing span bridge completed, Pyrmont to the City.
Oct 1	Creation of Public Works Department.
Dec.	Queensland created a separate colony.
1860	Fourth report by Captain Martindale.

It was the discovery of gold and the subsequent gold rushes to Bathurst and Wellington that had an immediate and dramatic impact on New South Wales. Combined with the cessation of transportation, it caused an acute shortage of labour and an explosion in wages, which rapidly increased a labourer's wage to three times the pre-gold rush rate and for skilled craftsmen, such as masons it peaked at ten times in 1856.

The Lennox-type masonry arch became prohibitively expensive and so the expertise of the indigenous bush-carpenter was used to extend the application of the abundant local hardwoods from short-span low-level timber beam bridges to elevated major bridges. The first of these was built in 1852 over Wallis Creek on the Great Northern Road between East and West Maitland. It was a three-span structure with each span consisting of three laminated timber bowstring arches. The effect of this was to provide a divided carriageway with traffic to either side of the central arch.



"A laminated timber arch bridge over South Creek at Windsor in 1872."

The design and construction details reflected imported British technology through the Colonial Architect's office. The total length of the bridge was 51.2 m and it cost $4,000-00. It's cost effectiveness, despite labour and financial difficulties, can be judged from a comparison with Lennox's Lansdowne Bridge, constructed sixteen years earlier, and using convict labour, which cost $2,000-00 for a length of 33.5 m. Successive Colonial Architects and Commissioners for Roads arranged to have about ten more of these laminated bowstring arches built during the next twenty years and sought other structural forms to better use the local hardwoods.

But the laminated timber arch had a number of faults that limited the widespread use of these bridges. The main problem was the separation of the laminates, due to the large amount of shrinkage of the Australian hardwoods and the consequent penetration of water into the joints. Once fungi or termites attacked the timber it was impossible to renew individual laminates or portions of the arch.

The timber truss, with its gradual refinements, avoided this problem and eliminated the other faults but the start of that development was still four years away.

When the paddle steamer "Mary Ann" completed it's 1853 journey on the Murray River, from the South Australian border to Goolwa and return, it started the era of the river boat trade. For the next thirty years the wealth of western and south western New South Wales, particularly its wool, flowed to the rival colonies of Victoria and South Australia along the Darling, Murrumbidgee and Murray Rivers. All roads led to their river ports or landing places rather than towards Sydney.

Although many road bridges, both of timber beams and trusses, were built to improve land transport to those locations, the principal response of New South Wales was to extend the railway in the early 1880's to Bourke, Hayand Albury in order to redirect the river trade to Sydney. The railways were eventually to take the lion's share of public works funds, which had an important bearing on the extensive use of timber for road bridges, but none of these matters was anticipated in 1855 when the first railway in New South Wales was opened from Sydney to Parramatta.

The granting of self-government to New South Wales in 1855 was significant to bridges because it placed public works, hence bridges, well and truly in the political arena.

Henceforth, Government policies and priorities greatly affected the numbers, locations and types of bridges constructed both for roads and railways. Road bridges in particular became one of the most politicised items of public works programmes.

The history of timber truss bridges in New South Wales has its tentative beginning at the same time as the first elected Ministry was trying to cope with the immense problems of the rapidly changing conditions of the colony. On 12 December, 1855 the Sydney Morning Herald had the following report:-

"CARCOAR BRIDGE -a new bridge by Mr. Weaver (Colonial Architect) was commenced 31 ultimo and spans the Belubula Rivulet. It will be completed in time for the Governor-General to open it on his return to Sydney. In lieu of laminated arches, trusses are framed on the principle of the queen-post roof. Three 52 foot spans rest on strong piers and there are three trusses per span hence dividing the roadway into 12 foot widths. The overall length is 172 feet, 27 feet overall width and the deck is 18 feet above the water. The bridge is on the main cross road from Bathurst and Western Districts to the Southern Road and will afford utmost assistance opening up valuable land".

The importance of bridges and the public interest in them can be gauged from the last sentence and the expected vice- Regal opening. Unfortunately, drawings and other details of this bridge do not appear to have survived.

The 1850's decade is seen by most historians as the beginning of a new era for New South Wales. After that decade, just about everything was in complete contrast to conditions in the first sixty years of the colony. So it was with bridges, and it was the four REPORTS ON INLAND COMMUNICATIONS by Captain Martindale R.E., 1857-1860, that set in motion a train of events that improved the administration and construction of public works.

In the first report Martindale's conclusion was, "that the roads were ill laid out, ill drained and never sufficiently metalled but it was the want of bridges that suspends inter- communication". Bullock teams travelled only 3-4 miles per day, transport costs per ton were high with the result that "produce rots in the grounds". Grain imports at £718,000 were eight times the value of exports at £92,000 so the colony had much to gain by improving land transport. Only wool, with its buoyant market, could cope with these difficulties.

But Captain Martindale was a practical man and did not demand solutions beyond the colony's resources. He recognized that modest but well executed works could be very beneficial. Following his inspection of the Great North Road he said "steep and sliding banks of creeks would be obviated by very ordinary bridges of simple construction~

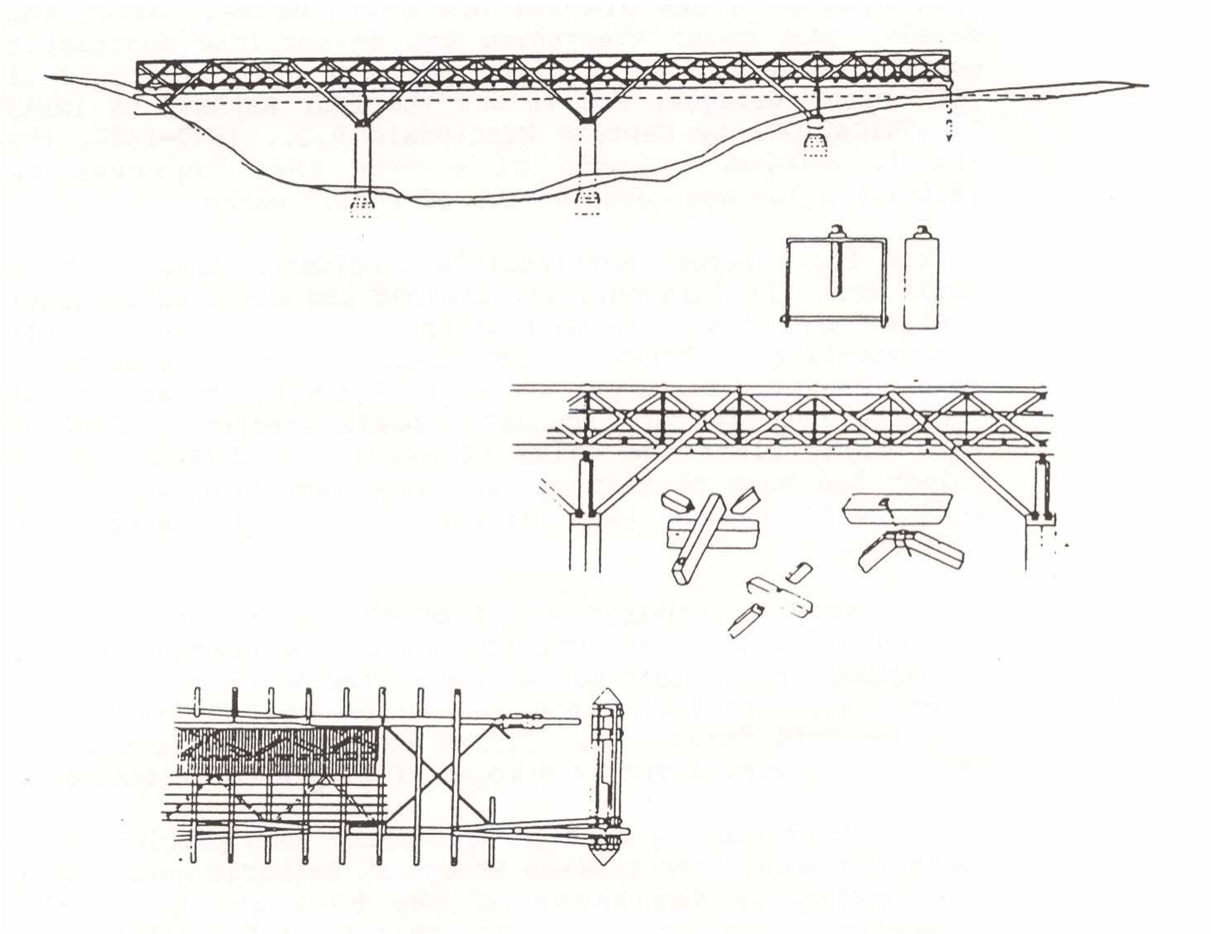
In his third report, he highlighted the main problem of the laminated arch, "the Denison Bridge at Bathurst having given way, owing to shrinkage of the bows and the timber generally, is in need of repairs that require a great amount of care and skill" .He also referred to a "queen truss" being erected over a stream called Falbrook north of Singleton. Fortunately the original drawing of this has survived.

Although Captain Martindale recommended that construction of public works be carried out by contract rather than by Government day labour, it did not always work out that way in practice. In the same Report he said, "tenders were called for the bridge over the Peel (at Tamworth) without success, nor was any tender sent in for the bridge over the MacDonald at Bendemeer".

Finally, in the fourth report he specifically lists the order of priority "in the first place to bridge the creeks and rivers, particularly those that habitually stop traffic in times of flood or render transit generally difficult, and in second place to improve the worst places along the road after construction of the bridge then gravel the roads".

PROPOSED BRIDGE OVER FALBROOK

AT CAMBERWELL



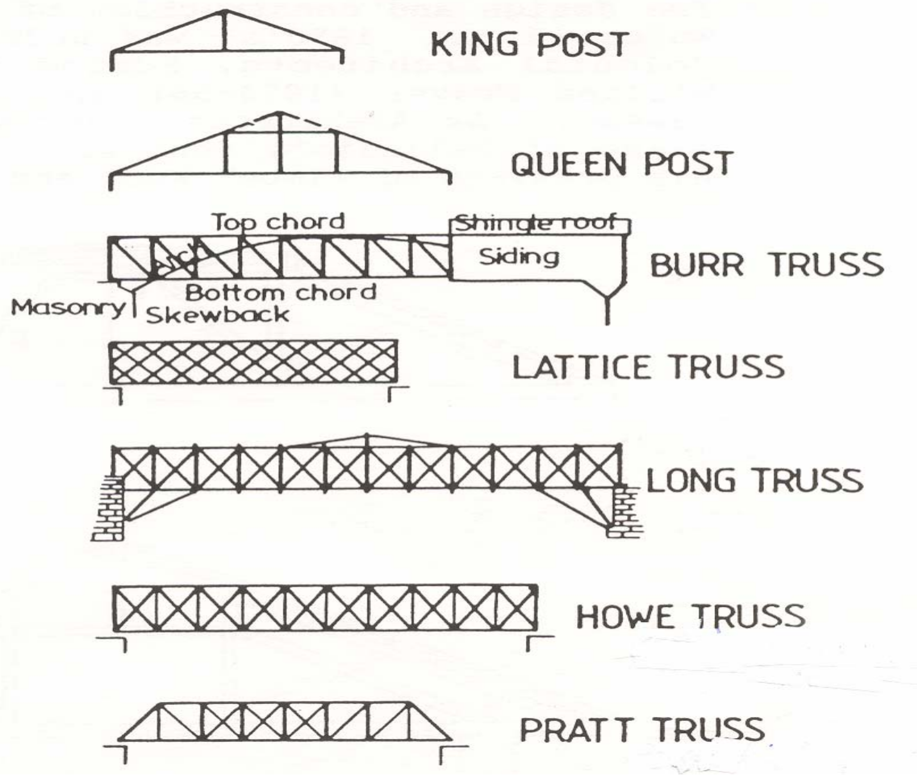
The Government of the day (the phrase is relevant because the average life of a Ministry was little better than a year) heeded Martindale's advice by establishing the Public Works Department on 1st October, 1859 and it appointed Martindale the Under Secretary for Public Works and Commissioner for Internal Communications. He served a useful transition period until January 1861.

During the second half of the 1850's the young Superintendent, William C. Bennett, showed ability and competence in bridge works -for example, the successful repair of the Denison Bridge as mentioned in Martindale's Third Report. He was appointed Commissioner and Engineer-in-Chief in 1862 and remained in office until his death in 1895. The history of timber truss bridges in New South Wales effectively begins with his appointment and many important developments occurred during his long term in office.

1.3 ORIGINS OF THE TIMBER TRUSS BRIDGES.

1.3.1 American Influence:

The timber truss bridge is generally regarded as an American development because during the period 1810-1840 a great deal of inventiveness, adaptation and refinement to the truss form took place in the eastern States of America. There were individual builders and bridge-building companies marketing bridges around the country, just like any other commercial product. Ethiel Town, for example, extolled the adaptability of his lattice truss by claiming to "make it by the mile and cut it off by the foot".



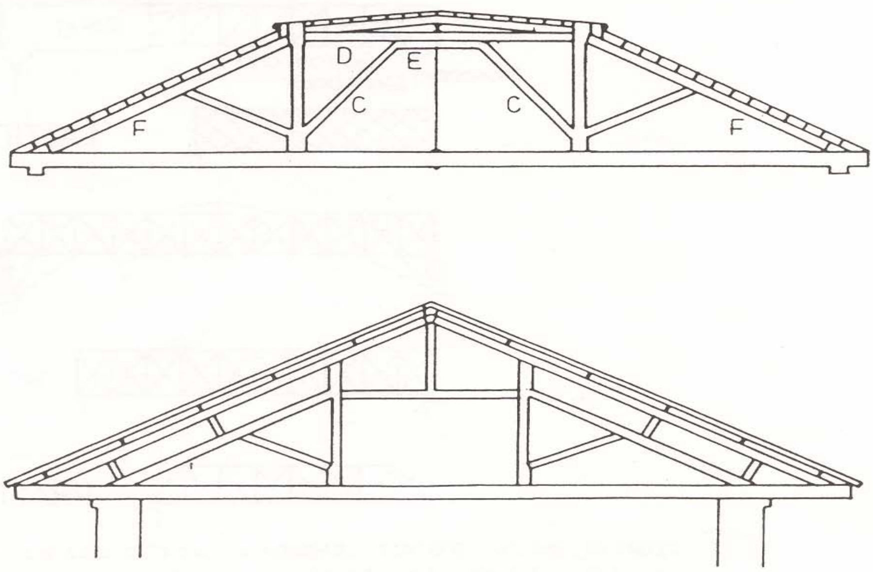
There were about twenty structurally viable designs at the time in America but eventually the Howe and Pratt trusses proved to be the best in terms of initial construction, performance and maintenance. Our own Allan truss (1893) and the De Burgh truss (1899) are direct decendents of these two American designs. It should also be noted that neither the King Post nor the Queen Post trusses were of American origin; both had been in widespread use in Europe as roof structures since medieval times.

Because of the important North American contributions to bridge engineering in the second half of the nineteenth century, particularly the truss bridge, engineering historians have suggested that the early timber trusses in New South Wales had their origins in America. They argue that with the flood of miners from the 1849 California gold rush to Australia between 1851-1856, it would be reasonable to assume that some among them brought the American truss technology here.

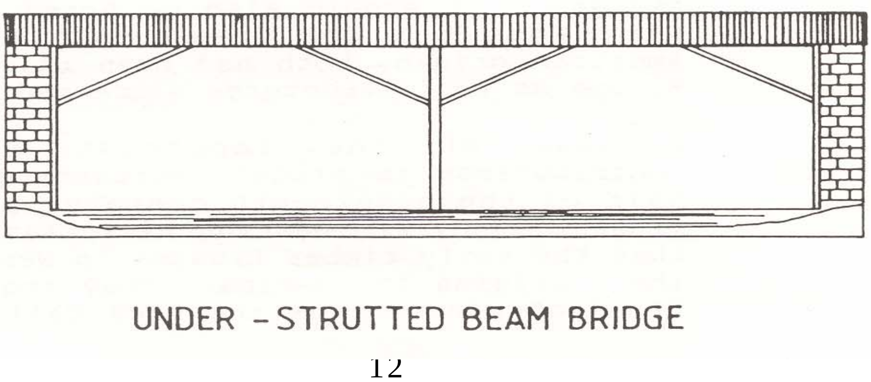
1.3.2 European Influence:

During the 1860's in New South Wales there may well have been some infusion of that technology into the design and construction of timber truss bridges, but other historical evidence suggests that these early timber trusses were really of European origin, in particular they were derived from designs by the sixteenth century Architect Palladio. The following statements are offered in support of this claim.

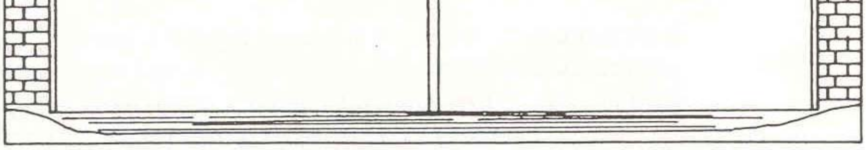
The design and construction of bridges in New South Wales in the 1850's was under the control of the Colonial Architects, Edmund Blackett (1849-54) , William Weaver (1854-56) and until 1859 Alexander Dawson. As Architects, they would have been well aware of Palladio's four books on Architecture and his drawings of timber roof and bridge trusses.



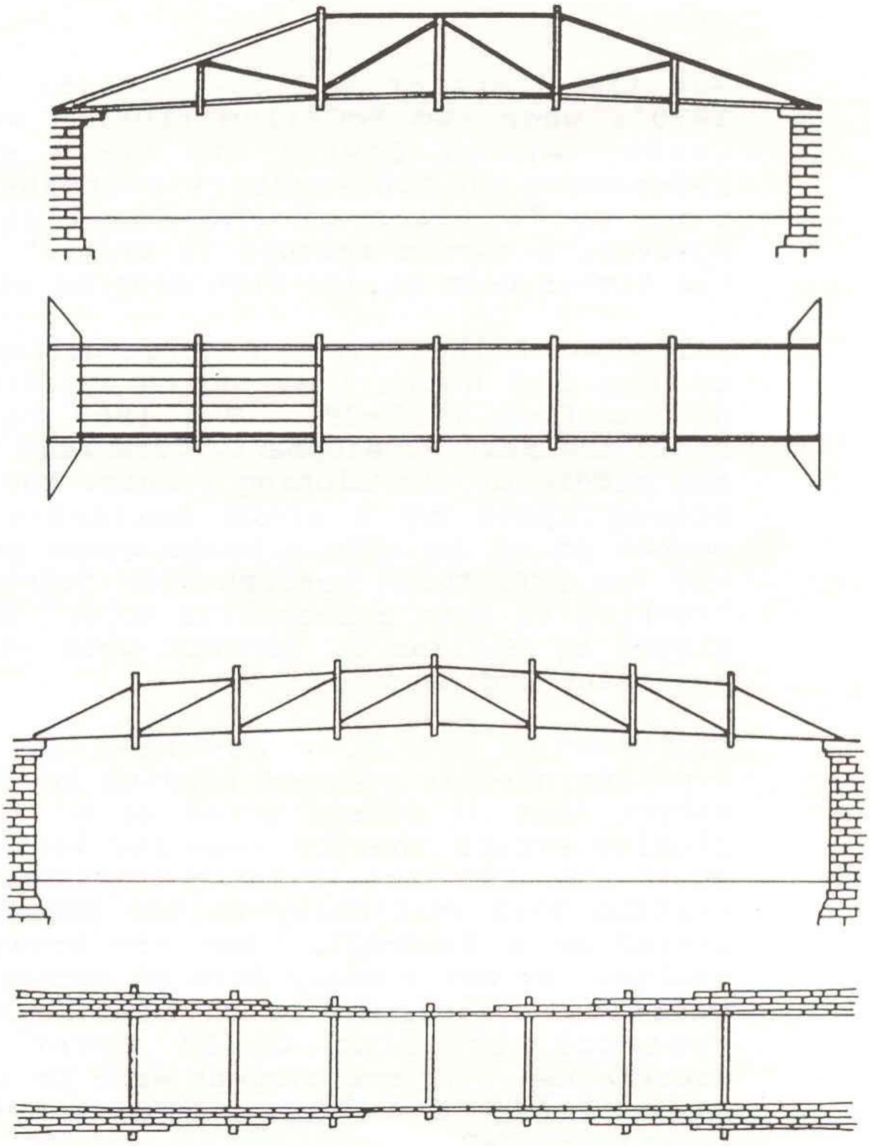
QUEEN POST ROOF TRUSS



UNDER -STRUTTED BEAM BRIDGE



UNDER -STRUTTED BEAM BRIDGE



"These sixteenth century timber truss bridges by Palladio have a modern appearance. Both forms were adapted by Bennett, Macdonald and Allan to suit local hardwoods."

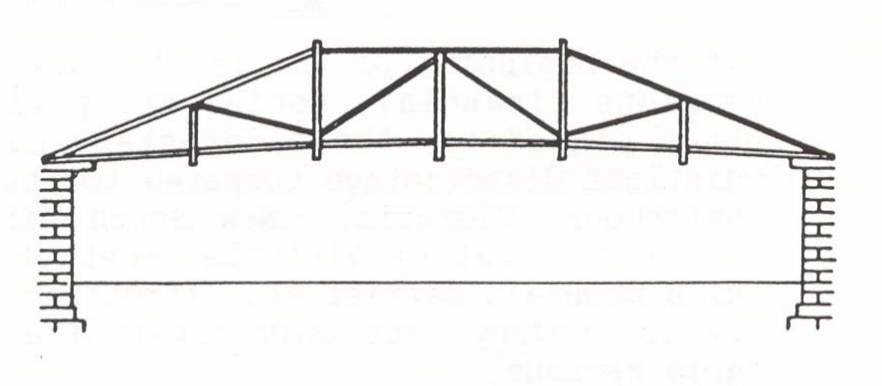
These officers and their staff adapted British technology (the laminated arch) to local conditions and could have referred to British or European books such as the 1820 edition of Abraham Rees's The Cyclopaedia of Arts, Sciences and Literature.

There were no comparable publications from America,in fact there was fierce commercial competition at the time among American bridge builders, so their expertise would have been jealously guarded. Therefore, transfer of sufficient American technology in the 1850's for a major programme of bridge works in a British colony seems unlikely.But, the transfers did take place, later, in the 1870’s when two McCallum trusses were built (at Casino and at Cowra) and there were frequesnt references in contemporary newspapers after this time to “bridges of the American principle”. However, a common feature in British technology was the timber beam bridge with sloping struts.

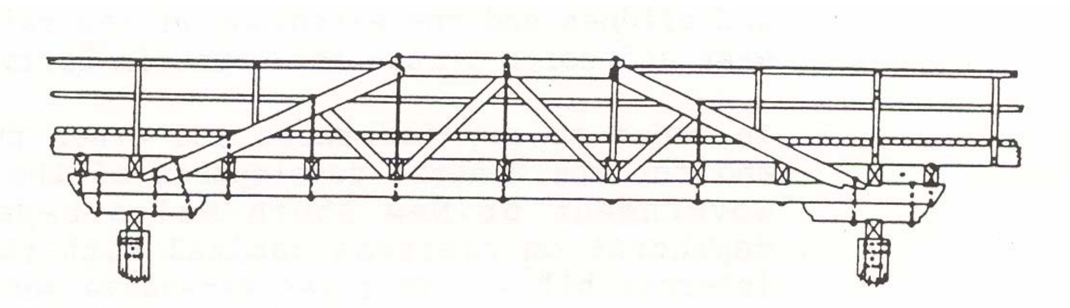
Evidence of this type of construction still exists on the Old North Road north of Wisemans Ferry, dating from 1828-29. The 1860 Falbrook Bridge shows the next development. The beam was lowered to the middle of the sloping struts, the top ends were braced apart by a stout horizontal compression member so as to form a basic queen post truss, and the two structural systems were jointed by vertical trussing to form a comosite unit. The drawing was signed by William C. bennett when he was still an Assistant Engineer.

The design had some advantages, the vertical trussing greatly reduced bending in the beam to the extent that it mainly acted as a tie between the sloping struts thereby reducing thrust against the abutments, the same trussing transferred some of the traffic load vertically to the abutments, and also served as a handrail. But the bridge had serious faults. It was a messy form of construction and the relative contributions of beam, queen truss and vertical trussing could never be properly ascertained. If one element were to weaken then how effectively did the other two carry larger contributions?

It is possible to assume that Bennett was aware of the faults or was in some way dissatisfied with the Falbrook design because while this bridge was being built he produced a new design. It was clearly an improved version of Palladio's sixteenth century design which Bennett could have learned about during his earlier service with the Colonial Architect's Office. Because Bennett had become Engineer-in-Chief of the Public Works Department, this timber truss bridge came to be known as the Old PWD Truss or Truss Type "A" in the 1962 Bridge Maintenance Manual. It would appear that the first of these improved Queen Truss bridges was built over the Pages River at Murrurrundi in 1860, followed by a number of others including the 1861 crossing of the Cudgegong River at Rylstone.



“The similarities between Palladio's truss and Bennett's improved queen truss are too striking to suggest the early truss designs came from America”



“A copy of the original drawing of the 1861 road bridge at Rylstone. The drawing shows details that became a common feature of timber truss bridges in New South Wales.”

Finally, Bennett's own words of 1865 might suggest that American technology had yet to make a decisive entry into colonial bridge engineering practice in New South Wales, "As yet, from want of full experience of the capabilities of the indigenous timbers applied to intricate framing, and from the very great shrinkage and warping which occurs if not seasoned, spans exceeding 100 feet have not been used; but a design for large spans, on the principle of the McCallum truss, so extensively used with the softer and lighter timber in the United States, has been under consideration for some time, and will be applied when opportunity offers".

1.4 TRUSSES USED IN NEW SOUTH WALES.

1.4.1 William C. Bennett. The Old PWD Truss (1861-1886):

At the beginning of the 1860's, New South Wales had serious financial, social and political problems that placed it, the elder-statesman colony, at a distinct disadvantage compared to its young southern neighbour, Victoria. New South Wales had an area 3.5 times that of Victoria, most of it to the west of a mountain barrier that stretched the full length of the colony, but only obtained a quarter of the gold revenue.

The social problems developed after the easily won alluvial gold petered out in the late fifties. There were thousands of people looking for other ways of making a living and from them came the cry for land. The political solution came in 1861 with the Robertson Land Act which led to the progressive break-up of the large areas controlled by the Squatters. The numbers of farms greatly increased and consequently, the amount of produce requiring transport to markets, both local and overseas. There was community agitation for improved roads and bridges and the extension of the railways south, west and north across the mountain barrier.

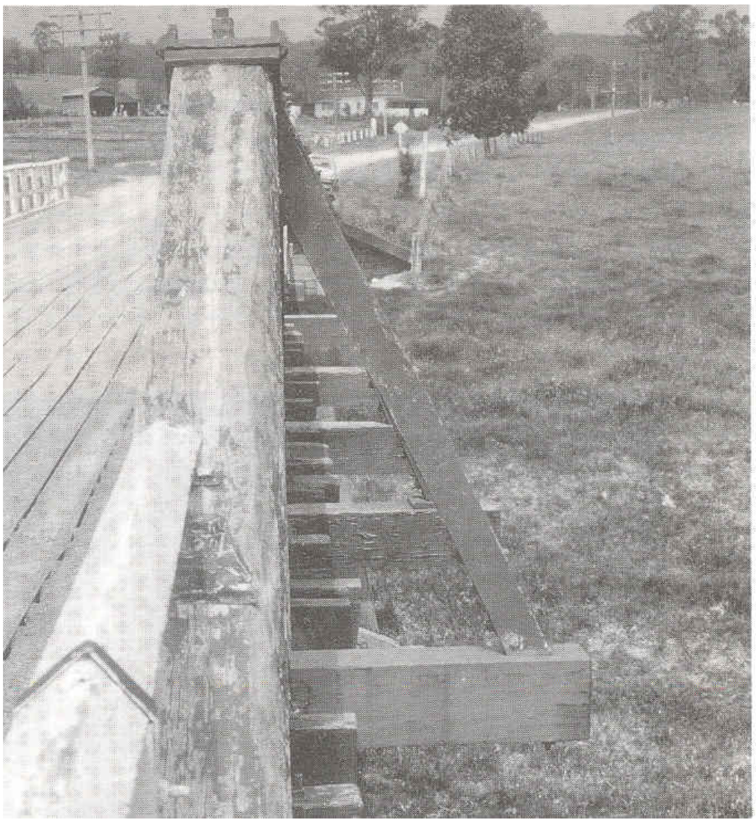
In order to pay for these and other public works, nd for the general development of the colony, the Government of New South Wales became heavily dependent on overseas capital with the attendant interest bills. This was expensive money and was a burden on the colony's still limited sources, so the Government sought ways of keeping expenditures down.

One way, by an 1861 decree, set New South Wales on its course of becoming the colony/state of timber truss bridges. The Legislative Assembly required that local materials (and skills) be used as far as practicable thereby keeping imports to a minimum, particularly that of costly iron. For road bridges, this meant the extensive use of timber, and thousands of beam bridges and hundreds of truss bridges were constructed during the next sixty years.

Fortunately, New South Wales was blessed with an abundant supply of native hardwoods well suited to low-cost bridge construction, and William C. Bennett, Engineer and Commissioner for Roads (1862 - 1889) ,was able to use the truss as the dominant mode in road bridge construction. With a better knowledge of the material properties of the timbers, of the new methods for calculating forces in trusses and design detailing, Bennett was able to extend the span of the timber truss bridge to 30 m (100ft.).

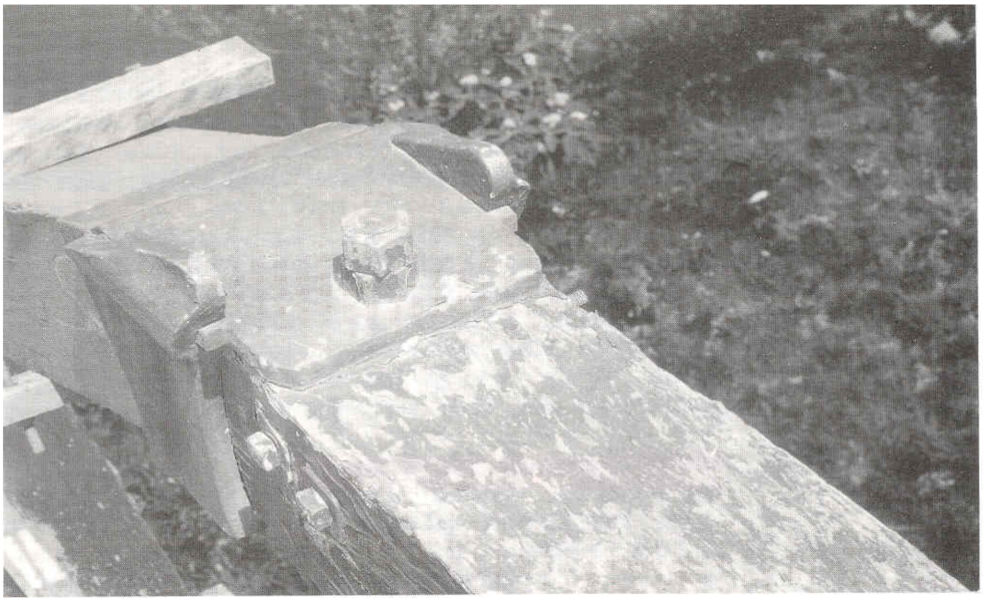
The Old PWD trusses were built in two distinct styles depending on the span, below and above about 15 m (50ft.). None of the former survive but drawings of them are held by the DMR. Two of the larger trusses do surviv, at Clarence Town and at Monkerai. These trusses have single member principals and top chords. The bottom chords are constructed from three vertical laminates bolted together. There are single suspension bolts passing through the chords. Webs are crossed in all panels. The deck is placed on cross girders which are carried on the bottom chord between panel points.

Below about 15 m span the structure was composed of a single queen frame with a timber tie, braced in the vertical plane by timber diagonals and vertical iron rods. All timbers were solid, one length pieces, typically 300 mm x 230 mm x 4.6 m for the compression members and 250 mm x 200 mm x 18.3 m fro the tension tie. Obtaining excellent specimens of these sizes soon became a problem both for new constrcutions and for repairs. The long vertical bolts were usually 32 mm diameter, one per panel point with its hole drilled centrally through all timbers including the cross girders.



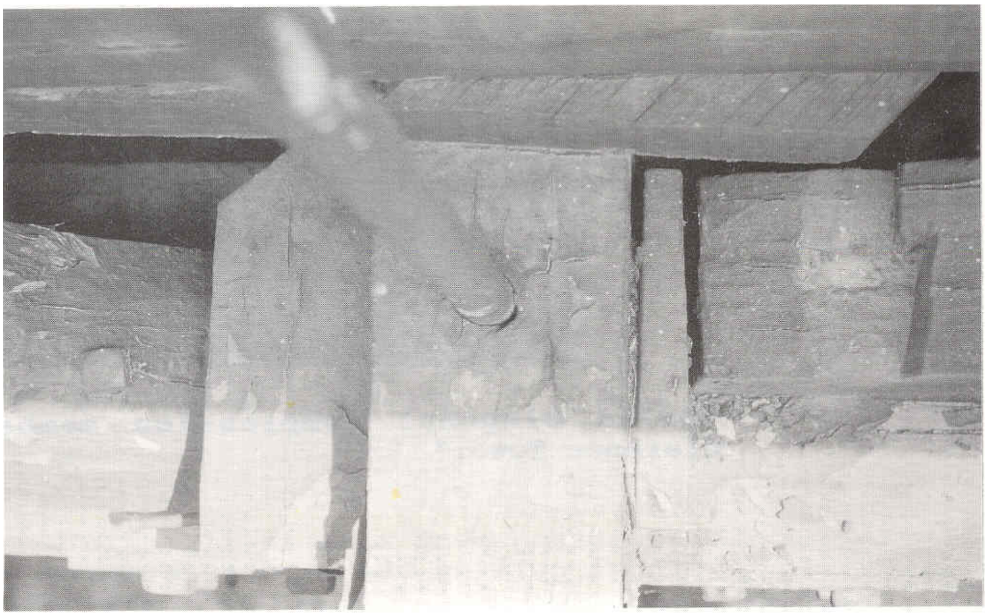
"Solid Diagonal compression member as used at Clarence Town".

This arrangement made it impossible to renew members without pulling the structure apart.



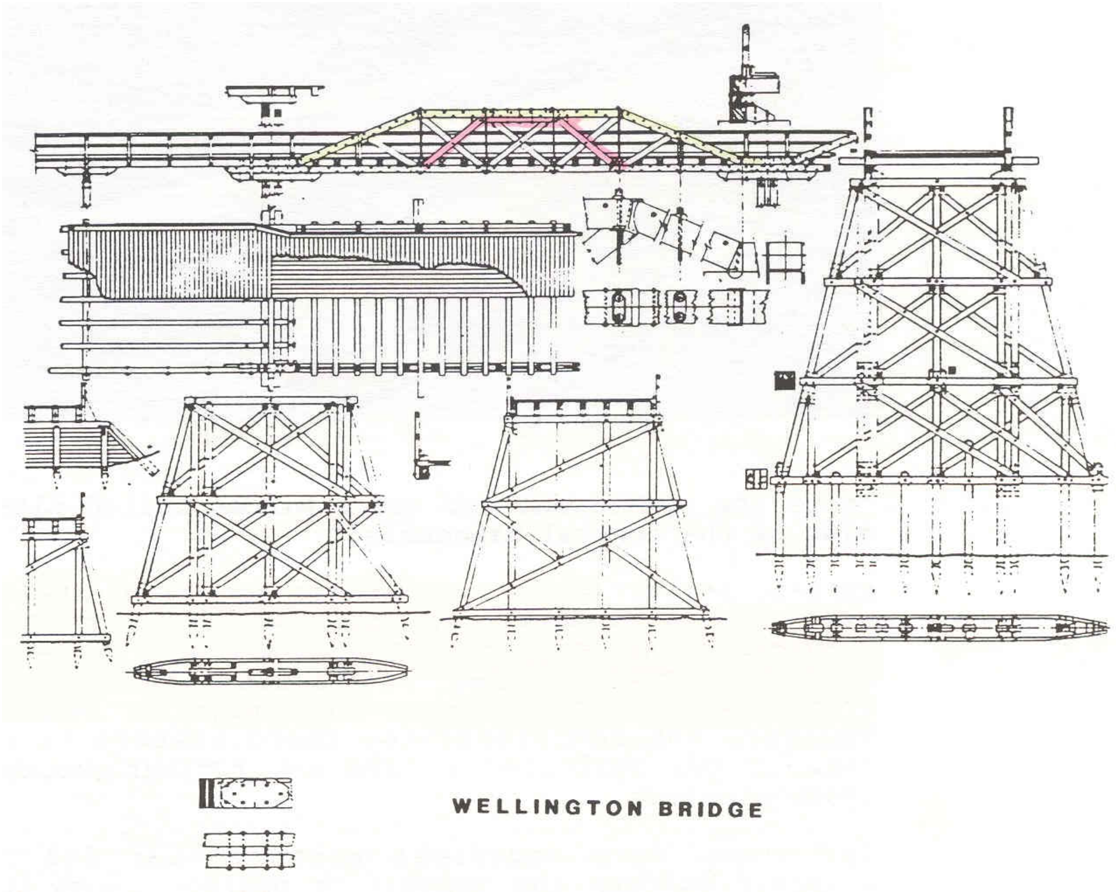
"Old P.W.D. trusses had long vertical bolts drilled centrally through the timbers."

The joint details of these early trusses were formed simply by shaping the ends of the timbers so as to bear against each other. At some joints, smaller bolts were used to hold the members together and so ensure the structural integrity of the joint, but not the joints for the diagonal members. It was assumed they would always bear against the sides of the cross-girders and remain snug for load transfer. Unfortunately, a characteristic of the local hardwoods was their considerable distortions due to shrinkage and creep, so much so, that the bottom chord joints opened up thereby making effective structural action very difficult to obtain. It was not possible to tighten up the truss in order to close the joints hence attempts were made to fill the gaps with wooden wedges.



"Shrinkage in the bottom chord connected with wedges."

For spans above 15 m, Bennett seems to have again adapted ideas from his earlier experience in the Colonial Architect’s Office, particularly from the successful Europea roof trusses. As shown on the diagrams on page 1.12 taken from The Cyclopaedia of Arts, Sciences and Literature by Abraham Rees. Note particularly the top illustration in which an inner queen truss CEC is used to strengthen the outer queen truss FDF. The same concept appears in Bennett;s designs for the 20 m, 23 m, 27 m and 30 m span timber truss bridges shown below.



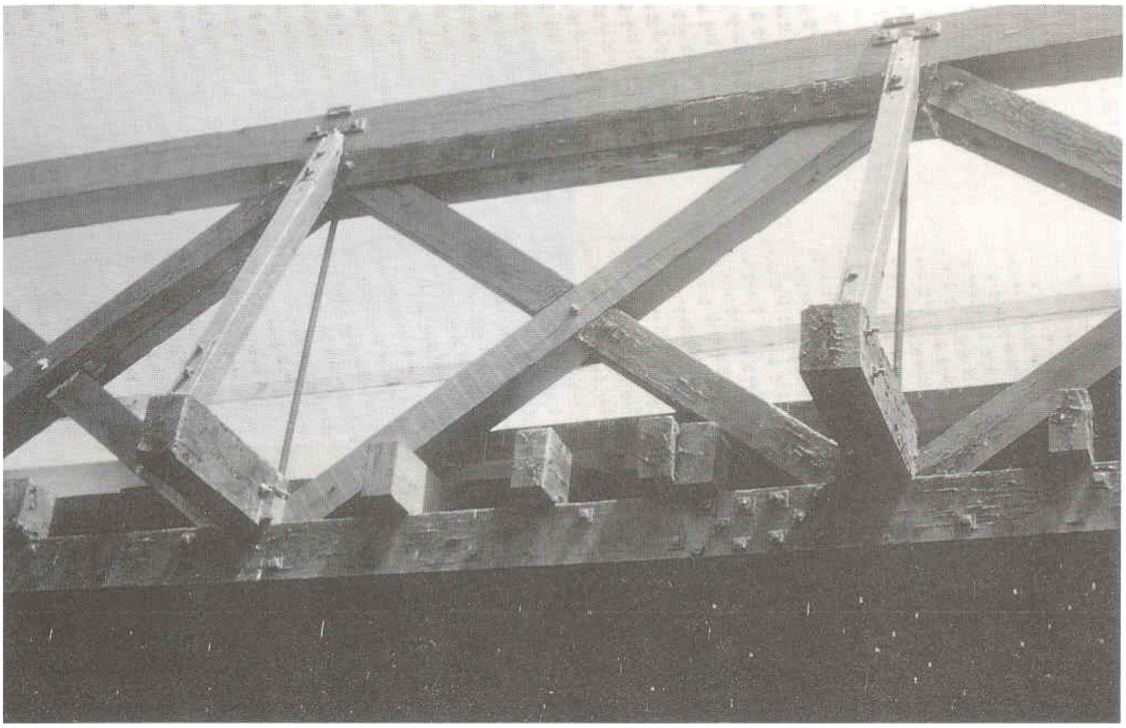
“Tall testled piers kept bridges open during most floods.”

There were some improvements of course in this adaptation from roof truss to bridge truss, for example metal plates were incorporated at the twomain compression joints, the shoulder joint and the joint above the trestle. The earlier practice ofallowing timber to bear against timber had proved tobe unsatisfactory. Each panel was cross-braced in the vertical plane to account for reversal of force in the diagonals, the splice plates (called fishplates) were included wherever joints occurred within the length of a member.

“Note the additional top chord pieces bolted either side of the central diagonals.”

Unfortunately, these changes did not eliminate the basic faults of weak iron rods, particularly at the shoulder joint where the shear force was large; of shrinkage distortions; of insufficient lateral stiffness and difficulty in the renewal of members. However, the additional top chord timbers in the form of two half pieces did not further compound these problems.

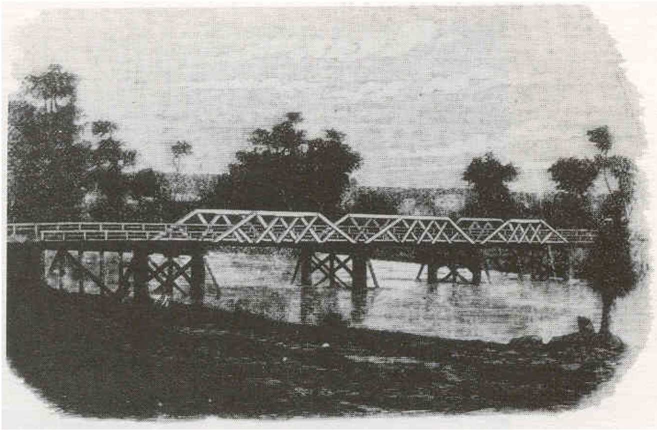
But these were technical matters that did not directly concern the travelling public. What they saw was a dramatic improvement at river crossings.Bridges were built on tall trestles well above most floods, which allowed for year-round usage, and the deck was always clear for traffic thus enabling farm produce and general goods to move to and from the market places with considerable ease and reliability. Bennett was able to report in 1865 that, "on the Southern Road the mail time has been reduced one-hal f " and there was "a saving to the country of £150,000 per annum in the cost of carriage alone" .In the same report he reiterated Martindale' s order of priori ties. " 1st -To remove interruptions to traffic by bridging rivers and creeks".



"Old PWD truss bridge over the Karuah River at Monkerai elevated above floods.-

The importance of bridges, in drawing trade and commerce to the town at or near the bridge, was quickly appreciated. Bridges became an asset, an enhancement to a town, a status symbol, even something to squabble over. This occurred in Dubbo in 1866. The following is a summary of the contemporary report in The Town and Country Journal, lOth June, 1871 page 721.

"A few years ago there was a civil feud between those who resided at the north and those at the south end of town. The southerners "bucked" at the building of the Exchange Hall, the Court House and Post Office at the northern end rather than at a more central location. The northerners were accused of having the ear of the Government. The southern faction adopted the nickname of "Lambs" and the northerners were referred to as "Trotters" .When the new bridge was ready for opening, the Lambs decided to have the first christening, so at 12.00 am on 24th May, 1866 they assembled on the bridge and named it the Oxley Bridge after the local hero explorer. Then at 12 o'clock the Trotters procession arrived and the official title of the Albert Bridge, after Queen Victoria's consort Prince Albert, was bestowed".



"The Dubbo Bridge of 1866, probably the only bridge to have two opening ceremonies in one hour, highlighted the public awareness of the overall benefits of good bridges."

The Dubbo bridge is possibly the only bridge to have two opening ceremonies within an hour. But all the pettiness was to no avail, the bridge was known as the White Bridge for most of its life because that was the colour of paint used by the maintenance gangs, and this distinguished it from the reddish colour of the metal railway bridge.

The success of these early timber truss bridges led to a surge in petitions and a rapid increase in the number of bridges constructed. The pace continued in subsequent decades through into the twentieth century and records show the dominance of the timber truss road bridge for important river crossings over other forms of construction. When the locations of these timber truss bridges are marked on a map of New South Wales it can be seen how the title "timber bridge colony" came about.

But success had its price. These bridges were, after all, of low-cost construction with narrow deck widths and designed to carry lightly-loaded carts of about 1.5 tonnes. As early as 1865 Bennett reported that the combination of better roads and bridges enabled larger carts and drays to be used with loads in the range of 2.5 to 6.5 tonnes. By the 1880's the first series of bridges required either extensive repairs or renewal and this afforded J. A. McDonald the incentive and opportunity to engage in redesign to avoid the technical faults of the Old FWD truss and to produce a wider and stronger structure suitable for the heavier loads and larger volumes of traffic.

1.4.2 The McCallum Trusses (1870-1875):

Only two bridges using McCullum trusses were built in New South Wales. The structures were over the Lachlan

River at Cowra and over the Richmond River at Casino. Both bridges have since been replace twice. McCullum trusses were in use at Cowra from 1870 to 1893, and at Casino from 1876 to 1908. They are reported upon here only because of their historical significance.

Both sites called for high level spans to 40 metres, which was beyond the design limits of the Old PWD trusses. D. J. Mc Callum was one of the best know rairoad bridge builders in America, and his truss was patented there as early as 1851 as “McCallum’s Inflexible Arched Truss”.

The two bridges had shorter lives than might have been expected and John McDonald, Engineer for Bridges, reported after only 16 years (in 1886), that the Cowra Bridge was "in poor condition".

1.4.3 The McDonald Trusses (1884-1894) :

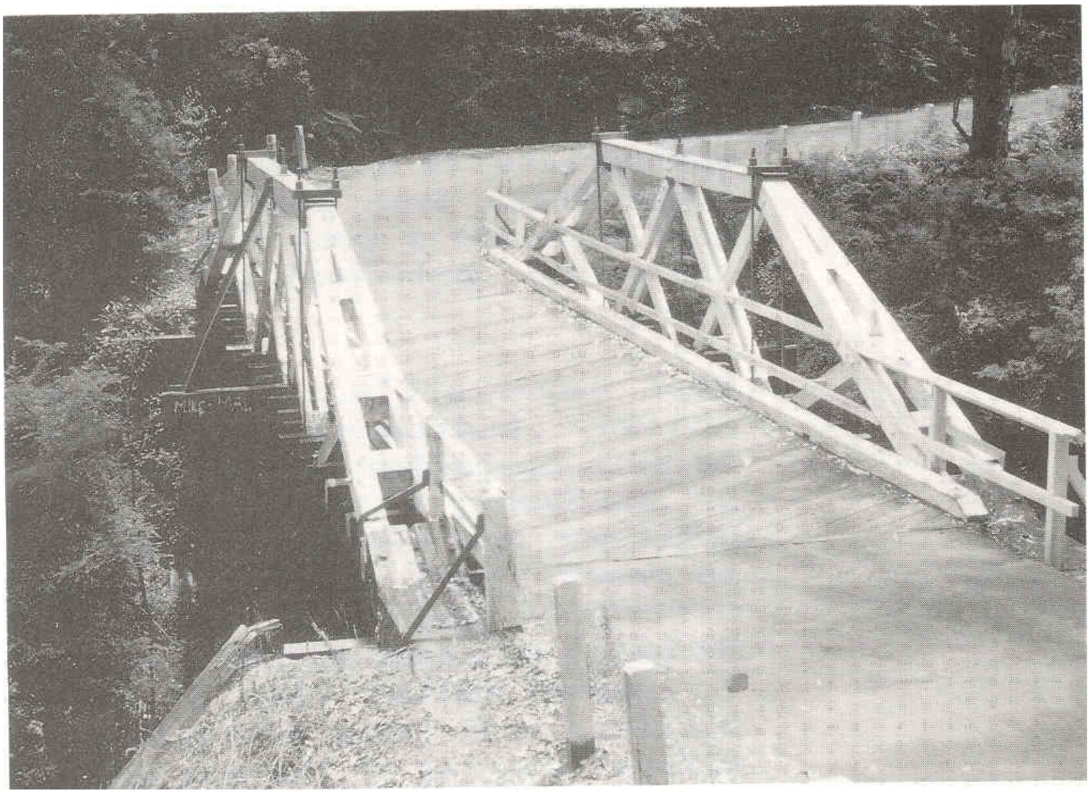
Before describing this design, it woull appropriate to review the relevant history of New South Wales over the twenty years (1865-1885), so that McDonald's work can be seen in the conte~ the social, political and economic influences 0: time.

Most importantly, the period was dominated by railway construction. In the late 1860's major terrain obstacles to railway extension in the areas of Goulburn, Lithgow and Murrurundi were being overcome, and there was a feeling of urgency firstly to reach Albury and tap the wealth of the Riverina District, particularly the river trade at Hay. Secondly to reach Bourke and redirect the wool trade to Sydney rather than down the Darling River to Victoria and South Australia, and then to tap mineral sources of the New England Districts and the rich farming lands of the North West slopes plains.

The social pressures for an extensive railway network were strong and the Governments (the plural is relevant because the average life was only slightly more than one year) responded by borrowing heavily overseas in order to finance the standard of construction insisted upon by John Whitton, Engineer-in-Chief for railway construction (1856-1890) .The extent of the railway system by 1885 is indicated on page 1.53.

Of the moneys voted for public works from 1865-1885 the railways averaged 50% up to 1878 then increased this to a peak of 65% in 1887. Over the period, and extending right up to World War I, moneys voted for road bridges averaged 10%. But overall, the railway boom was beneficial to New South Wales. More people were settling in rural areas, it was possible to sow wheat further west and wool production increased. As a consequence more roads were needed to link farms and isolated towns to railheads. Thus more rivers and creeks had to be crossed and so the number of bridges increased. The combination of a continuing need for bridges, the technical faults of the Old PWD design and the restriction of funds, stimulated Mr. John A. McDonald M.I.C.E., Engineer for Bridges, to produce a more cost-effective timber truss bridge.

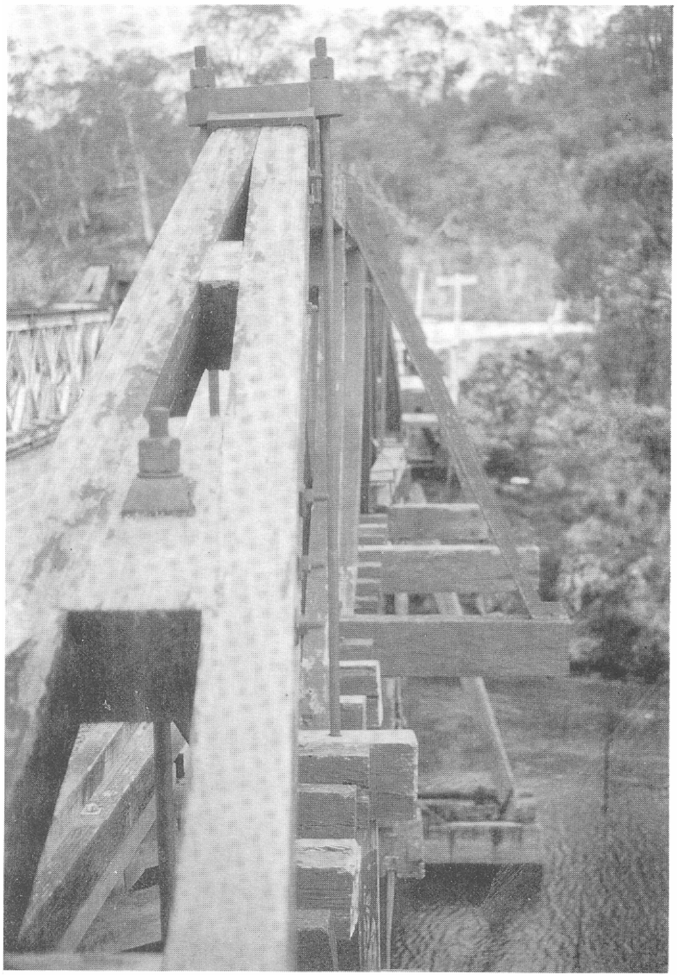
The design which now bears McDonald's name had standard spans of 19.8, 22.9 and 27.4 m (65, 75 and 90 ft.). Elever bridges with McDonald trusses still exist.



"McDonald truss, 19.8m long, over Galston Gorge at Hornsby."

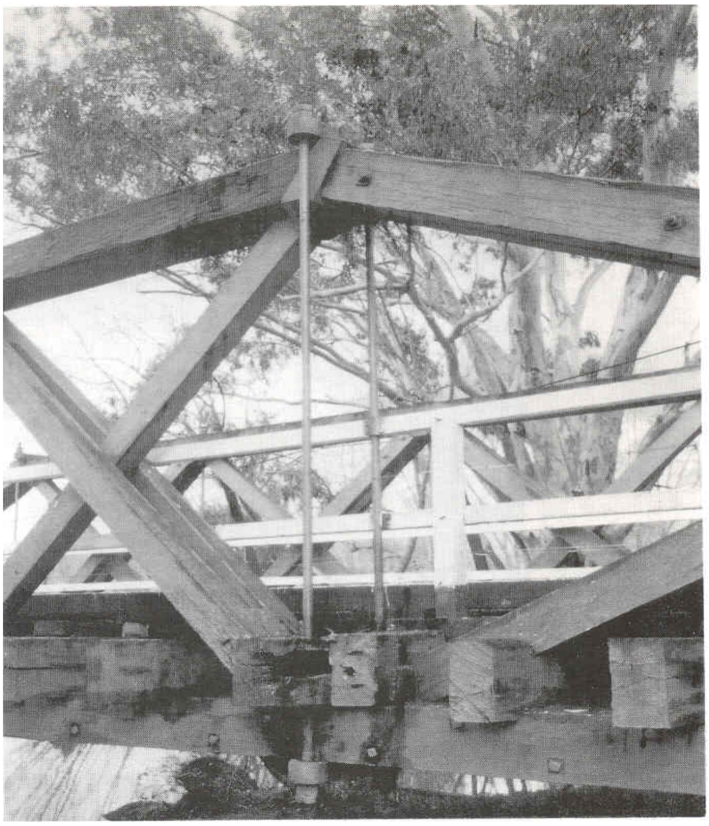
The McDonald truss showed quite a number of improvemets on the Old PWD design. The improvements were:-

1. The sloping end-struts (principals) were made from two lengths of timber, spreading apart towards the supports but tied together by space pieces. These units thus act as spread columns of greater strength, ileproviding some lateral support at the ends of the chords.



“Sloping principals made from two lengths of timber, spread apart towards the supports, but tied together by spacer pieces.”

2. Suspension rods were of increased sectional area with additional vertical rods incorporated at the shoulder joints by using bridging plates across the top and bottom chords, enabling the rods to be located outside the timber. This increased shear strength and made it a little easier to replace component members.

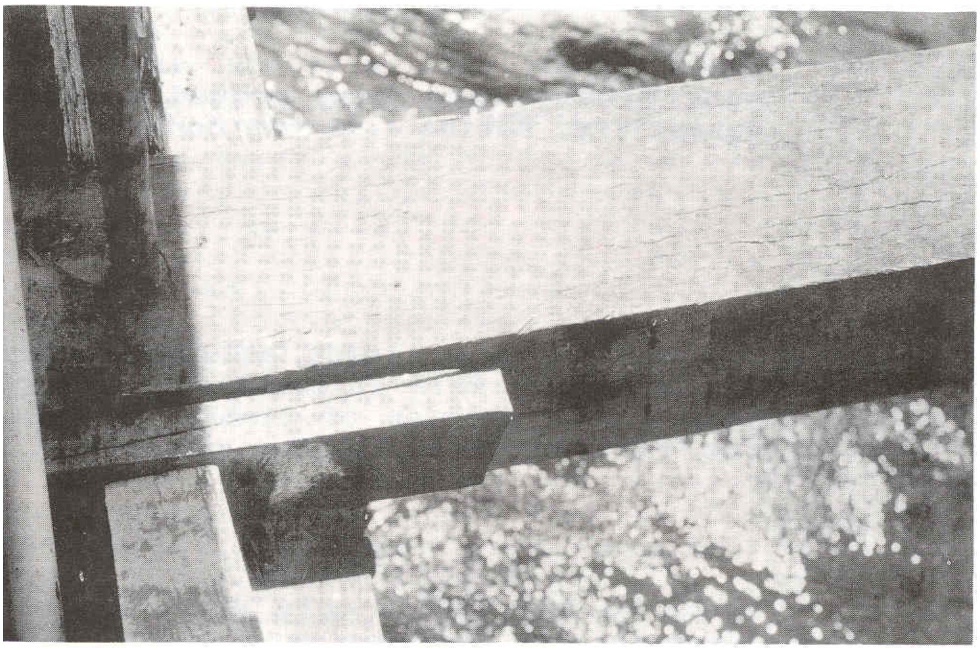


"Suspension roads in pairs either side of the timber."

3. The diagonal web members were a mixture of single and double timbers, which provided greater stability, and allowed for partial renewals without losing the structural integrity of the web.

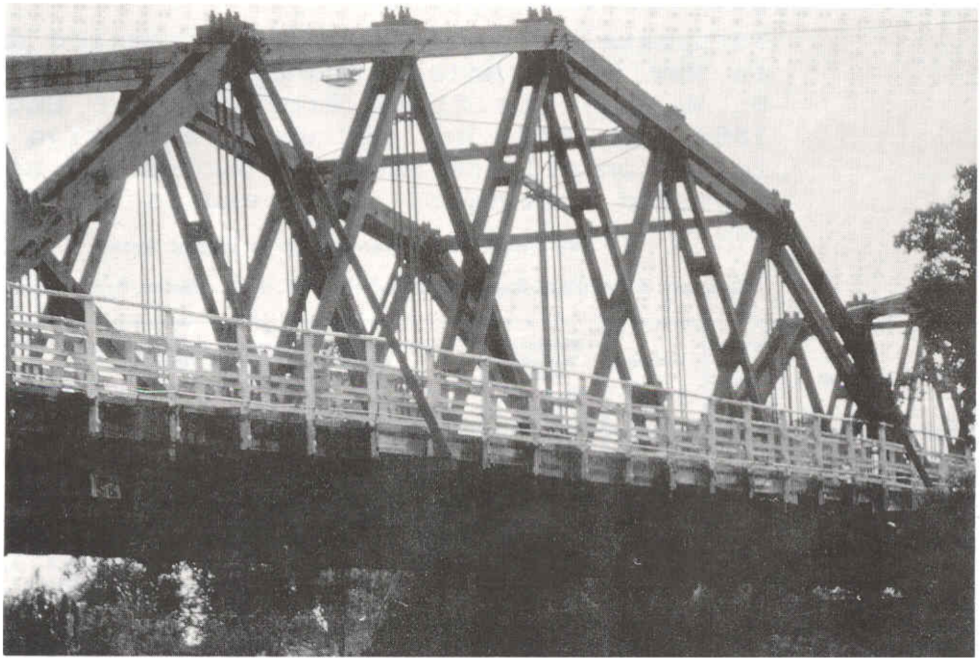
"Some diagonal members are single timbers, some are double timbers."

4. Opposing metal wedges were placed between the ends of the diagonals and the sides of the cross girders so that, by regular blows from sledge hammers, shrinkage and creep distortions could be taken up.



"Metal wedges for making up shrinkage".

5. Better bottom chord splices.



" McDonald truss at Cowra showing principle features."

6. More general use of timber sawn free from heatwood.

7. Planned procedures for the replacement of damaged members of the bridge with minimum interruption to traffic.

At around $4,000.00 per span the McDonald Truss Bridges cost about the same as the laminated arch bridges built some thirty years earlier, but were stronger and had longer service lives.

1.4.4 Professor Warren:

The abundant local hardwoods, ironbark, grey gum and many others, had long proved their strength and durability, dating from the convict era. But little was known about their physical properties so that when McDonald began refining the timber truss so as to increase the ratio of load capacity to self weight, he needed reliable information about tension and compression strengths, shear and bearing strengths, and the effects of grain direction, particularly when loads occurred across (crushing) the grain. This information was required for as many viable species of timber as might be used in the various parts of the trusses. Ironbark was reserved for the main members but for minor members and the deck planks other cheaper species could be used.

Prior to the 1880's only three series of tests on local timbers had been carried out, by Col. Ward and Mr. Trickett in 1861, by John Whitton during the 1870's, and by Thomas Laslett of the Admiralty in 1865. The tests were concerned with bending strengths of beams and although they produced reliable data, the information was of little use in the design of timber trusses.

Fortunately for engineering practice and education in New South Wales, Sydney University appointed W.H. Warren its first Professor of Engineering in 1883. In 1886 he set up an extensive programme of tests on all the local hardwoods and some local and imported softwoods. The results were published in 1893.

1893.

NEW SOUTH WALES TIMBERS USED IN BRIDGE WORK.

Summary of Results of Experiments made by Prof. W. H. Warren, Sydney University.

Name of Timber.	Weight in Lbs. per Cubic Foot.	Modulus of Rupture.	Modulus of Elasticity from Transverse Tests.	Compressive Strength in Lbs. per Square Inch. Ratio of Length to Least Dimension.					Modulus of Elasticity from Compression Tests.	Tensile Strength in Lbs. per Square Inch.	Shearing Strength in Lbs. per Square Inch.
				4 to 1.	8 to 1.	16 to 1.	24 to 1.	36 to 1.			
		Lbs. per Square Inch.	Lbs. per Square Inch.						Lbs. per Square Inch.		
Ironbark	73	18,205	2,635,470	10,572	9,764	9,670	7,875	6,866	1,951,010	21,700*	2,164
Grey Gum	70	17,581	2,547,300	9,822	10,178	8,134	7,357	5,125	1,873,713	17,709	2,041
Grey Box	73	16,209	2,766,435	8,021	8,525	8,032	7,210	Not given	2,048,940	21,897	2,095
Brush Box	63	15,821	2,052,770	8,327	7,914	7,223	5,722	4,343	1,703,181	13,236	2,140
Messmate	54	15,414	2,137,383	9,037	9,517	7,786	7,233	5,264	1,849,824	16,081	1,688
Forest Mahogany	69	15,290	2,607,908	8,477	8,095	7,986	6,786	5,641	1,693,139	20,353	1,719
Tallow-wood	71	15,272	2,248,613	8,548	7,987	7,767	5,942	5,169	1,750,223	14,744	1,667
Spotted Gum	60	15,245	2,351,002	8,545	7,921	7,966	6,207	5,250	1,961,717	16,440	2,005
Blackbutt	62	14,845	2,167,880	8,611	8,170	7,762	6,309	6,008	1,808,034	21,112	1,821
Blue Gum	67	14,765	2,160,509	8,090	8,049	7,977	6,842	6,259	1,736,825	17,452	1,880
Red Gum (*E. Tereticornis*)	70	14,608	2,101,005	9,397	7,915	7,265	5,208	5,000	1,668,634	13,618	2,039
Turpentine	65	14,381	1,976,530	8,495	7,906	7,283	5,514	4,781	1,605,758	17,854	1,636
Woollybutt	64	14,182	2,255,640	7,168	7,784	6,884	5,931	4,975	1,589,023	19,190	1,728
Mountain Gum	60	13,260	1,615,520	7,258	7,850	6,785	7,056	3,656	1,607,850	13,494	1,870
Stringy Bark	61	13,083	1,384,042	6,698	7,636	6,805	5,920	3,651	1,505,579	15,976	2,089
Mountain Ash	54	12,148	1,965,665	7,403	7,693	6,419	5,665	5,656	1,580,416	19,713	2,102
Murray Red Gum (*E. Rostrata*)	64	9,098	1,067,656	6,298	4,920	6,030	3,775	3,325	1,023,077	8,571	1,818

The engineering courses presented by Professor Warren and his staff included the latest information on the analysis and design of structures, particularly trusses, and he introduced a great deal of American bridge technology into local engineering through the courses and his many technical papers. He became directly involved in many bridge projects, for both roads and railways, and demonstrated the benefits that could be obtained from a more scientific and mathematical approach to bridge engineering.

J. A. McDonald, Percy Allan and the other bridge designers were quick to use this information in order to further improve and refine the timber truss bridge.

1.4.5 The Allan Trusses (1893-1927) :

Percy Allan M.I.C.E. M. Am. Soc.C.E. was an outstanding public works engineer, particularly in the area of bridges. He designed over 550 bridgesbuilt in New South Wales, including several remarkable structures. He designed bridges in steel and concrete, but was always a supporter of timber in which material most of his bridges were built. Fortunately, he was also a prolific writer and the work of his t~me is well documented.

He was born in Sydney on 12th July, 1861 and was educated at Calder House. He joined the Public Works Department on 8th September, 1878 and gained his engineering knowledge by pupillage under senior engineers with the Department. He became a competent and innovative bridge designer and one of his personal successes was the lift bridge at Swan Hill completed in 1896 over the Murray River.

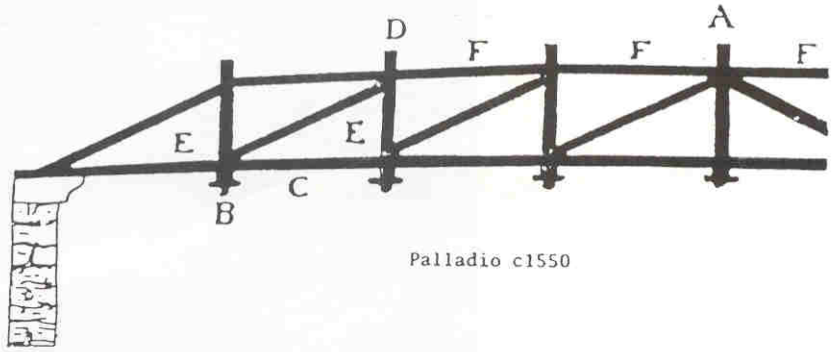
“Bridge over the Murray River at Swan Hill. 1896.”

Probably his best known works were the swing bridges at Pyrmont (1902) and Glebe Island (1903); claimed to be the first electrically operated swing bridges in the world.

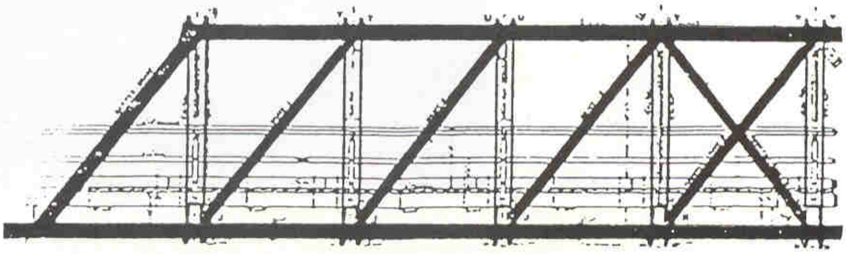
"Swing span on Pyrmont Bridge. 1902."

In 1896 he was appointed Engineer-in-Chief of bridgedesign and from 1900 to 1908 assumed the increased responsibility for rivers, water-supply and drainage, which included Sydney's sewerage system and the ocean outfalls. While District Engineer for Newcastle, he designed wharves and cranes and supervised construction of the northern breakwater. He became Chief Engineer for public works in 1911 and was appointed to

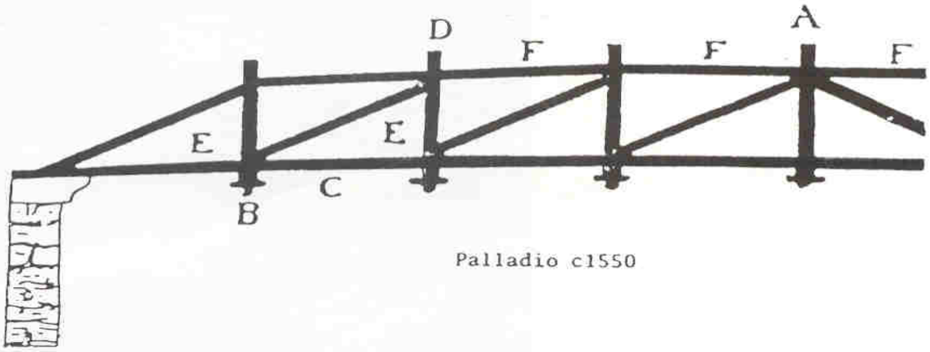
"Allan Truss over Molonglo River at Burbong."



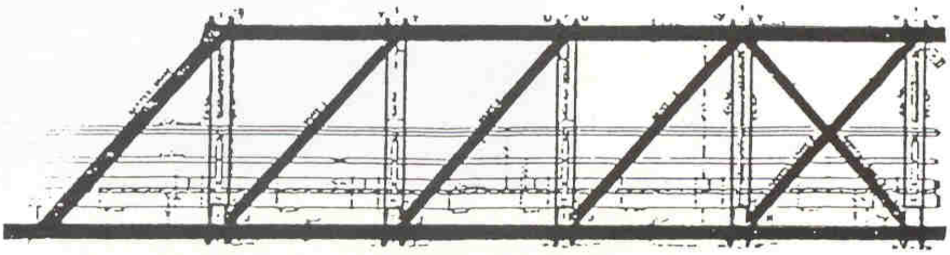
Palladio c1550



Allan 1893



Palladio c1550



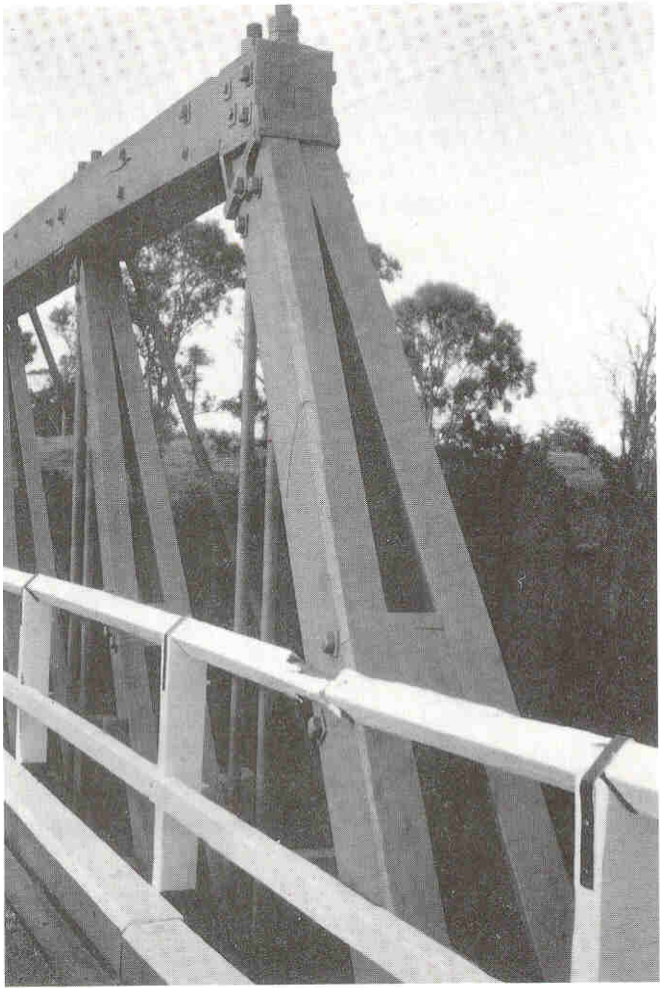
Allan 1893

"A comparison with Palladio's sixteenth century truss suggests that Allan's design was not entirely original or based on contemporary American truss technology."

The significance of this new design was its suitability for the materials available, particularly during a period of severe economic constraint.

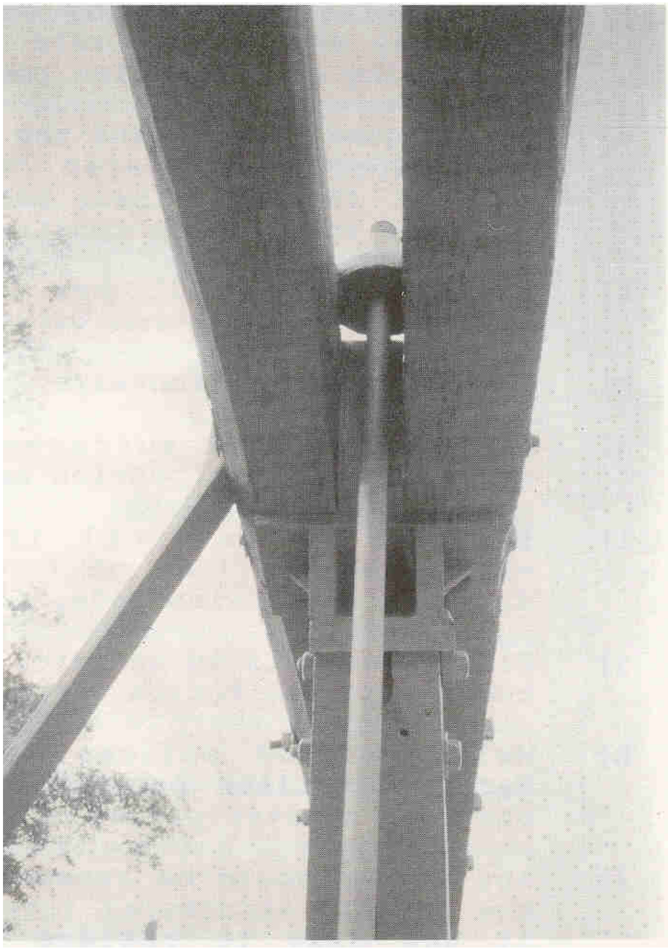
Features of the design were:-

1) Cast iron shoes at all joints reduced problems with dampness, allowed simple squar shaping at the ends of timbers and ensured a better distribution of forces through structurally sound joints. They also made renewal of half members much easier.



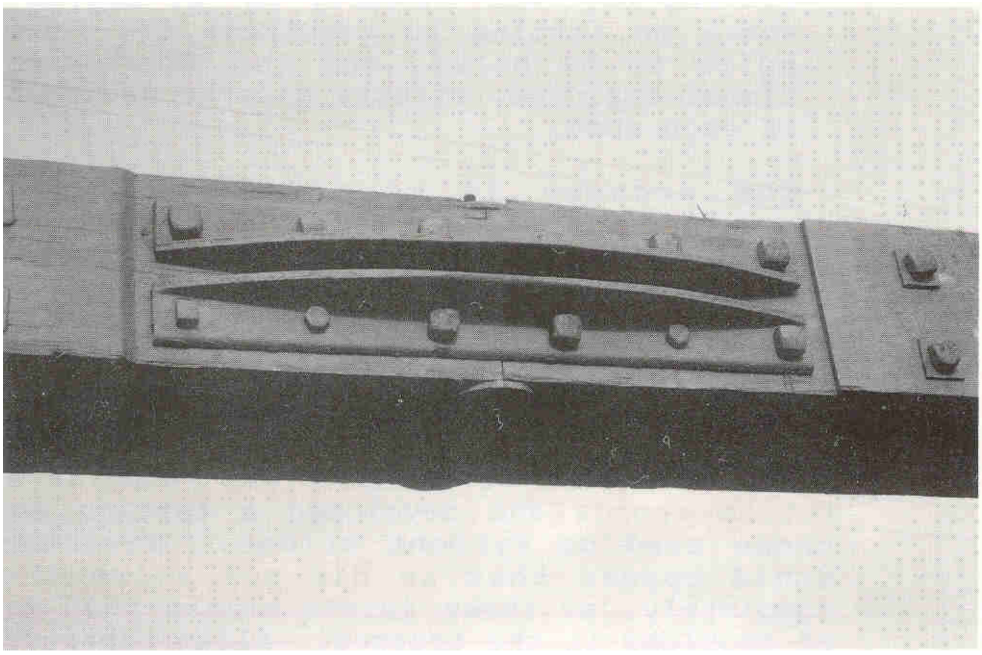
"Diagonal braces and principals are of spaced construction."

2) The adoption of open top and bottom chords for easier painting, also reducing the decay due to the entry of water between the members in a built up chord.



"Top chords are open and joints have cast iron shoes."

3) The omission of counter braces in all except centre panels, i.e. the use of single diagonal webs, eliminating redundant crossed members.



"Metal splice plates are well designed."

4) The placing of all webs on the same angle so that any shrinkage could be taken up by the tightening of suspension rods.

5) All diagonal braces and the sloping end members (principals) of spaced construction, which greatly increased their buckling strengths for a modest increase in construction costs.

6) The use of sawn flitches in all braces, bowed to prevent warping and twisting.

7) The provision of footways.

8) All joints and surfaces of members left accessible for inspection and maintenance.

9) The use of external iron clamps almost eliminated drilling of timbers for the large diameter suspension rods.

10) Floor beams placed at panel points to eliminate bending in the bottom chord.

11) Well designed splices (a direct result of Warren's earlier programme of timber testing) enabling shorter pieces of timber to be used.

12) Any member could be renewed without destroying the overall structural integrity of the truss. It was easy to replace half members and traffic could be left running.

The economy of the system was quoted by Allan,

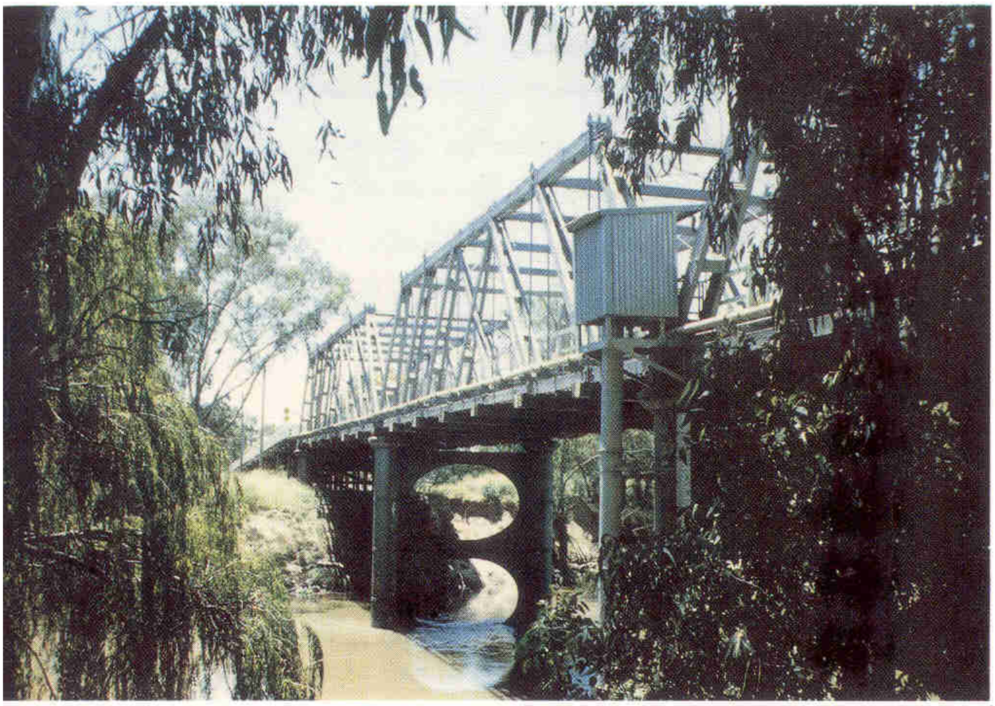
> "In the superstructure of one 90ft. span carrying a 15ft. deck, there is 500 cub.ft. less timber than in the 1886 type of truss, which, in conjunction with the greater ease in framing together (notably in the bottom chord, where no fitting is required) the fewer bolt holes to be bored, and the short length of timber employed, effects a large saving in cost of each span.
>
> The economy is more marked when it is considered that the old trusses were designed to carry a 15 ft. carriageway, whereas the Allan trusses are designed to carry two 5ft. footways in addition to a 15ft. carriageway. Thus it will be seen that the later design of truss bridges offers greater facilities fortraffic at a much reduced cost".

Allan was aware of the problems found in splices in bottom chords and developed a testing machine forthose used on Pyrmont Bridge. Nevertheless, it would appear that he did not solve the problem completely, as these joints remain the major cause of problems in the trusses. Allan reported that his splice detail was adopted in

America. Longer spans (over 27 m) required overhead bracing to stabilize the top chord. This required the trusses to be 6.4 metres deep “to allow clearance under the bracing for a loadeed wool wagon”.

However, due to Percy Allan, timber truss road bridges were by now (around 1900) relatively cheap and remained serviceable much longer than the earlier designs. In 1984 there were about 80 sites with Allan trusses, many of which are from the original batch of the 1890's. Although superceded by steel and concrete bridges for highways and main roads, after World War I, some Allan trusses were built during the 1920's and 1930's.

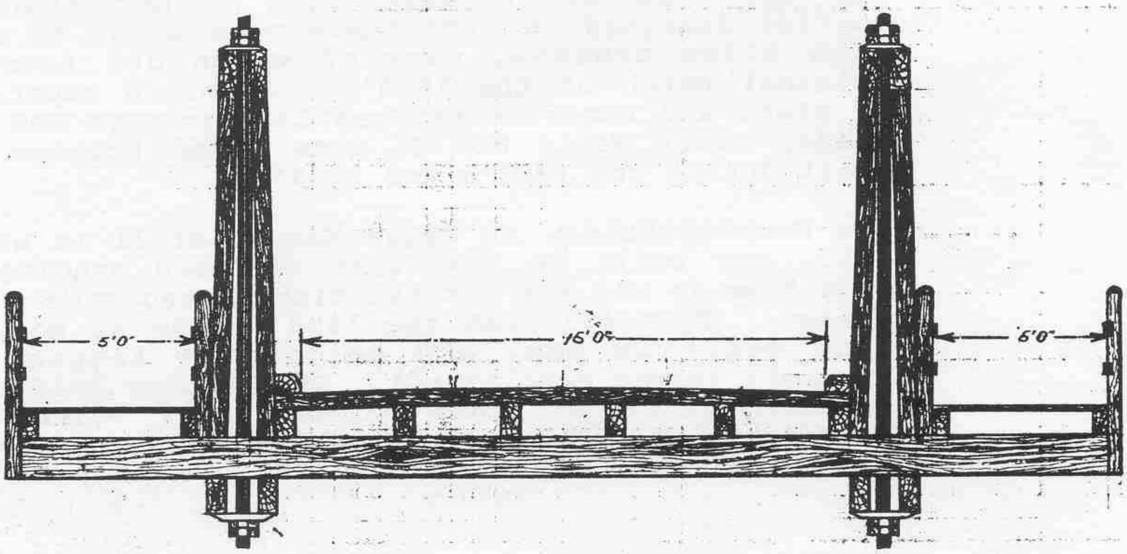
The Hampden Bridge at Wagga Wagga, still in use in 1986, was built in 1895 with overhead bracing. At that time it was the largest timber structure colony. Then followed the 1898 bridge at Morpeth, also still in use, and bridges at Kempsey and Inverell (since demolished). The Kempsey Bridge had the longest timber spans in Australia. There were four spans of 46.65m, with a 6.86m carriageway.



“Allan Trusses in bridge over Murrumbidgee River at Wagga Wagga.”

(Allan)
Standard 90' Truss. 1893.

15' between kerbs – Two footways each 5'0".



- Planking. – Roadway 9" × 4"
  Clear span 3'0" – 6" = 30"
  Load at centre of plank = 4·75 Tons.
  Bending Moment = $\frac{4.75}{2} \times 30/2$ = 35·625 inch tons.
  Moment of Resistance (Ultimate) 1/6 × 6 × 9 × 4 × 4 = 144 inch tons
  ∴ Factor of Safety = 4.

  Footway 9" × 2"
  Clear span 4'6" = 54"
  Dead Load = 4'6" × 9" × 2" × 80 lbs = 45 lbs
  Live Load = 4'6" × 9" × 84 lbs = 283·5 lbs.
  Total 328·5 lbs = ·15 Tons.
  Bending Moment = ·15/2 × 26" = 1·95 inch tons.
  Mt. Resistance 1/6 × 6 × 9 × 2 × 2 = 36 inch tons.
  ∴ Factor of safety = 18·5.

Roadway Stringers = 10" × 6" –
  Dead Load. Planking 10' × 3' × 4" × 80 lbs = 800 lbs
  Stringer 10" × 10" × 6" × 80 lbs = 333 lbs
  Total 1133 lbs
  Bending Moment = 1133 × 10 ÷ 8 = ·61 foot tons.
  Live load (distributed) = 10' × 3' × 84 lbs = 2520 lbs
  Bending Moment = 2520 × 10 ÷ 8 = 1·41 foot tons
  Live Load. Traction Engine = 4·15 Tons at centre of spa

1.36

An on-site inspection of remaining overhead bridges shows that Allan was able to vary the amount of material to suit varying amounts of strength required throughout the structure. For example, in the Morpeth bridge, it can be seen that there are three vertical rods in the first panel where the shear force is a maximum. As the shear force decreases towards mid-span so the number of rods decreases to two and then to one. Throughout the structure there is a changing and efficient use of materials, and yet the overall appearance is one of uniformity.

"Bridge over the Hunter River at Morpeth."

It is surprising that Allan did not use iron or steel members for the bottom chord. McDonald had done so before him and it was not long before the construction of timber trusses would be phased out in favour of the use of steel and concrete.

1.4.6 The De Burgh Trusses:

Ernest Macartney De Burgh after whom this new style of truss was named and whose name is perpetuated by De Burgh's Bridge over the Lane Cove River, was born in Ireland in 1863. He gained his engineering degree at the Royal College of Science, Dublin, and worked for some time on railway construction. He came to Sydney in 1885 and obtained a position with the Public Works Department. For the next eighteen years he designed bridges and supervised their construction, and eventually became Engineer-in-Chief of Bridges. In 1903 he transferred to the Department of Water Supply and Sewerage and he did important design work on dams such as the Burrenjuck, Cataract, Cordeaux, Avon and Nepean. He also played a part in the lcoaiton of the Nation Capital at Canberra by proving the adequacy of river flows in the region to cope with future developments. In many respects, he had a parallel career to Percy Allan. He also retired in 1927 and died one year earlier than Allan in 1929.

The 1899 Annual Report of the Public Works Department contains the following:-

"The Queanbeyan Bridge is rapidly nearing completion and is of considerable interest. With the exception of the bridge over the Lachlan River at Cowra, it is the first in which the composite form of truss has been used in New South Wales. It is of the Pratt style of truss, with vertical post and inclined tension members, and has been adopted in lieu of the Howe type in order to botain a stiff cross-section. The superiority of steel over timber in tension and the great costs of replacing timber chords, which are the first to decay, points to great economy in maintenance."

In the next Annual Report the cost is given as £6,270 "which compares favourably with the trusses previously adopted in which timber was used throughout", and the Building, Engineering and Mining Journal of 7th April, 1900 (P.110) in noting these general details, also report that Miss Eva O'Sullivan (daughter of the Minister of Works) opened the bridge; that Hungerofrd and Sons built the bridge, and, it was designed by E. M. De Burgh.

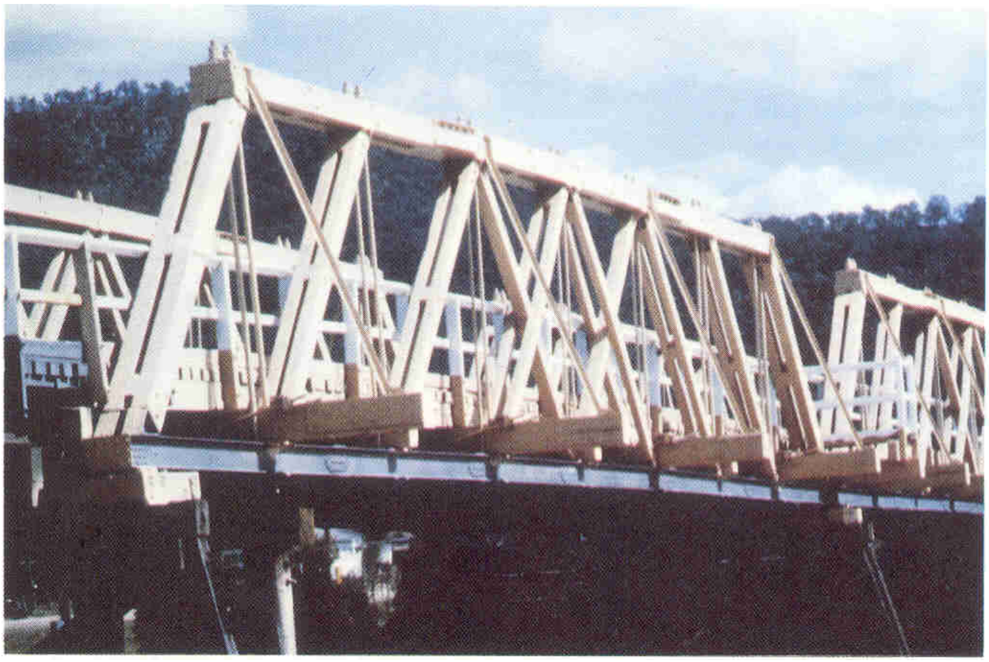
The case for composite construction was effectively summarised by one of De Burgh's colleagues, Harvey Dare. He pointed out that by 1900, composite construction in America had been superseded by all-steel construction aided by a large increase in steel production in that country.

In New South Wales, however, conditions were quite different, steel was still an expensive import and was in limited supply, and Australian timbers were superior to those in America both in strength and durability. Therefore, composite construction offered a compromise between all-timber and all-steel structures.

Two types of composite trusses were developed, the Pratt type by De Burgh in 1899, and the Howe type Dare 1903.

Among the most impressive examples of composite trusses, still existing, are the eleven De Burgh/Pratt trusses, which helps explain why De Burgh's name is perpetuated. The bridge over the Clarence River at Tabulum has five De Burgh trusses each of a nominal 32m span. At St. Albans over the MacDonald River there are two 36m trusses, the largest spans withou overhead bracing.

"Pratt type truss, designed by De Burgh, over Mulwaree Ponds, Goulburn."



"Howe type truss, designed by Dare, voer Wollombi Brook at Bulga."

“De Burgh trusses over MacDonald River at St.Albans.”

De Burgh's longest span is the 5Om deck truss that once carried Ryde Road over the Lane Cover River. This bridge is the only deck Pratt truss in New South Wales and is the largest timber span in Australia. Its future is in doubt because it is no longer required even to carry water mains.

“De Burgh Bridge over Lane Cove River. Official opening ceremony 23rd February 1901.”

(Reproduced by permission of Ryde & District Historical Society.)

De Burgh's designs included improvements consistent with the Pratt system and all the good features of the 1893 Allan truss. Features were:-

1) A permanent bottom chord in steel, fabricated in the end panels but for most of the span consisting of two steel flats,

2) spaced top chords for greater stability and shedding of water,

3) top chord splices so that shorter, readily available timbers could be used. New South Wales was exporting a lot of the best quality ironbark which restricted the size and quality of timbers for use in bridgeworks,

4) custom designed metal shoes for good jointing of timber and metal members,

5) well-detailed joints for proper structural action,

6) accessible ends of the tension rods for tighening-up the bridge to counter shrinkage and creep deflections,

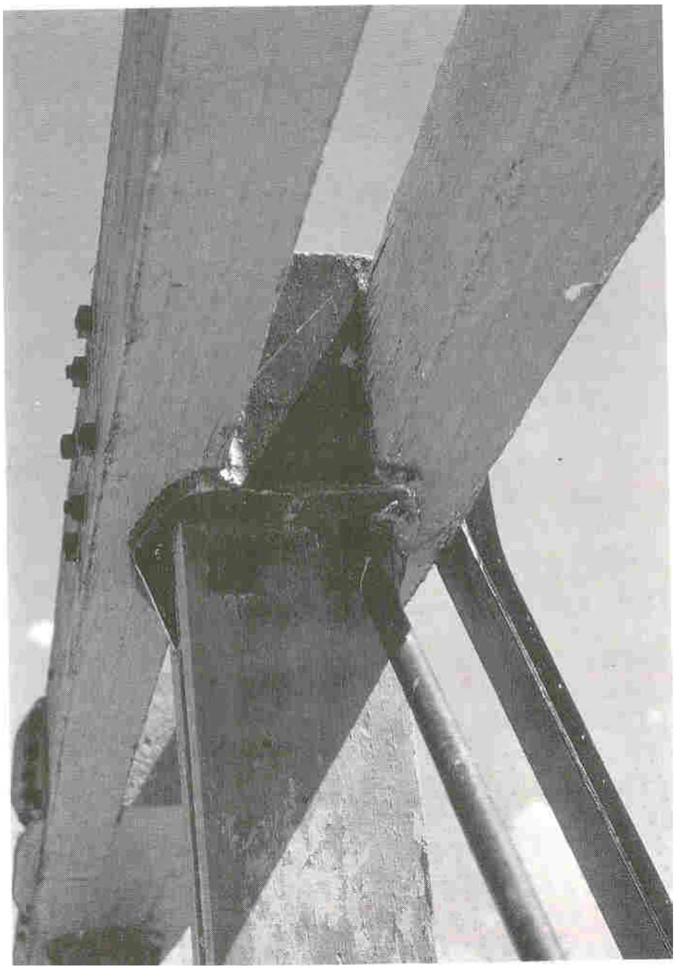
7) the number of diagonal rods varied to suit the shear force.

8) the section size of compression verticals also varied to suit the shear force, and spaced construction was used to increase stability, (in the St. Albans bridge there are four vertical timbers, spaced to form a square and bowed to give greater stiffness at mid-height) .

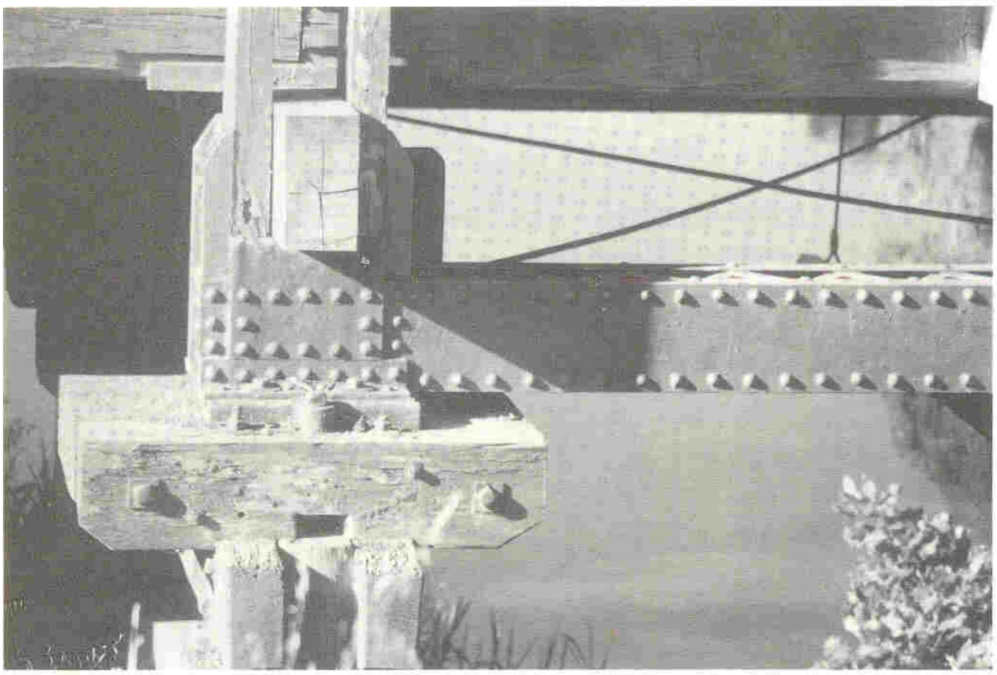
9) simple pin joints in the bottom chord to ensure proper joint action combined with 'easy connections to the diagonal rods and timber verticals,

10) duplicate members for easy renewals plus an easy slide-out-slide-in replacement of cross-girders, which allowed repairs to be made without underpinning or taking the bridge out of service. De Burgh trusses feature vertical principals, steel diagonals and timber vert- icals. There are eleven De Burgh type bridges still in use in 1986.

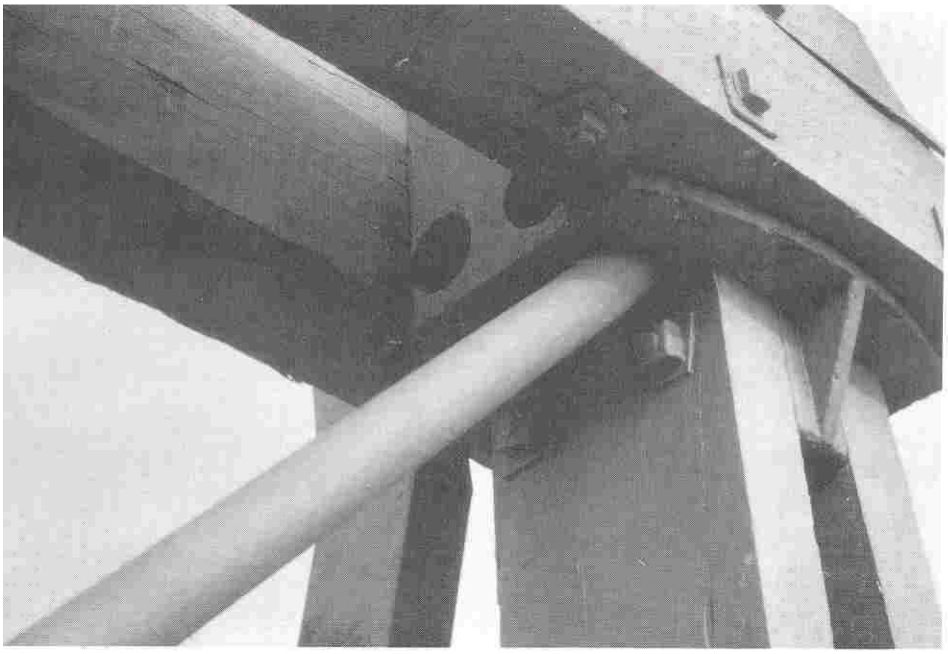
“Features of De Brugh Trusses.”



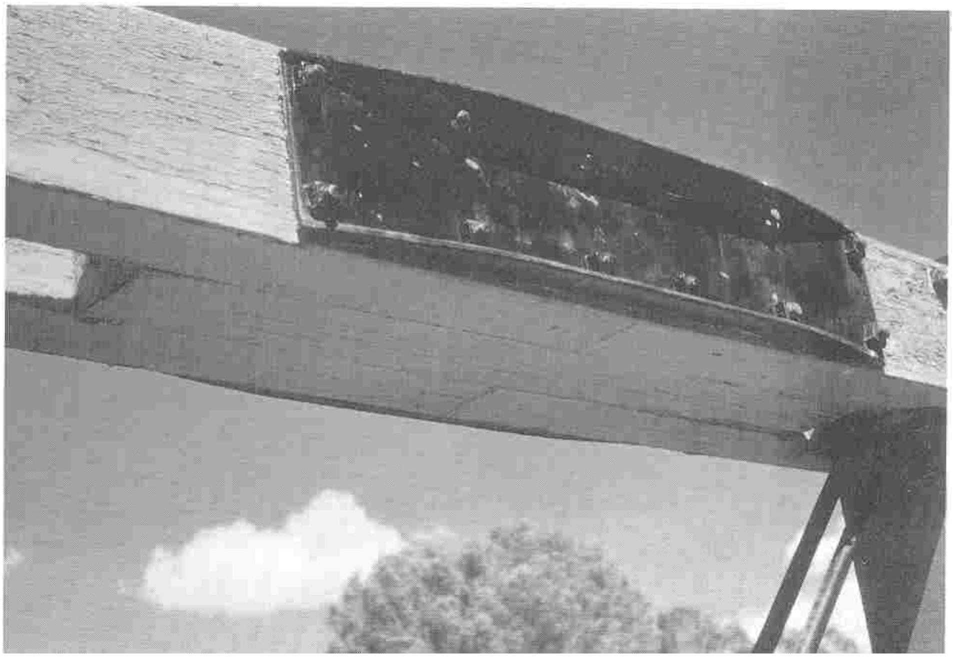
“Top chords are spaced.”



“Bottom chords are of steel.”



"Custom Designed metal shoes at joints."

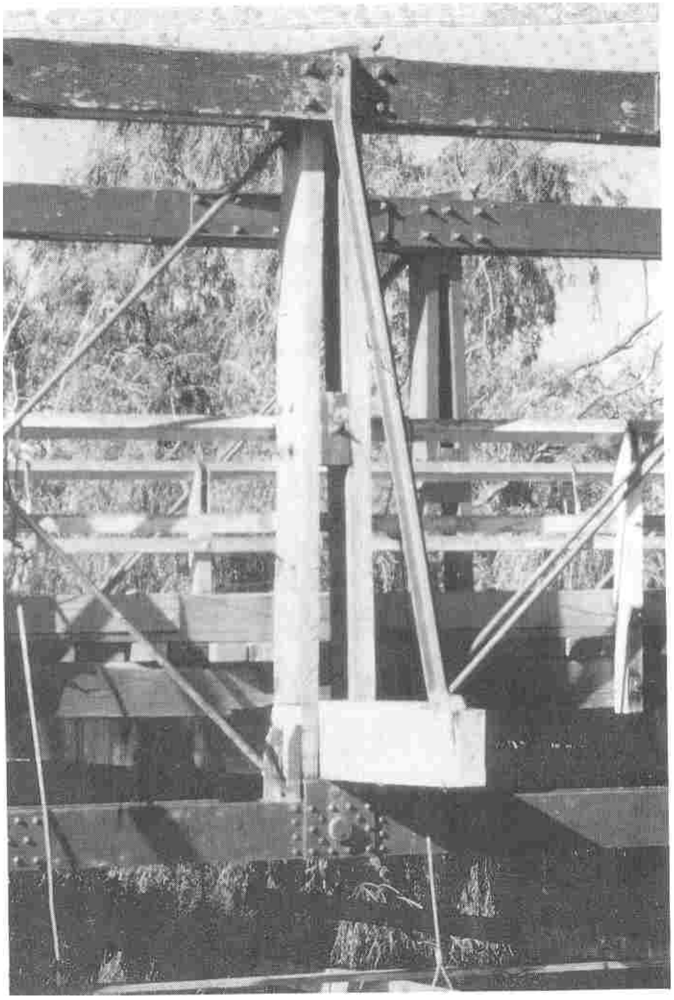


"A new design for splice plates."

1.4.7 The Harvey Dare Trusses:

Harvey Dare was one of De Burgh's colleagues. He introduced many improvements to truss design to the extent that no more De Burgh trusses were built. Of the limited numbers of timber truss road bridges built between 1905 and 1935, nearly all were of hiscomposite design. There are 25 Dare type bridgesstill in use in 1986.

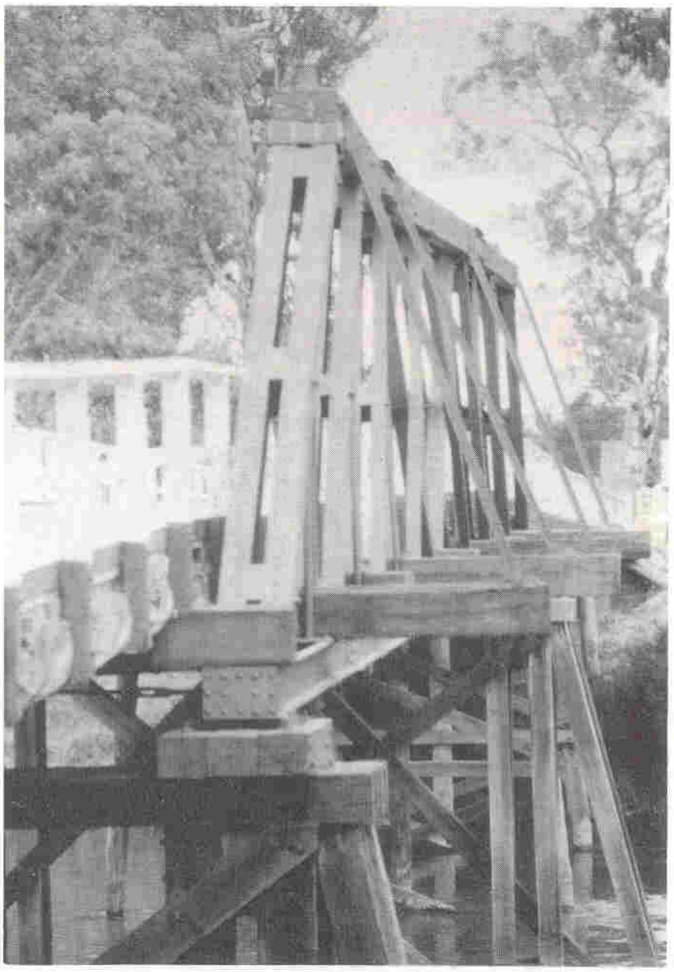
The composite Pratt/De Burgh truss may well have been the best form of construction for the large spans for which it was used, but at the majority of bridge sites shorter spans were possible and the Howe/Allan truss was adequate. Recognizing the advantages of composite construction, Harvey Dare redesigned Allan's 1893 truss in order to incorporate a steel bottom chord and simplify the bottom chord joints by eliminating the pin used in the De Burgh truss.



“Dare truss showing steel bottom chord and ease of member replacement.”

Fabrication of the bottom chord was simplified by using rolled steel channels spaced back-to-back with the vertical rods passing through the gap to simple bridging plates on the underside of the channels. The timber cross-girder was positioned between the vertical rods which allowed slide-out- slide-in replacement as in De Burgh's design.

Harvey Dare also simplified the end detail of,the Allan truss by eliminating the tapered end member and using parallel spaced timbers instead.



“Parallel spaced timbers are used for the principals of a Dare Truss.”

The development by Dare of the Howe type truss was carried out in 1903. Harvey Dare pointed out that by 1900, composite construction aided by a large increase in the steel production in that country. In New South Wales, however, conditions were quite different – steel was an expensive import and so was in limited supply, and Australian timbers were superir to those in America both in strength and durability. Therefore composite construction offered a compromise between all timber and all steel structures.

1.4.8 Types Of Deck:

Both the old FWD and McDonald trusses were intended for narrow bridges. Cross girders were placed between the trusses (at right angles to the road centreline and deck timbers placed diagonally across these girders. The diagonal layout was presumably to prevent the problems of waggon wheels catching in longitudinal gaps between timbers.

As described earlier, Percy Allan adopted the principle of placing floor beams at panel points to eliminate bending in the bottom chord. As these were widely spaced, l;ongitudinal stringers were placed on top of these corss girders and the decking laid at right angles to the bridge axis. This method was followed in all later timber truss types.

1.4.9 Types Of Substructure:

Timber truss bridges were supported on substructures of timber, masonry,concrete, cast iFon and wrought iron. No use of steel is known. (This handbook deals with the maintenance of timber substructures only).

1.4.10 Timber Piers:

Timber piers were constructed by driving piles into the ground. They carried their loads by end bearing on stiff foundation material, and/or by friction along their sides. The friction also resists uplift forces from overturning moments caused by wind and currents. In some cases piles stopped at a concrete sill, which spread the vertical load thus reducing the bearing pressure on the soil, while its weight prevented uplift.

Pile groups were braced to transfer lateral loads to ground level. Occasionally the bracing was omitted and the piles were sheeted in instances where bracing would attract too much debris.

At the top of the piles either one or two horizontal members carried the trusses. The single member (headstock) was more commonly used on the older bridges, and the double member (capwales) was more common on the later ones. The use of capwales allowed for easier replacement because the unloaded truss could be carried on one. wale while the other was being replaced.

1.4.11 Timber Abutments:

Most timber bridges had timber abutments consisting of vertical piles sheeted on the rear with horizontal timbers. This sheeting retained the material of the approach embankment. The piles had a headstock or capwales similar to piers.

1.4.12 Bearings:

Bearings were never used with timber trusses. The trusses had a short span relative to their stiffness and th~refore rotate little and have small temperature movements. The timber structure was found capable of accommodating all movements without distress to individual members.

1.4.13 Timber Types:

Trusses were invariably constructed from the best hardwood available. This was almost exclusively ironbark. Other timbers found include tallowwood and grey box. At the time of the original construction large naturally grown trees were plentiful and the timber used, being slow grown, was dense and durable. Replacement timbers have not always been of such good quality.

Similar timbers were used in substructures, although turpentine was always preferred for piles in marine environments. Decking and sheeting were of many species. Blackbutt, Ironbark, Grey Box, Brush Box and Tallowwood were the most common.

1.5 SURVIVING TIMBER TRUSS BRIDGES

1.5.1 Location Of Bridges:

The attached maps show the location of the timber truss bridges remaining in N.S.W. in 1986. As can be seen they predominate in the Mid and Far North Coast, which are the areas where the best timbers were found. Appendix B is a list of all current timber truss bridges giving the type and line diagrams of the trusses. Note that approach spans have been omitted.

1.5.2 End Of The Timber Truss Bridge Construction:

World War I (1914-1918) acted as a technical watershed for bridge engineers in New South Wales. Prior to the War, the timber truss had been the dominant form of construction for major road bridges. After the War, into the 19201s, steel trusses were used for all major crossings involving spans in excess of 30m. For shorter spans, steel girders were used.

For spans less than 13m the timber beam bridge was still very popular but was being replaced wherever possible by the new technology of reinforced concrete. After the War, the construction of timber truss bridges averaged less than one per year.

But this trend had started 'during the first decade of this century, well before the war. By the beginning of the War there had been a ten-fold reduction in the numbers of timber truss bridges constructed in New South Wales. There were many factors contributing to the demise of timber truss construction, the most significant of which, though not in order of importance, were:-

1) In the 1896 Annual Report of the Public Works Department comment was made o~ the difficulties of

obtaining suitable timber, and in 1908 the report stated that such difficulties were causing delays in construction. Only thirty years earlier Commissioner Bennett had said that "New South Wales was blessed with an abundant supply of native hardwoods", but during those thirty years huge amounts of the native hardwoods had been used for railway and wharf construction and there had been a steadily growing export trade of these timbers.

(i) In addition to this the procedures for ordering and stocking timber did not suit the timber industry, so that the unit rate~ for suitable bridge timbers became unecomonic.

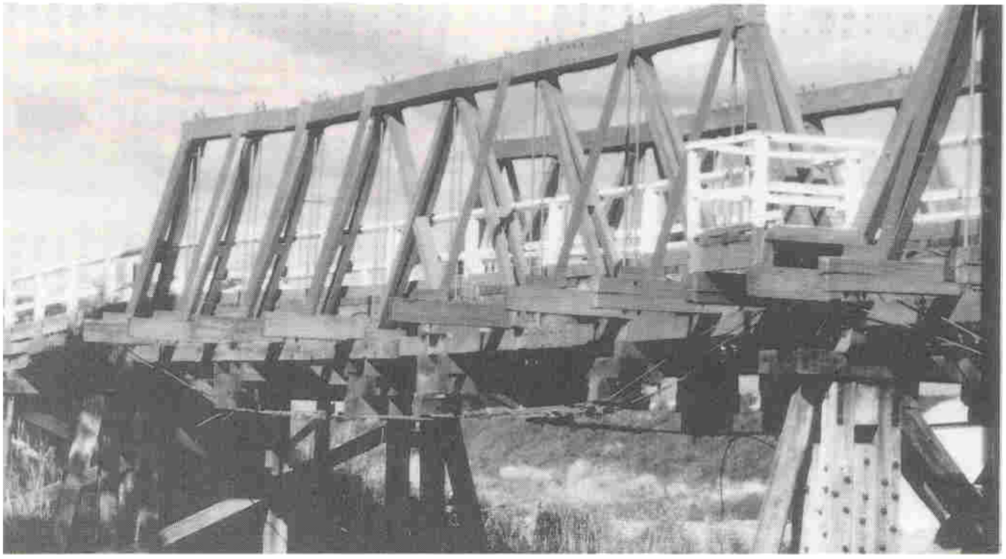
2) The availability of skilled bridge carpenters had declined" by the turn of the century.

3) The cost of maintaining timber bridges, which is labour-intensive, increased with the steady rise in labour costs by comparison with the actual and anticipated costs of maintaining new bridges constructed from modern materials.

4) Better roads, grades and bridges had allowed for heavier carts and teams~~ By 1905, traction engines weighing 17 tonnes were a feature on many roads. These machines travelled faster than the horse/ bullock teams and qonsequently the impact on bridges was greater. The deck system was the first to suffer and in the 1905 PWD Report the "extra expense of strengthening" is noted.

5) Increased loading meant that the main timber trusses were s.ubjected to progressive overstressing during the twentieth century and were showing distress. Some trusses developed overall weakness and required strengthening by underslung cables.

(ii)



"This Allan truss over Wybong Creek on the Denman to Sandy Hollow road typifies the problems with timber trusses. The combination of creep, shrinkage and heavier faster traffic renders the bridge structurally inadequate, hence the strengthening by underslung cables. This bridge was replaced by a continuous steel girder structure in 1984."

6) Some designs were showing shortcomings. For example a problem with pony trusses (i.e. trusses not tall enough to allow overhead bracing) was inadequate lateral stability of the top (compression) chords. At some locations the top chord has buckled out of line. In extreme cases, the top chord has required strengthening by the addition of overhead portal frames.

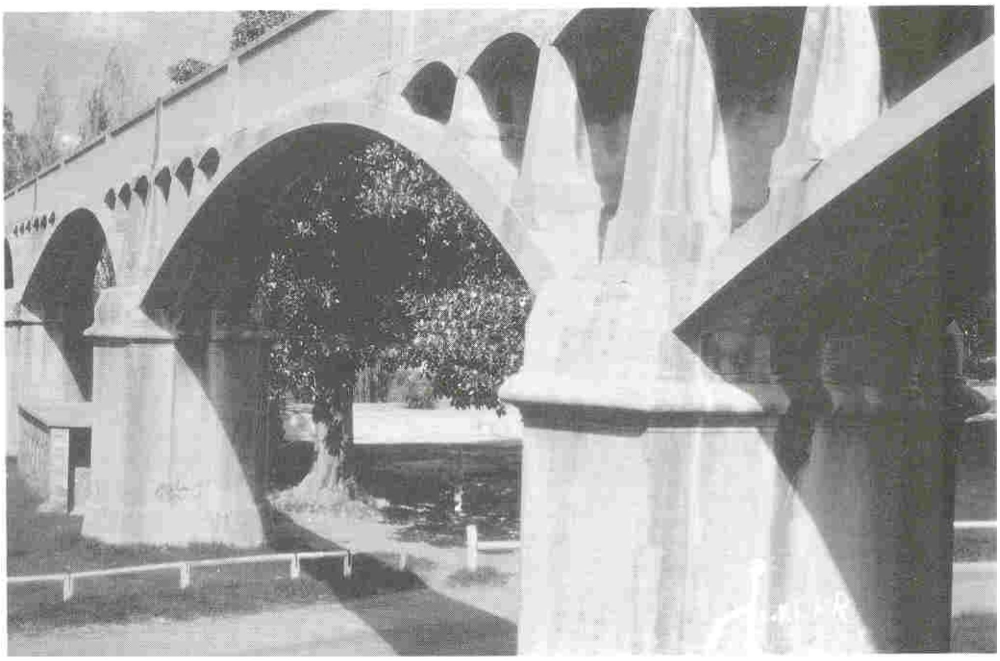
"Overhead portal frames stabilise the top chords."

The sag deflection of the cross-girders causes their ends to rotate and rise, thereby pushing the top chord, via the rakers, inwards. Unequal sag causes un~qual lateral movement of the top chord hence an additional source of misalignment.

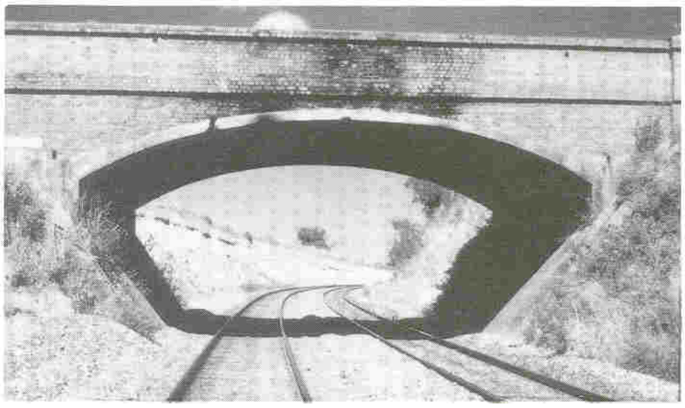
7) Experience of the flood history of New South Wales rivers, in both the volume of water and the amount of debris carried down by floods, required that bridges be built at higher elevations.and the overall economy of bridge construction (the cost of the superstructure should be in keeping with the cost of the sub-structure) meant that only longer spans gave economical solutions~' Despite Allan's overhead timber trusses with spans up to 47m and the composite truss at 50m span, the timber truss bridge was at its technical limit. This became particularly noticeable for crossing the wider tidal reaches of the coastal rivers.

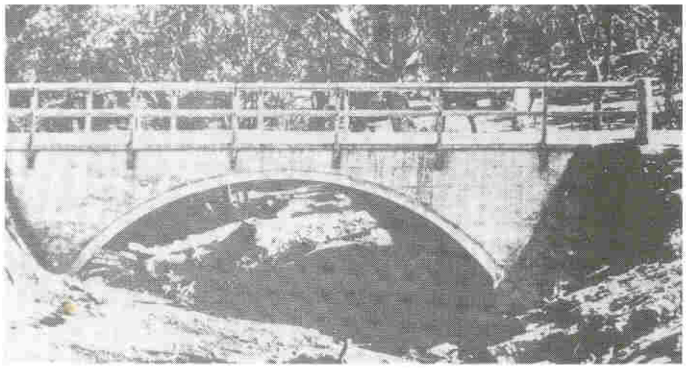
8) When the steelworks opened in Newcastle in 1916, the cost of the supply of steel was reduced relative to imported steel. This further reduced the appeal of timber for major bridgeworks.

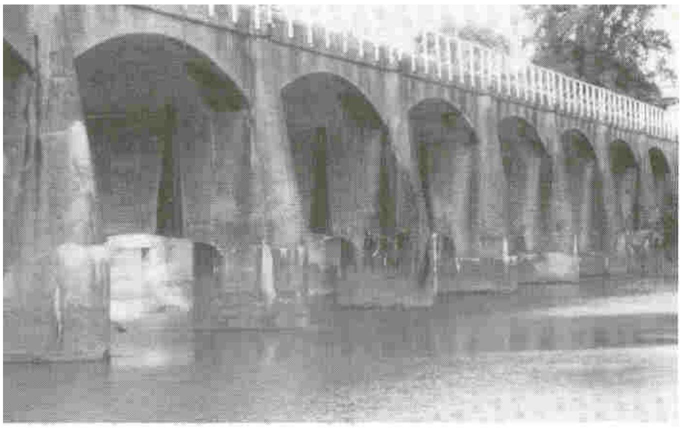
9) A new technology had arrived by 1900 – reinforced concrete. It was first used in the form of Monier Arches for the 1896 sewer aqueducts at Annandale, Sydney, but the system was quickly applied to roads crossing railways and small rivers or creeks.



"Reinforced concrete arches, built in 1896, support a sewer at Annandale, Sydney."

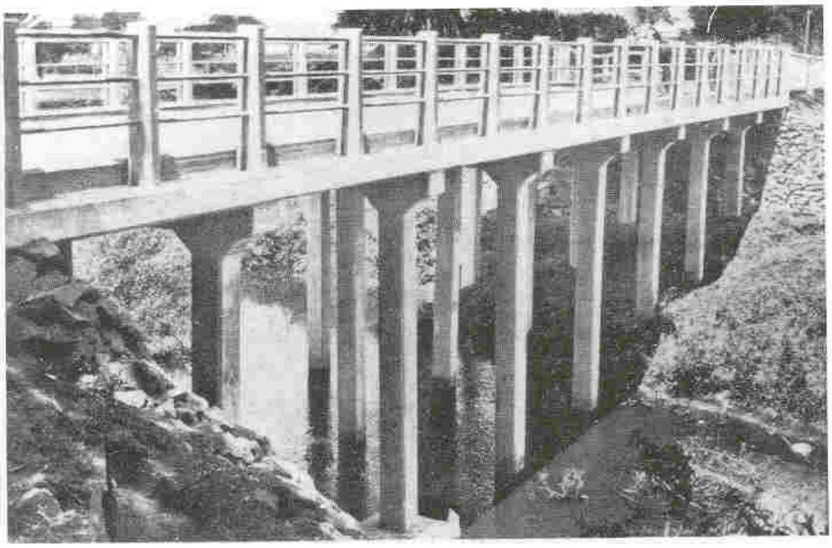




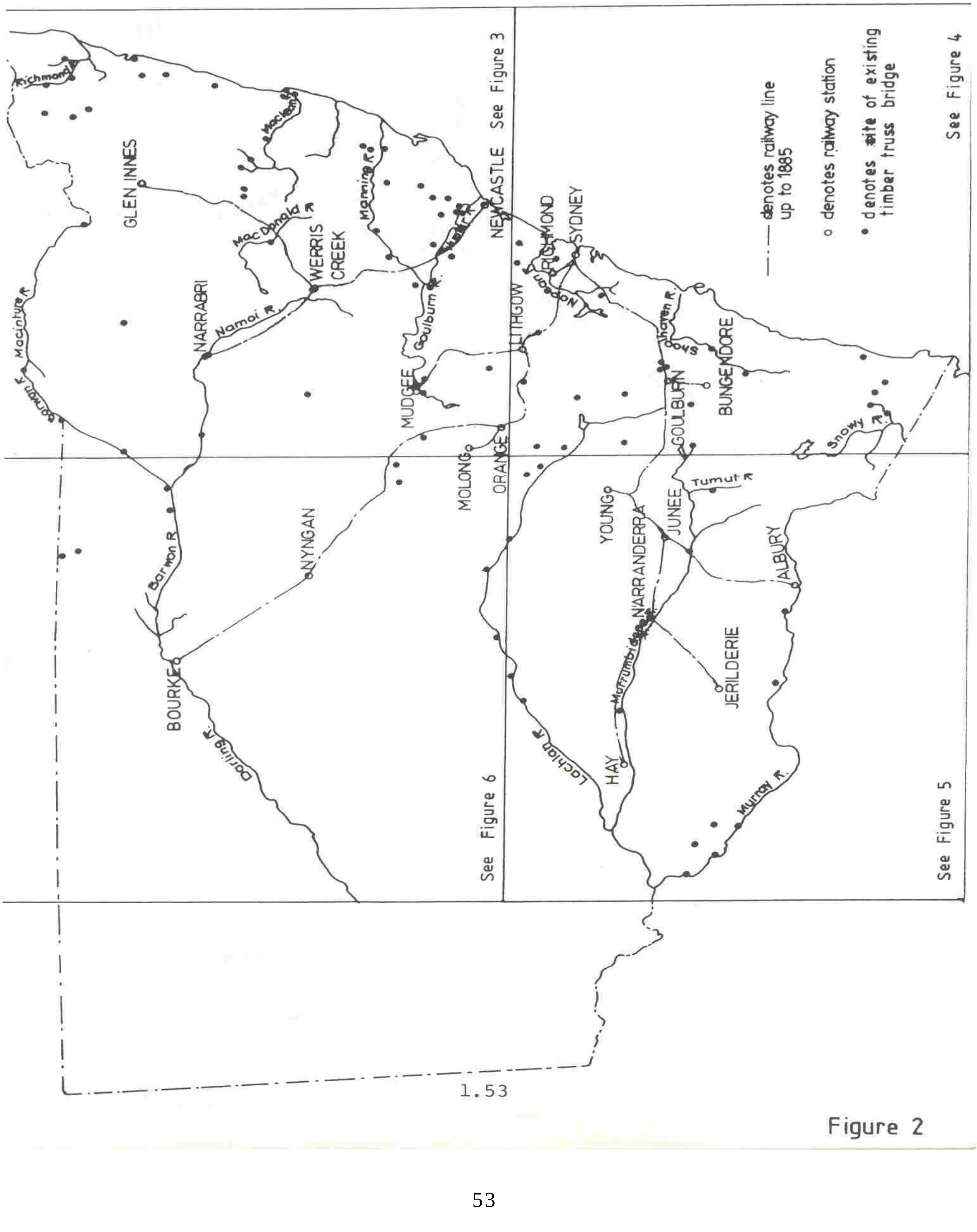


"The early reinforced Concrete bridges were Monier arches such as the single span railway overbridges, the 1900 arch at Moonbi and the 1905 multiple spans oVer the Hawkesbury River at Richmond. The economy and durability of these structures added to the rapid decline in the use of timber bridges."

By 1914 reinforced concrete slab bridges and beam/girder bridges were being built thus reducing timber construction.

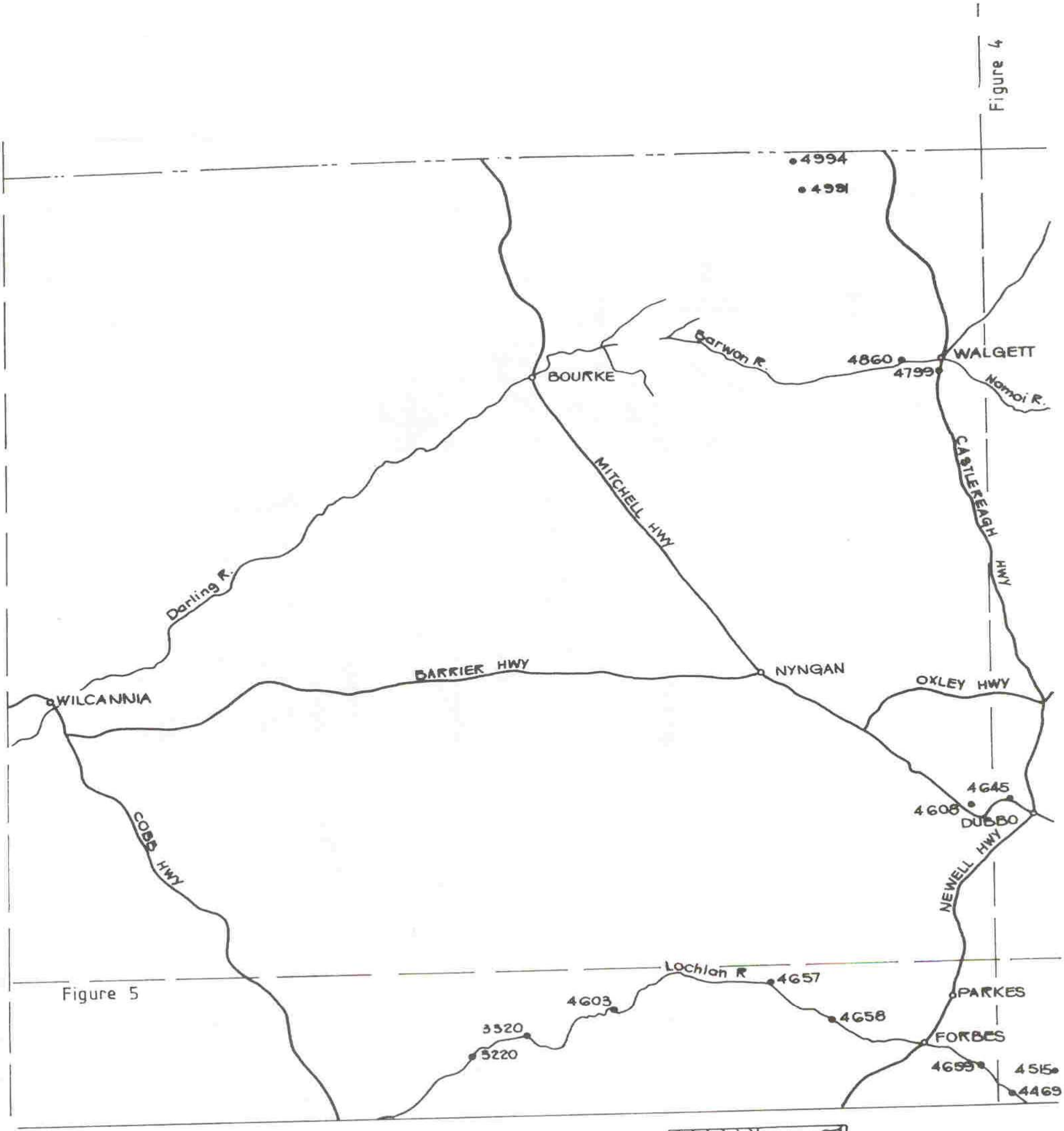


“The concrete Monier arches heralded a new era of road bridge construction, but their use was short-lived because few sites were suitable for arches. On the eve of World War I reinforced concrete beams and slab bridges, such as this 1914 structure over American Creek near Figtree (replaced in 1982), were displacing timber beam bridge ridges and the shorter timber trusses.”


Richmond R.
Macleay R.
GLEN INNES
Manning R.
MacDonald R.
WERRIS CREEK
NARRABRI
Namoi R.
Macintyre R.
NEWCASTLE
Goulburn R.
MUDGEE
LITHGOW
Nepean R.
RICHMOND
SYDNEY
Shoalhaven R.
BUNGENDORE
GOULBURN
Snowy R.
Tumut R.
ORANGE
MOLONG
NYNGAN
YOUNG
JUNEE
NARRANDERRA
ALBURY
JERILDERIE
Murrumbidgee R.
Barwon R.
BOURKE
Darling R.
Lachlan R.
HAY
Murray R.
See Figure 3
See Figure 4
See Figure 5
See Figure 6
denotes railway line up to 1885
o denotes railway station
• denotes site of existing timber truss bridge

1.53

Figure 2



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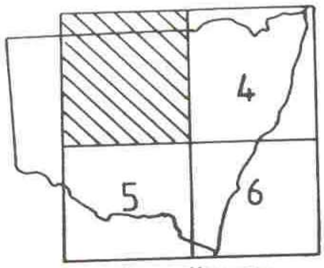

Key diagram

Figure 3

Figure 3
Barwon R.
3071
Macinture R.
3088
MOREE
3138
NEWELL HWY
NARRABRI
Namoi R
INVERELL
GLEN INNES
NEW ENGLAND HWY
ARMIDALE
Mac Donald R
TAMWORTH
BRUXNER HWY
2445
2581
2678
Richmond R
2564
2675
2260
2584
LISMORE
2566
2501
2531
2540
GRAFTON
2680
2509
COFFS HARBOUR
PACIFIC HWY
3788
3772
3791
1917
Macleay R
PORT MACQUARIE
1951
1950
Manning R.
1958
2082
3806
3804
3803
3796
3802
3801
MUSWELLBROOK
1564
Golburn R
1504
1203
1199
4660
MITCHELL HWY
1779
Hunter R
1784
1477
1472
1535
1527
SINGLETON
1752
1737
1683
1482
1481
NEWCASTLE
Figure 6
1185
Figure 5
ORANGE
1301
BATHURST
LITHGOW
1302
413
455

1.55

3
5
6
Key diagram

Figure 4

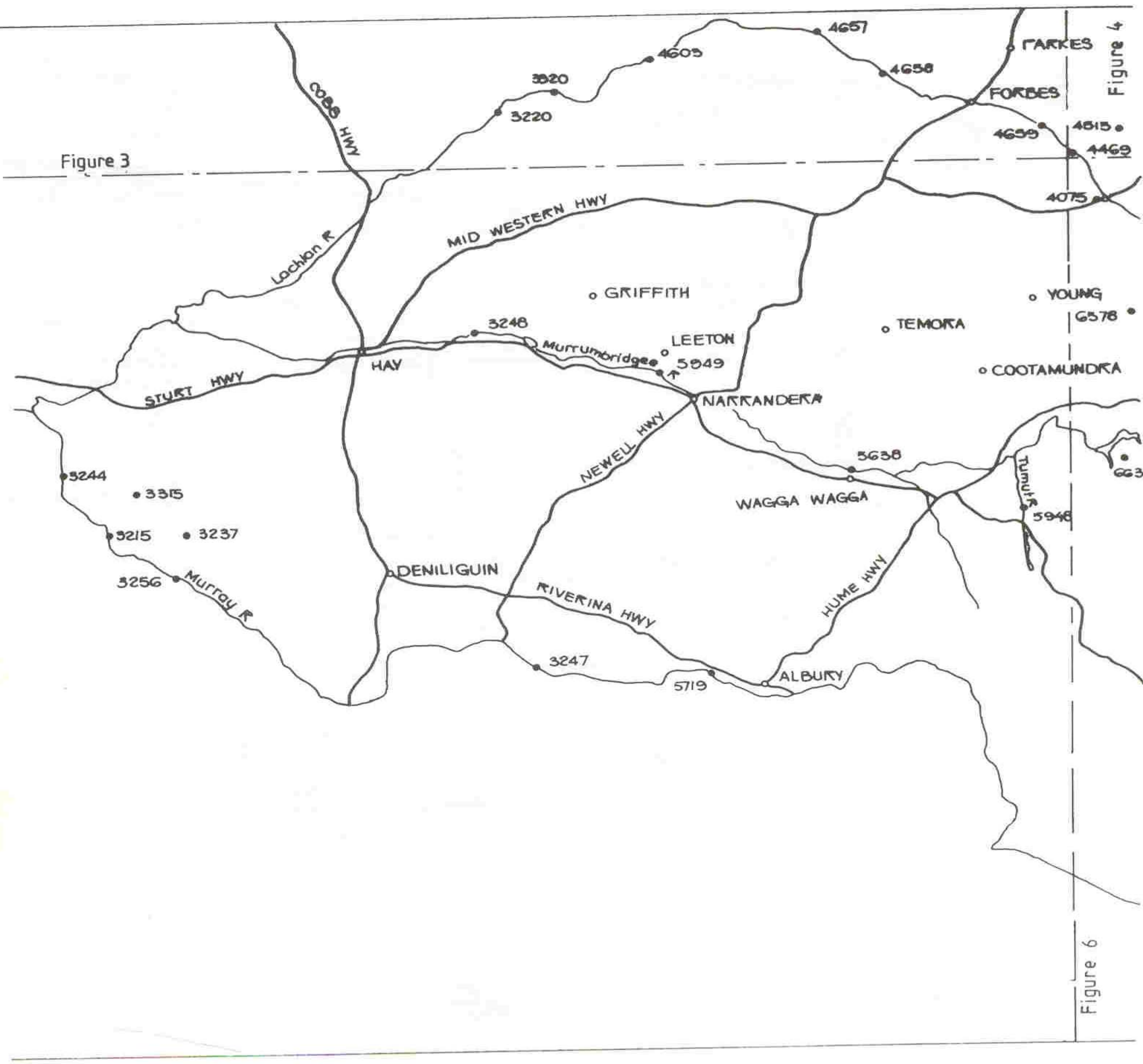

Figure 3
Figure 4
Figure 6
COBB HWY
MID WESTERN HWY
STURT HWY
NEWELL HWY
RIVERINA HWY
HUME HWY
Lachlan R
Murrumbidgee R
Murray R
Tumut R
PARKES
FORBES
GRIFFITH
LEETON
HAY
NARRANDERA
TEMORA
YOUNG
COOTAMUNDRA
WAGGA WAGGA
DENILIGUIN
ALBURY
4657
4605
3820
3220
4658
4659
4815
4469
4075
3248
5849
6378
5638
6633
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3244
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3215
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3256
3247
5719

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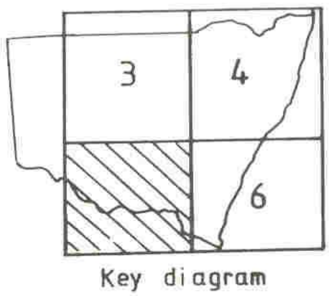
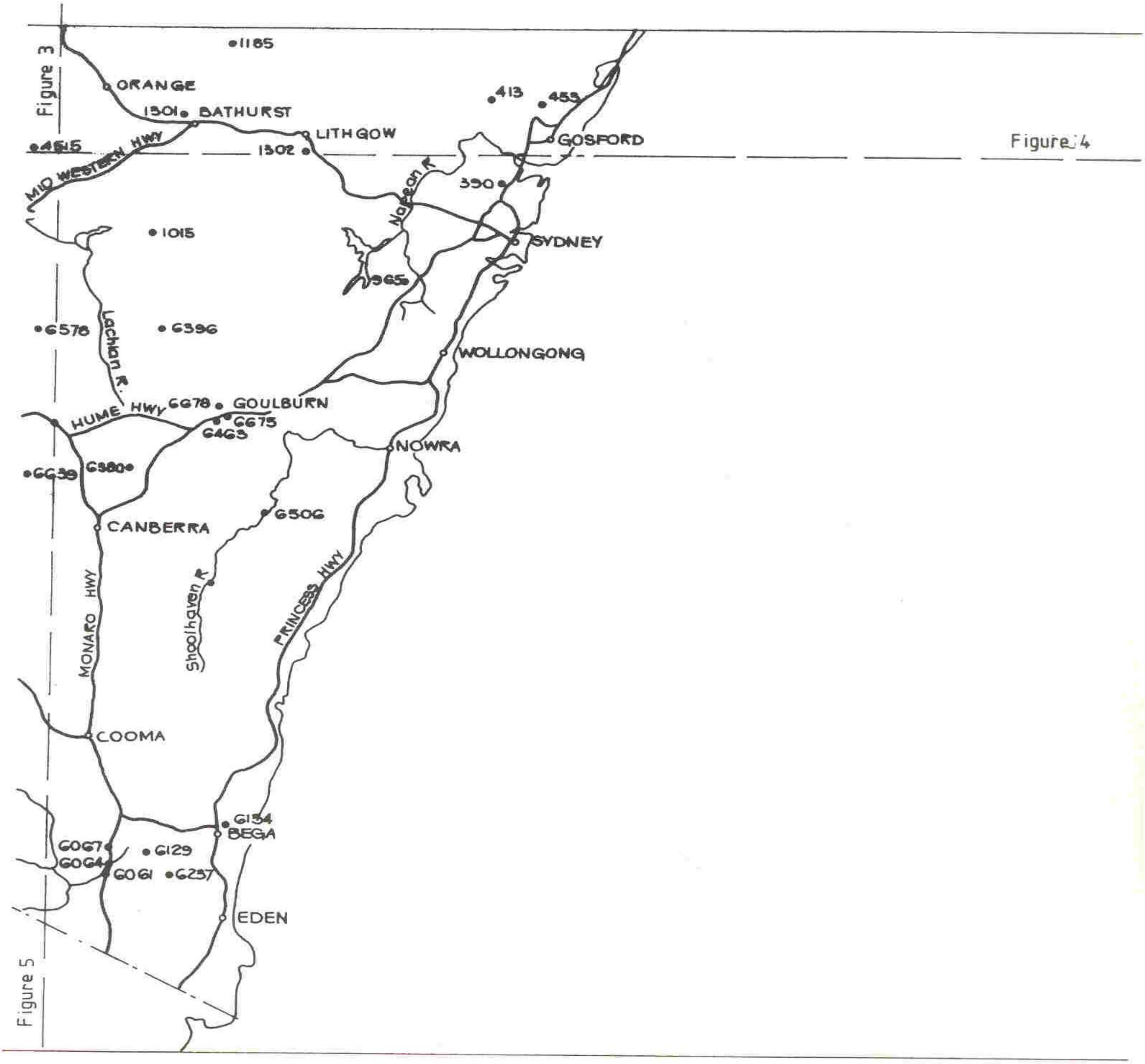


3
4
6
Key diagram

Figure 5



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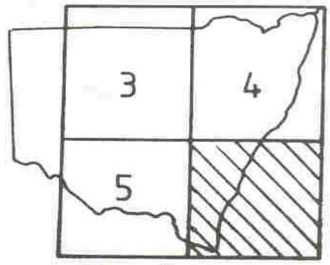


Key diagram

Figure 6

SECTION 2 ECONOMICS AND SAFETY

2.1 CONSIDERATION OF MAINTENANCE NEEDS

Timber truss bridges, using local hardwoods, have served the road users of N.S.W. for more than 100 years, with maintenance largely limited to replacement of deteriorated members, protection against termite attack, prevention of accumulation of moisture and debris and some painting. The technology now exists to inhibit this deterioration, thus reducing the demands on capital for replacement. The remainder of this handbook deals not only with this technology, but also with problems encountered in the field and techniques involved in the solution of these problems.

Timber trusses were never expected to have an indefinite life. Contemporary writing would indicate that early bridge engineers anticipated the replacement of these structures within 30-50 years. Surviving bridges are now 80-110 years old, and have more than exceeded their anticipated useful life.

Economic problems of the 1980's have resulted in a reappraisal of all capital projects, not only bridges, with a view to maximising the results that can be obtained with limited resources. Consequently many timber truss bridges, particularly on minor roads, may need to remain in service for many years.

A typical Allan truss (27.4m span and 4.57m between kerbs) would cost approximately $100,000 to replace on 1986 costs. Even with current maintenance procedures, this sum represents many years of annual maintenance expenditure.

Current practice is directed to checking for deterioration, and replacement of members when deterioration re9ults in excessive reduction in the strength of the member. Fortunately later truss designs were developed with a view to allowing easier replacement of members. However, techniques have now been developed for prevention of deterioration of exposed timbers and adoption of these could greatly extend the economic life of timber trusses.

The pole industry has faced similar financial problems. With an estimated 8,000,000 timber poles in Australia, and the estimated life of a pole at 30 years, the cost of replacement is becoming an increasing drain on revenue. Australian hardwood is unique, and overseas experience in preservation techniques is not applicable. Consequently CSIRO have carried out considerable research over recent decades into methods of preservation of hardwood poles, with a view to reducing maintenance costs. This work has been so successful that an indefinite life is now possible.

2.2 TYPES OF TRUSSES REMAINING

As can be seen by reading Section 1 of this handbook, there are still five basic types of timber trusses in use on N.S.W. roads, Old PWD type, McDonald, Allan, De Burgh and Dare. The last two are composite trusses. All timber trusses have some iron or steel webs - composite trusses have timber top chords and steel bottom chords (see Section 3.2 for terminology).

2.3 PROVISION FOR TRAFFIC

Where bridge repair work is in progress, arrangements for the provision of barriers, lamps, warning signs, temporary traffic lights etc., where required, are to be made in accordance with the booklet - "Provision for Traffic, etc., at Works in Progress". Reference also should be made to Australian Standard 1742 - Part 2 and M.R. Form No.121.

Typically maintenance work on truss bridges involves either re-routing of traffic or restriction of loads or speeds or both. Often the location of the bridge is such that there is no convenient temporary by-pass for traffic, in such circumstances temporary support methods may have to be implemented so that the bridge can carry isolated heavy loads while repairs are in progress.

2.4 SAFE WORKING

Working on truss bridges can involve working in proximity to traffic, in limited spaces, and over water. The bridge maintenance foreman is responsible for seeing that all staging and rigging is in accordance with the Department of Labour and Industry regulations. Safe working methods should be observed at all times to keep to a minimum the chances of accidents occurring. Foremen should study for and obtain (by examination) a Scaffolder's Certificate from the Department of Labour and Industry.

<u>SECTION 3</u> <u>STRUCTURAL DESIGN</u>

Timber is an unusual structural material. It is organic and subject to deterioration. This deterioration may not be structurally hazardous if it occurs at points of low stress, or if it reduces the timber cross section in a manner that has little effect on the capacity of the member.

To understand the effect of deterioration adequately and to make correct decisions on the need for replacement, it is necessary to understand the loadings on a bridge and the function of the structural system in carrying these loadings.

a. <u>LOADINGS</u>

When most timber trusses were built the roads carried horses and horse drawn vehicles, with occasional steam traction engines hauling a trailer. Loadings have gradually increased over the years and design requirements have reflected this growth. Of course many bridges have had to be replaced as loadings have increased and the continued ability of some timber trusses to carry the larger vehicles lies in the conservative size of members originally adopted. However increased loadings have resulted in increased stresses, thus reducing the amount of timber that can deteriorate before overstress occurs.

3.1.1 Traffic Loadings:

It is interesting to note the relationship between the original design traffic loadings and those currently specified.

McDonald trusses were designed for a distributed live load of 84 psf (4.0 kPa) or a traction engine of 16 tonnes.

Allan trusses were designed for a distributed live load equivalent to 140 psf (6.7 kPa) or the same traction engine as McDonald.

De Burgh and Dare used similar loadings to Allan.

These loads compare with the current NAASRA 44 tonne truck. On a typical truss (27m span) this is equivalent to a live load of 177 psf (8.5 kPa).

3.1.2 Dead Loadings:

While the bridge is constructed to carry traffic, it also has its own weight to carry. In fact this load exceeds the traffic load. In timber truss bridges dead load is approximately 150% of the design traffic load~ This must be remembered during maintenance operations. The truss still carries approximately 60% of the total load, even if traffic is diverted.

3.1.3 Lateral Loads:

Dead and live loads are gravity forces acting vertically downwards. Bridges are also subject to forces that act laterally, longitudinally and vertically upwards. The forces of particular reference to timber truss bridges include those due to:-

* Longitudinal.\braking and acceleration forces.
* Wind loading'~
* Expansion and contraction due to temperature changes.
* Stream flow pressure, debris loads and log impact.
* Buoyancy.

It is important to be aware of these forces, many of which can tend to overturn the bridge or its piers. Account must be taken of these forces in the selection of any temporary supports.

b. TRUSS ACTION AND TERMINOLOGY

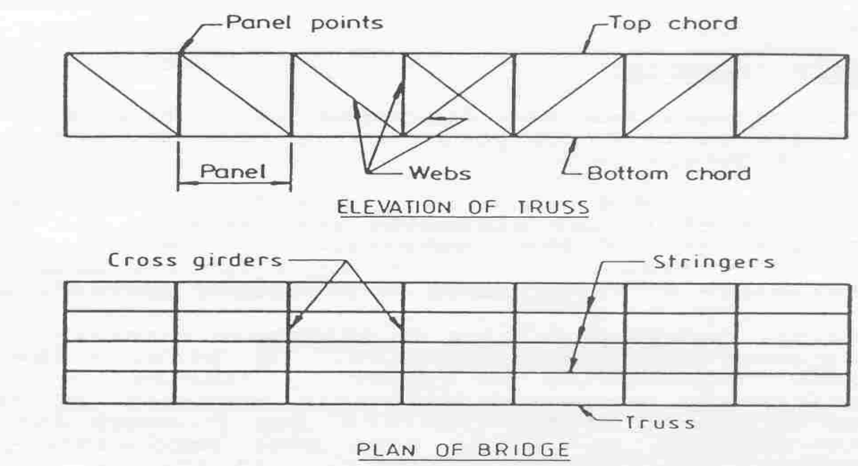
Trusses were developed as a simple method of spanning large spaces with a structure composed of small and more readily available elements.

Prior to the development of the truss, structures were limited either to post and beam construction, where the load is carried in bending, or to arches where the load is basically carried in compression where masonry is particularly effective.

Post and beam spans were limited by the size of the beam, with increased depth being required for increased span. Arch spans were limited by the need for good abutments to take the thrust developed by arch action.

Trusses consist of a series of elements - called members - joined together in a simple manner. The joint is called a panel point. These elements basically carry the load as a direct force - tension or compression. There can be some bending in some members immediately carrying the load, but these are limited to the much smaller span between panel points.

The following diagram shows the general terminology applied to trusses. Bridge members sometimes have different names, or name additional members. These will be referred to later.

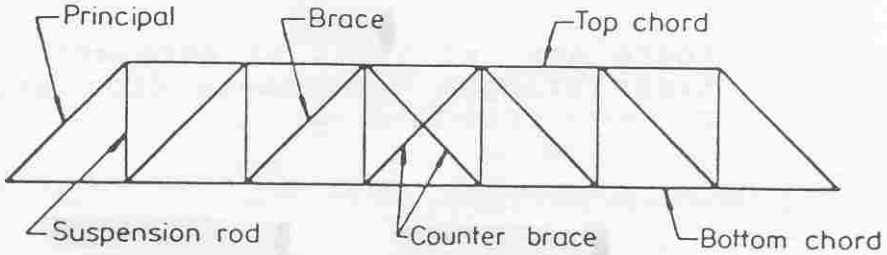


Under all vertical forces (such as the mass of the bridge, or traffic on the bridge), the top chord is in compression and the bottom chord is in tension. Web members can be in tension or compression depending on the configuration of the truss. Where the cross girders bear on the bottom chord between panel points (McDonald, PWD type trusses) there is also bending in the bottom chord. One of the improvements made by Percy Allan was to eliminate this bending by placing the cross girders at the panel points. Compression members tend to buckle under load. Consequently large timbers are used for compression members, while light steel or wrought iron rods are satisfactory for tension members. Some top chords have outriggers to stabilize them and prevent lateral buckling.

The direction of forces in members under truss action depends on the location of the loads and supports. Moving a load or support can change a tension member to a compression member with catastrophic results. Thus temporary supports, such as toms or Bailey bridging, must support the truss at its normal supporting points only.

Similarly, the truss action depends on the presence of all members in each panel, chord and webs. Removal of a web member will result in bending stresses in the chords and possible failure.

The following sketch shows suggested names - based on the original drawings and those most commonly used.



c. TIMBER STRENGTH

Timber properties are discussed in Section 4.1. However, strength is relevant to structural design, and is discussed in more detail here.

In Section 1.4.4 there is a description of the extent of knowledge of timber strengths available at the time of John McDonald, and of the extensive testing and analysis work done by Professor Warren. Percy Allan was able to increase permissible stresses based on Professor Warren's work.

However, modern knowledge of allowable stresses in timber is very much more comprehensive. It permits the much more careful description of timber by species, and results in considerably increased allowable stresses in the species used in timber bridge trusses. For Ironbark and Tallowwood this increase is nearly 600% over McDonald's permissible stresses, and 155% over those used by Allan.

A full table of strength groupings can be found in AS1720 and an extract of those timbers relevant to timber trusses is given in Appendix A. If replacement timbers are limited as recommended in Section 6.1.2.1, the result will be a minimum strength classification of F34 for all structural members in the trusses, deck girders, capwales, and headstocks, i.e. all structural members except for decking, sheeting and piles.

d. TIMBER SECTION

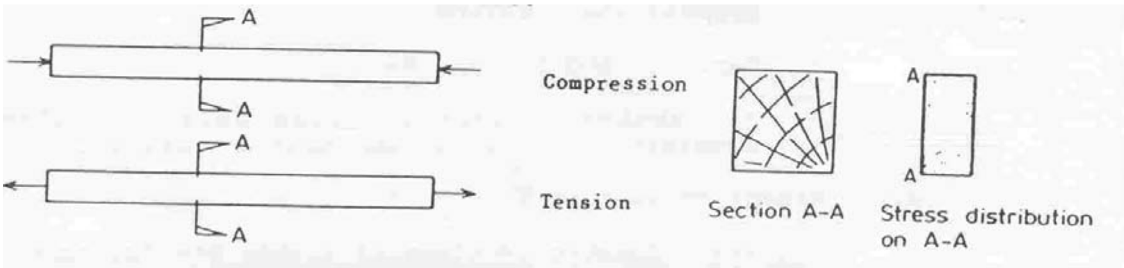
Timber decay or termite activity results in a gradual reduction in the cross sectional area of the timber member. A crucial maintenance decision is to determine when this reduction becomes excessive and the member needs replacement. The different locations of the deterioration in the cross sections (in the centre, on the top or bottom, or on the side) have different effects on the reduction in strength of the member. The effect is dependent on the manner in which the member is carrying the load.

The following sections explain the types of stresses encountered in truss members and the effect of deterioration on these stresses. Tables 3 to 12 are aids to the quick assessment of the reduction in section, and flow diagrams attached show how to use these tables.

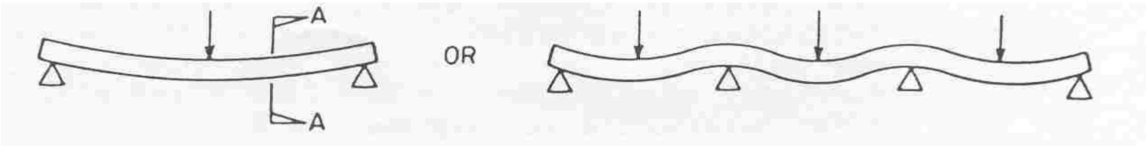
3.4.1 Types Of Stresses:

There are two types of stresses found in timber truss bridges -stresses from axial loads, and stresses from bending.

Axial stresses. These arise from direct compression or tension forces.

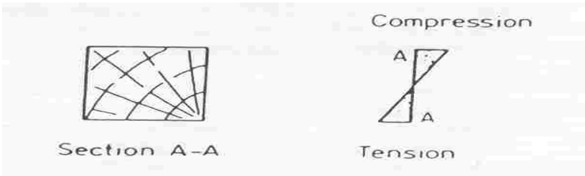


Bending occurs when the member becomes a beam, and the load is applied between the supports.



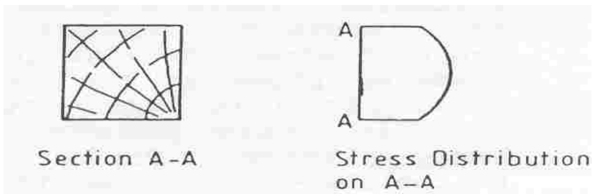
Bending forces produce two types of stress, bending stress and shear stress.

(a) Bending Stresses – These are highest at the top and bottom faces of the section, and zero at the centre.



They are highest at the centre of the span in a single span member, or near the centre of the span, and over the support for a member with more than one span.

(b) Shear Stresses – These are always highest adjacent to the support, and also vary across the cross-section.



Sometimes a combination of axial forces and bending forces occurs.

In a bridge truss all members have axial stress only except for the following which are in bending:-

* Bottom chords of PWD and McDonald trusses (combined axial and bending).

* Deck girders (cross girde-rs and stringers) .

* Decking and sheeting.

* Capwales and headstocks.

* All abutment timbers (piles usually resist a combination of axial and bending forces) .

3.4.2 Effect Of Section Reduction:

The least durable sections of timber are the sapwood and the centre (dead heart) .Bridge timbers are usually cut with boxed heart ie. contained within the total section, and free from sapwood, so deterioration generally commences at the centre of the section~ Some timber may have some sapwood - generally on a corner, or one face - and will then first deteriorate at this section.

a) Axial Stresses - Since axial stresses are uniform across the section, uniform deterioration in the cross section produces increased uniform stresses. Similarly, the force is uniform along the length of the member. If deterioration is eccentric to the centre of the section bending stresses will exist which may be of significance in compression members.

(iii) The amount of deterioration that is permissible is dependent on the relationship between the stress in the member and the allowable stress. Tables 3 in Section 8 show the permissible reduction in area for all axially stressed members in trusses.

b) Bending Stresses - Bending stresses are highest at the top and bottom of the cross-section. Consequently, piping has little effect on the strength of the member, provided it is at the centre. However, loss of timber due to sapwood at the top or bottom can greatly reduce the strength. Table 4 shows the permissible loss in strength for members stressed in bending. Tables 5 show the loss in strength for various diameter pipes at the centre and in slightly eccentric locations. The effect of pipes between these points can be obtained by interpolation. Pipes closer to the top or bottom faces should be treated as loss of area at the face (Table 6). This table also applies to loss of face timber due to sapwood deterioration.

(iv)Bending stresses vary along a member. While Table 4 shows the permissible loss in strength for each member at its most highly stressed section, Table 7 shows the variation of bending stress along the member, with an example of the application of this table, when combined with Tables 4, 5 and 6.

c) Shear Stresses - Shear stresses occur only in members in bending. They are highest at the supports and also vary across the cross section, being highest at the centre and lowest at the top and bottom faces. Table 8 shows the loss of section permitted for members subjected to bending. Table 9 shows the variation of shear along the members, and gives examples of the application of this table when combined with Table 8.

3.4.3 Bolts In Timber Members:

In tension members (bottom chords and braces), the load is transferred into the member by bolts. Bolts require good timber on which to bear - this is given as a requirement for edge distances. Table 10 gives minimum edge distance required. Defect free timber is required in this length.

Bolts in other members are basically for positioning, although they may transfer some lateral forces. Edge distance is unimportant in these cases, and some deterioration in the area of the bolt would be permissible.

3.4.4 Bearing Of Timbers:

Timbers in compression bear on their end fibres at their supports. Timbers supported by bolts are supported by the bearing of the bolt washer on the timber.

Timber is very strong in bearing. Table 11 shows the permissible loss in section for axially loaded truss members at their bearing ends. Bending members will normally redistribute load on the bearing area if some loss of section occurs. No replacement should be necessary unless the bearing area reduction exceeds 50% of the area.

e. TEMPORARY OVERLOAD CAPACITY

Permissible stresses in timber are based on very high factors of safety. For occasional short-term loads, such as heavy abnormal vehicles, or maintenance activities, it is permissible to accept higher loads in the members than are normally accepted.

For occasional heavy loads, driven slowly across the bridge, an increase of up to 40% in stresses would be permissible. For maintenance, where temporary changes in load pattern are necessary due to installation of temporary supports, or temporary removal of members, a similar increase in stresses would be permitted.

f. SERVICE CONDUITS

The load from service conduits added to bridges is rarely significant. However, care should be taken in the method of attachment. With the use of the Tables 3 to 9, a method of attachment can be devised that will not significantly weaken the member.

SECTION 4 MATERIALS

CHARACTERISTICS, DETERIORATION AND PRESERVATION.

4.0 TIMBER

Maintenance operations require a knowledge of the materials in use. Timber truss bridges use timber, cast iron, wrought iron and steel. However, timber is the dominant material and the one most subject to deterioration.

4.1 TIMBER CHARACTERISTICS

4.1.1 Hardwood and Softwood

Timbers are classified as hardwood and softwood, depending on the cell structure of the tree. All timbers used in N.S.W. bridges are hardwoods. N.S.W. is very fortunate in having extremely strong and very durable hardwoods, probably the best in the world. The best of these is selected for use in truss bridges.

4.1.2 Heartwood and Sapwood

The wood of the tree is usually differentiated into two distinct zones, the outer -sapwood, and the inner heartwood. Generally, the sapwood is lighter in colour, less durable and when freshly cut from the tree, of higher moisture content than the heartwood. In the heartwood there are no living cells and such wood is termed physiologically inactive; on the other hand, in the sapwood there are some living cells which act as storehouses for food and for the transportation of various other materials in and out of the sapwood. Thus sapwood has been termed physiologically active.

The change from sapwood to heartwood takes place when the living cells die and at this time there is a deposition of extraneous materials in the cell cavities. These materials affect the colour of the wood and may increase it's weight slightly but do not materially affect strength. Thus sapwood is as strong as heartwood. However, these deposits do help to confer some resistance to the attacks of fungi and insects. Thus heartwood is recognised as being more durable than sapwood.

Most trees have a comparatively narrow sapwood, 10-30mm in width, but in some species there is little or virtually no heartwood. Commercial timber cut from such species may consist entirely of sapwood.

Sapwood is acceptable in piles and in treated timber members such as decking or sheeting, bracing, kerbs or rails. Untreated sapwood in piles should be ignored structurally, because it quickly deteriorates and unless removed can act as a repository for moisture and become a place for fungal growth. Untreated sapwood particularly, should not be used in sawn truss timbers.

Because its cells are more open than those of heartwood, sapwood is much more readily penetrated by preservative fluids and so sapwood properly treated can be more durable than heartwood~

4.1.3 Strength

Timber species have been classified in the SAA Timber Engineering Code, AS1720-1975 into a number of different strength groups seven for green timber and eight for dry timbers. The strength groups are numbered Sl to S7, for green timber, and SD1 to SD8 for dry timber'. The lower number indicates the stronger timber. Each species falls into several strength groups depending on its grading (visual or mechanical) -e.g. freedom from knots, straightness of grain, etc. Only No.1 Structural Grade timber should be used in bridges. Full details of the grading of the timbers used in timber truss bridges are attached as Appendix A. From the strength groups the timbers are further classified into stress grades. These stress grades indicate the permissible working stress in bending for purposes of design. For instance, the stress grade is indicated in a form such as F34 which indicates that, for such a grade of material, the basic working stress in bending is 34 mPa.

Comment is often made that the timber quality currently supplied is not as good as that originally used due to the faster growth. There is some justification in these remarks. Current classifications are based on properties of timber from trees of an age, dependent to some degree on species, but usually greater than 25 to 30 years. They are also based on a growth rate of not less than three rings per 25 mm.

This is indicated by the average number of growth rings per 25mm measured in a radial direction on an end section.

4.1.4 Durability

The sapwood of timber is susceptible to decay when temperature and humidity provide suitable conditions for growth of the fungi responsible. This applies even when the heartwood of the species is very durable, and is due to the fact that sapwood may contain considerable quantities of sugars and starches while the toxic substances found in durable heartwood have not yet been formed.

Classifications of the durability of species are most commonly based on the behavior of their heartwood when exposed to the hazards of ground contact with its risk of attack by fungi and insects, especially termites. Because of the combined attack of fungi and insects, such ratings do not take account of the special qualities of species which are very resistant to termites, but only moderately so in relation to decay fungi.

Decay resistance is determined largely by the extractives produced at the time of conversion of apwood to heartwood, many of the extractives being toxic to fungal organisms. Termites are less susceptible to discouragement by extractives and will attack many durable species if conditions are favourable, though they naturally favour the soft species.

Appendix A shows durability classification of the more commonly used bridge timbers.

4.1.5 Shrinkage

All timber shrinks, but green hardwood shrinks more than most timbers. Consequently seasoned timber must be used whenever possible. In trusses, shrinkage affects joints particularly, but can also have an overall effect on the geometry of a truss, causing an apparent deflexion. Reserve timber should be purchased sufficiently in advance to allow adequate seasoning. It is preferable, in an emergency, to seek timber from another Division rather than using green timber.

Shrinkage along the grain is small, but the effects of tangential and radial shrinkage are most pronounced. Appendix A gives an indication of the relative shrinkage of timbers used in truss bridges.

4.1.6 Creep

Creep is the characteristic of timber which causes a timber member under load to have increased deflexion with time.

When a timber member is loaded, either axially or in bending, there is an immediate change in shape – a compression member becomes shorter, a tension member becomes longer, and a member subject to bending deflects relative to its support. If the application of the load is continued, the change in shape increases. The extent of this creep depends on the initial moisture content and the rate of drying. As a general rule it can be assumed that green timber will eventually creep to a total deflection three times as large as the original deflection, and dry timber to twice that deflection. While creep continues throughout the life of the member, it can be assumed that, for all practical purposes, all creep occurs in the first 2-3 years.

4.2 TIMBER SUPPLY

The timber industry is based on the supply of sawn timber to the domestic market. Generally all trees encountered in felling operations are sawn to small sizes. Ordering of bridge timbers must be suited to the felling operations if supplies are to be assured, and prices are to be reasonable. Needs should be assessed annually, to allow supply at any period over the next twelve months. This allows sawmillers to retain suitable trees found during felling operations.

More detailed comments on ordering procedures are given in Section 6.1.2.2.

4.3 TIMBER DEGRADATION

Timber itself does not deteriorate significantly in service it must be attacked by some outside agency before degradation will take place.

Depending upon conditions of service, one or a combination of several such agencies could be at work in timber at any one time.

Timber destroyers can be classified under four headings:-

1. Fungal deterioration,
2. Insect attack,
3. Marine borer attack,
4. Fire.

4.3.1 Fungal Degradation.

Fungal attack is the main cause of deterioration in bridge timbers. Certain conditions are necessary for the development of fungi that will attack timber.

These are:-

a) A temperature range suitable to their life cycle.

b) A moisture content suitable for their development.

c) An adequate oxygen supply.

d) A food supplycon which they can grow.

It is this last condition that is satisfied by timber. If the conditions of temperature and humidity are suitable, the fungi will use the timber as a source of food. The spores of fungi, microscopic plants which must have organic material on which to live, are abundant in the air.

Wood that is continually saturated with water, or dry wood whose moisture content is kept below 20%, is not attacked by fungi, except for "soft rot", a form of fungal attack common in areas of considerable dampness.

Fungi will attack both sapwood and heartwood under favourable moisture and temperature conditions, causing breakdown of the wood substance, which is then said to be "decayed" or "rotten" .The decay fungi produce surface moulds, usually of white or brown colour, that may be velvety or fluffy; sometimes they produce fruiting bodies in the form of toadstools, brackets or crusts, such as are often seen on decaying logs.

Microscopic strands, called hyphae, permeate the wood and use some of its constituents as food. Decayed wood may be white or brown in colour, white if the particular fungi present consumes lignin as well as cellulose, brown if mainly cellulose is attacked.

The term "dry rot" is sometimes applied to wood that has been attacked by brown rot fungi and appears dry and powdery. The term is very misleading because wood must be in a damp condition (above 20% moisture content) to be attacked by the locally occurring types of fungi.

The term "wet rot" is also a misnomer and gives a wrong idea of decay; its use should be avoided.

Timber Application Most Subject to Decay.

Timber in contact with the ground is likely to have a moisture content £avourable to decay in the vicinity of the ground line.

External timbers not in ground contact will generally be relatively free of decay because their moisture content will be below the danger level of 20% unless:-

a) the timber is located in a very damp situation;

b) inadequate construction or maintenance permits excessive moisture in a usually safe location,

c) there is a combination of absorbent non-durable sapwood and a relatively impervious paint coating, which tends to maintain dampness in the timber.

Timber bridges appear to suffer from fungal decay which might have been avoided by more attention to detailing of the design. There are many horizontal surfaces such as tops of girders, truss chords, braces, etc. Often these have developed shakes, or are end grain, and water penetrates into the timber. Although exposed to the sun, the temperature inside the timber piece rarely exceeds that required to prevent fungal growth, thus providing conditions for degradation. Large timbers too should be placed with the side closest to the heart facing upwards. With shrinkage due to drying out this produces a convex upper surface which sheds water.

4.3.2 Insect Attack.

There are several types of insects in Australia that attack timber. However, the termite is the only insect that attacks seasoned heartwood. All the others attack softwood, or sapwood and green

heartwood of hardwood timbers,' and are not of concern in respect of truss bridge timbers.

Termites

Termites are found in all the warmer regions of Australia. Tasmania and the colder districts of Victoria are not troubled to any extent by them. The term "white ant" is commonly given to the termite but as it does not belong to the ant family, the use of such a description is better avoided. An ant has a different body structure, well developed with separate head, thorax and abdomen and the antenae or feelers are bent. The termite has a two segment body; the head, and the thorax/abdomen. The feelers are straight or slightly curved.

In the forest, termites help to return fallen trees and stumps to the soil, so serving a useful function.

The termite life cycle is quite a complicated one. Winged forms flyaway from the colony and establish a new one, characterised by a queen and king. The queen becomes greatly distended in the abdomen due to her egg laying activity, is virtually helpless and remains in her cell. Her eggs produce various castes workers, soldiers, and alates (those capable of reproduction). These creatures are all basically "whi te" (except the winged insects when they are mature) though close examination will show that the colour is more "creamy".

Many kinds of termites are rather translucent and one can note the darker coloured earth or other food which has been eaten. The "worker" is "white" all over while the "soldier" generally has a honey coloured, bony looking head with destructive jaws; some soldier species do not have visible jaws but a pointed shaped head and a tiny "snout". All soldiers exude a sticky white substance as part of their equipment for repelling invaders.

It is highly unlikely that a queen will be found easily. She and the king are kept deep inside the colony. The alates, the future kings and queens, are rarely found outside the main colony.

The workers, comprising 80-90% of the colony, are small wingless sightless creatures with strong jaws for eating wood. The workers construct the nest and gather food. The soldiers, 2-3% of the total, are blind too, but are equipped so that they can attack invaders.

The reproductive forms are tended by the workers while their wings are undeveloped; when mature the winged males and females leave the nest in a swarm, settle, shed their wings and mate. Each pair searches for a suitable spot to colonise. The workers produced soon assume this task, and the queen devotes her time to egg laying.

Termites seek dark, humid, poorly ventilated positions for their nests. Their presence is oftennot discovered until infestation is quite widespread because they leave an outside skin of wood intact on the pieces being eaten. However, they do have to provide an earth-surrounded gallery back to their nest and this tell-tale construction will generally reveal their presence when regular inspection is carried out.

Termites work along the grain eating out large runways; in the early stages of attack a lot of sound wood is left between the runways but eventually only the thin outside layer of wood may remain. They will often build access galleries of earthy material across resistant or even preservative treated timber to reach a species they find palatable.

They must have contact with the ground, or access to a continuing source of moisture.

4.3.3 Marine Borer Attacks

Marine borers are of several types, and the danger from the different types is very much dependent on geography and water salinity. Although different borers attack different sections of piles, the simple rule is that protection must be provided from below the mud line to above high tide level.

In NSW there are very few timber truss bridges remaining in areas susceptible to marine borer attack. Although marine borer attack can be extremely heavy, particularly in northern NSW, the need for a detailed knowledge of the types and habits of the different borers is not relevant to this handbook.

4.3.4 Fire

Fire is a hazard in any bushland area. There are no effective prevention procedures. Timber may only char -

the loss of section should be checked for strength as detailed in Section 3. Steel and wrought iron members should be checked for serious damage from heat and replaced if necessary.

4.3.5 Summary

Timber maintenance in truss bridges is mostly concerned with the deterioration caused by fungi and termites.

Current techniques are effective against termites, but little action is taken to prevent fungal attack. This has therefore become the major cause of timber deterioration. Fortunately new preservatives have been developed to prevent decay in Australian hardwoods.

4.4 TIMBER MAINTENANCE TECHNIQUES

There are basically two methods of preventing timber degradation from fungi and borers (termites or marine borers).

1. Provide conditions that inhibit the lifestyle of the attacking fungi or borers

2. Destroying the fungi or borers in place.

4.4.1 Fungi Inhibitors

4.4.1.1 Timber Selection

The first and obvious method of inhibiting fungal attack is to use only durable timbers. This is current practice. Appendix A lists the durability of timbers currently used in truss bridges. AS2082 (Visually Stress-Graded Hardwood for Structural Purposes) has a full list of all Australian Timbers.

4.4.1.2 Moisture Prevention

Fungi require moisture. If a bridge can be maintained in a dry condition, or if moisture dries out quickly, the fungi will die. Consequently, all horizontal surfaces or pockets capable of holding moisture must be protected, or shaped to allow moisture to drain or evaporate. The use of galvanised caps is recommended for all exposed surfaces, but end grain, particularly, must always be capped. Unfortunately, caps can permit the entry of moisture; particularly at the ends of horizontal timbers, and then prevent drying by evaporationi' They should therefore always be combined with a fungicide. (See Section 4.4.2).

If caps require fixing they should be bolted or screwed. Caps need to be removed every three years and repeated nailing could eventually destroy the timber.

Any maintenance operations should be carried out with a view to reducing moisture retention. Where timber surfaces are exposed to the sun or wind the likelihood of fungal growth is low.

4.4.2 Fungi Killers (Preservatives)

Timber preservatives protect timber from decay by poisoning the fungi. Preservatives are of two types-barrier and diffusable.

Barrier preservatives form a protective layer on the surface of the timber.

Diffusing preservatives are injected internally into the timber, and diffused by moisture. Fungi require moisture, but the moisture also carries the preservative, effectively destroying the fungi.

4.4.2.1 Barrier Preservatives

There are many preservatives that will penetrate softwood or the sapwood of hardwood. However, no barrier types will effectively penetrate heartwood of hardwood the timber used in truss bridges. Pressure treatment (and associated refinements) can result in a very small penetration, but is only useful where timber is sawn, cut to length and shaped before treatment. Its use in bridge maintenance is therefore limited to deck timbers, or abutment sheeting.

a. Creosote - The best known and most effective preservative of this type is creosote. Unfortunately, contact with creosote is now known to be extremely hazardous and its use is prohibited.

CSIRO have now developed a new form of creosote called PEC (Pigment Emulsified Creosote). This preservative weathers in about 1-2 months to a dry, brown-coloured finish with almost no vaporising or weeping. PEC is only intended for pressure impregnation, and its use in bridge maintenance is therefore limited to decking and sheeting. Such timbers should preferably be ordered cut to length, and if possible with predrilled holes. The pressure treatment is then applied to all exposed surfaces.

b. Copper Naphthenate - From a maintenance viewpoint the most useful barriers need to be capable of brush or flood application. Copper naphthenate has been known to be an effective fungicide for many years. It has now been incorporated in propriety solutions which allow its use as a surface barrier treatment. These solutions are usually based on a low viscosity penetrant, preferably oil based, which allows the copper naphthenate to be carried into very fine joints. Application can be by brush or stirrup pump. Flood application results in deep penetration of joints, and provides a protective layer in the joints which will not leech out.

Copper naphthenate is non-toxic and it does not affect most metals. Paint can be applied after the coating has aged at least three weeks, provided a solvent based undercoat is used.

An emulsion or gel incorporating copper naphthenate is available from several manufacturers. It is prefered for use under all caps, but certainly should be used under caps on vertical surfaces, because the gel will remain in place rather than running to the bottom.

Copper napthenate in all forms should be renewed at three yearly intervals.

c. Other Compounds -There are other effective barrier fungicide compounds. For instance there are boron salts which are available in both liquid and gel form. These have the disadvantage of immediately requiring a protective coating such as paint. However when the paint deteriorates the fungicide is washed away and the timber left unprotected. The use of these compounds is not recommended.

4.4.2.2 <u>Bandages</u>

A particular form of barrier has been developed by CSIRO for protection of the high attack area at ground line. A diffusing preservative (see Section 4.4.2.3) is loaded into a polyurethane foam, which in turn is combined with a thick plastic sheet.

These sheets are cut to the correct size to wrap around a pile, and heat sealed to the top and bottom to the pile, and vertically down the joint. Provided the bandage is maintained, and replaced as necessary, no rot can develop at this high attack area.

4.4.2.3 Diffusing Preservatives

Barrier preservatives prevent the ingress of fungi into timber. However, all timber that has been exposed to moisture probably has some fungi present. In particular, at decayed locations fungi can be found to a depth of 300mm into apparently sound wood.

For timber that already has decay, and for positions that have high decay hazard (end grain, joints, top surfaces) , a diffusing preservative must be used. These are place into drilled holes so that there is a reservoir of preservative. After the preservative has been added, drilled holes should be plugged, preferably with pressure treated softwood plugs. Diffusing preservatives in emulsion or gel form include Blue 7, Basilit BFB, and Busan Pole Gel. Impel rods in solid form are available in various diameters and lengths. All are different chemical compounds, but have been tested and proven under Australian conditions. Quality and price are different and the ones most economically effective in bridges can only be found with experience.

4.4.3 Termite Inhibitors

4.4.3.1 Timber Selection

As with fungal attack the use of durable timbers is the first method of resisting termites. Timbers that are durable against fungi are not necessarily durable against termites. The durability rating given in Appendix A refers to a combination of both, and is a preferred rating for bridges.

4.4.3.2 Moisture Prevention

Termites require moisture for life (again like fungi) .Consequently, the measures suggested for fungi control by prevention of moisture penetration are also effective against termites. (see Section 4.4.1.2).

4.4.3.3 Site Maintenance

Timber left lying around a site provides an ideal environment for termite growth, being moist and in ground contact. Consequently any replaced timber must be cleared away from the bridge site.

4.4.4 Termite Killers

Most barrier and diffusing fungicides are mildly toxic to termites. There are also some commercial compounds that are claimed to kill termites. However, the only effective way of completely eradicating a colony of termites is the use of arsenic powderi; Termi tes groom each other and eat their dead so it is possible for poison to be carried throughout the colony. The method of eradication is based on the injection of white arsenic powder with a hand operated blower into a runway in a piece of the wood being devoured, or into the earthen galleries, with a minimum of disturbance so as not to frighten the termites. The amount of powder introduced should not be such as to block the runway, and the opening should be sealed with wet clay or something similar, to exclude lightand air, after treatment. The procedure should be repeated in a number of locations. Arsenic poisoning will be most successful during the warmer months when the termites are most active. In very cold weather it may be ineffective. Arsenic is highly toxic to humans so it must be handled very carefully. Several repetitions of the treatment may be necessary.

Another effective method involves filling drilled holes with a mixture of arsenic and caustic soda. The termites locate this hole during passage through the timber and transmit the poison to one another by grooming.

4.4.5 Marine Borer Inhibitors

4.4.5.1 Timber Selection

The use of turpentine for untreated piles in marine environments in NSW is generally accepted as mandatory. It should be understood that variations in the environment - pollution, current changes, long term temperature changes - can alter the types of borers to be found in different locations. However, under current conditions turpentine piles should be used. Bark should be left on although it is only resistant to some species of borers.

However, its efficiency is dependent on the retention of bark without damage – a very difficult requirement. Piles should be examined for defects such as knot holes. These should be covered by copper sheeting.

4.4.5.2 Barriers

Provided a barrier is placed around the pile from above high tide level and 600mm below mud level, the pile will be protected from marine borer attack.

Barriers can be of many materials, but probably only two are practical and economic on bridge substructures concrete and wrapped plastic.

Concrete sleeves can be poured around piles, but should preferably be reinforced to prevent access to the pile by borers through shrinkage cracks. Glass fibre reinforcement is particularly recommended. PVC wraps are extremely effective, but should be protected by a rigid material against impact by debris, boats, etc.

Proprietary materials are available and can be used provided the manufacturers recommendations are followed. Metal sheetings (copper or Muntz metal) can also be effective. Sheets must beoverlapped and joints secured by nails. If the sheets become pitted or joints are damaged they should be replaced immediately.

4.4.6 Marine Borer Killers

Cresosote is the only preservative that can be applied to piles in place, but there are problems in the handling of this material. Consequently, the use of preservatives is limited to the time of pile replacement. Double treated piles can be used, with an expectation of considerably extended life. In this process, a hardwood with a thick sapwood is pressure treated with a copper-chromium-arsenic compound, followed by creosote. The preservative kills the eggs of the marine borer, which are floating in the water looking for suitable timber to attack.

4.4.7 Paint

Paint on timber trusses can be an effective barrier to moisture. However, unless it is perfectly maintained, it will crack, allow moisture penetration, and provide a location for fungal growth. While paint, particularly flexible acrylic coatings which have less tendency to crack, can give reasonable protection~ other preservatives should be used also. Paint may be applied for traffic safety, and for appearance. The paint should be examined regularly and carefully for any deterioration, and reapplied as necessary.

a. Surface Preparation

All unsound paint and decayed timber should first be removed by abrasive blast cleaning. By adjusting the abrasive stream, sound paint can be left intact, with margins of sound paint being well feathered. Any deep recesses formed by removal of rot should be coated with copper napthenate and after adequate time for curing filled with epoxy before painting (see section 4.5.2).

b. Painting

Timbers should be coated with three applications of acrylic emulsion based timber finish at 40 pm DFT per coat. Suitable colours include white, mission brown and redwood. Where copper napthenate has been used, an oil based primer shottld first be applied prior to the application of the acrylic top coats.

4.5 OTHER MATERIALS

4.5.1 Metal Parts -Wrought Iron, Cast Iron, Steel

Other materials in timber truss bridges are wrought iron, cast iron and steel.

Metal parts should be abrasive blast cleaned and primed with a zinc phosphate pigmented primer, prior to the painting of timber.

Following priming, major truss members such as bottom chords and tie rods should be given two top coats of MIO chlorinated rubber paint, 125 pm DFT per coat.

Other metal parts such as bolts, washers and connecting plates may be primed and given top coats of the timber paint only in lieu of the MIO chlorinated rubber paint, although this offers less protection.

All new bolts should be galvanised. Galvanised bolts should be degreased by wiping over with a rag dampened with mineral turpentine or other solvent and coated with a primer suitable for galvanised surfaces. If the timber is treated with copper chromium arsenic (see Section 4.4.6.), the bolts should have a top coat of epoxy paint.

4.5.2 Epoxy Resins

Epoxy resins can be used as fillers in timber sections, for the high strength jointing, or for rebuilding a destroyed section of a timber member.

Shakes and recesses caused by decay or damage are potential locations for ponding of water, and development of decay. These should be filled with an epoxy that is suitable for use with timber. The edges of the recesses should be squared to ensure that no "feather" edges are used.

Although epoxy pastes for timber have very low shrinkage, they nonetheless shrink a minute amount and can crack or leave surface cracks at the timber-epoxy joint, and so allow the ingress of moisture. To prevent decay occurring under the epoxy, the timber surface should be first painted with copper naphthenate oil.

Jointing with epoxy should be carried out with care. One of the advantages of timber truss construction is the ability to replace damaged or decayed members. Epoxy jointing could remove this ability. Butt splices would be acceptable provided provision for shrinkage is made at the other end to the epoxy slice.

Rebuilding a destroyed section is expensive, and usually requires reinforcing of the epoxy. It is unlikely to find any use in timber trusses. A silicone rubber sealant should be applied to butt joints and mitre cut joints.

4.5.3 Bitumastic Wearing Surface

A sealcoat on the timber sheeting provides protection for the sheeting, better skid resistance, and a slightly better riding surface. It also helps in quick shedding of water. However, problems currently exist with failure of the surface due to large gaps between boards. Solutions include filling the cracks with rope or screenings.

This problem can be reduced by using seasoned timber and replacing sections of the deck at regular maintenance periods, in lieu of occasional replacement of individual timbers. Also, the use of 75mm thick sheeting reduces splitting and consequently the need for intermittent replacement.

SECTION 5 PREVENTATIVE MAINTENANCE

INTRODUCTION

Maintenance methods should be aimed at prevention of the cause of deterioration instead of replacement of members which have deteriorated beyond safe limits. Only when this system is neglected should there be need for replacement.

Preventative Maintenance requires a regular and organised programme. Periodic inspections and scheduled maintenance tasks must be undertaken faithfully. The failure to observe this regular programme can result in the commencement of deterioration and collapse of the entire maintenance system.

5.1 METHODOLOGY

5.1.1 Inspection and Recording

The methodology of all maintenance depends upon making an inspection and report at regular intervals, recording all defects, diagnosing the cause of decay and proposing an effective cure that involves only the minimum intervention. Examination must be meticulous, and interpretation will relate this report to previous reports of the same area. Effective interpretation requires a sufficient data base, and an ability to appreciate the messages contained in the data.

Inspections and reports give the facts as they relate to each individual bridge, and, combined with previous reports, provide the basis for estimation of rate of change and hence for need and cost of any maintenance.

The quality of decisions and the effectiveness ofthe actions taken is dependent on the extent and detail of the data recorded. This data base represents the foundation of any effective maintenance programme.

Recording and maintenance will rarely, if ever remain the responsibility of anyone person for a significant period. Consequently, the form of recording must be both clear and simple, yet sufficiently detailed to show the evolution of any problem areas.

Bridges have a life expectancy of many human generations, so the recording system must satisfy the changes in personnel and of methods, and changes should be recorded in a manner that allows interpretation without relying on the particular expertise of the time, or the manners of communication of the time. Obviously, graphical and photographic methods are preferable – followed by tables relating to standard drawings. Written reports should only be used as a last resort where other methods fail.

Records should be maintianed on materials which are as permanent as possible, and stored in a location that is designed for long term storage of these materials, as well as prividing regular access for the users of the records.

5.1.2 Maintenance Files

The maintenance file should contain the full history of the bridge since its construction, and should include any construction data of significance to its future maintenance. Such data should include original drawings, specifications and any technical papers given on the subject bridge and relating to design methods, construction techniques and materials used, or problems encountered.

Records should include general reports on the bridge as a whole, as well as detailed reports on specific elements. The boring diagrams currently in use are a most satisfactory basis for recording, but need some modification and expansion. The standard drawings for each type of truss are attached. By using these drawings for both quantitative and descriptive data the history of the bridge maintenance can be compiled. It is suggested that one copy be used at each inspection for recording of measured data i.e. test boring, shigometer, etc., while a separate sheet should be used for descriptive data i.e. extent of repairs by epoxy, etc. Inspectors should refer to previous reports to determine any areas that need regular observation. It must be accepted that the form will require modification with use, as only practical experience will ensure that the required detail is included. Similarly, while the format should be similar for all elements, to allow easy use by unskilled personnel, it will probably be necessary to have minor variations to suit the peculiarity of particular elements.

Recording will not only be a product of inspection but must follow any maintenance activities, regular or unplanned, that may affect the structure.

Unplanned activities, such as graffiti removal or damage repairs, are difficult to record in a simple form, but are probably more important to note for future effects. They will involve undirected use of materials, which can have long-term effects on the structural elements. Without detailed knowledge of this activity, the cause of deterioration can be unexplained, or wrongly diagnosed, with possible major effects on structural integrity, and maintenance expense.

5.1.3 Programme

Maintenance falls into two types:-

* Routine (or periodic) and

* Special (or intermittent)

Routine maintenance must be on a regular basis. A suggested programme is outlined in Section 5.4. Routine maintenance is preventive maintenance and is essentially a process of inspection and recording, then developing a work programme based on the data collected.

Special maintenance is required when unplanned damage occurs such as floods, vandalism, fires, etc. Such maintenance activities must still be recorded to allow future interpretation of any otherwise inexplicable deterioration.

5.1.4 Cost Recording

Only from accurate records of costs can the effectiveness of the maintenance programme be assessed. Costs should be dissected into labour and materials, and give quantities as well as costs. This allows development of an excellent database for estimating purposes, as well as an assessment of the economics of replacement of a bridge. The cost recording should also be dissected into the appropriate sections of the work i.e. truss, deck, superstructure (cross-girders etc.), abutments and piers. For instance, a continual expenditure on

Idecking or sheeting would indicate the necessity for an examination of the detailing used, rather than suggesting the need for bridge replacement.

Central storage and computer analysis of cost data can indicate local deficiencies, as well as design imperfections.

5.2 INSPECTIONS

Inspections are the basis of maintenance. Unless inspections are effective in locating problems, preventive maintenance is impossible.

Experience with timber bridge examination is necessary to understand the potential problems. Consequently, bridge inspections should only be carried out by experienced personnel.

Recording should be meticulous. Each report not only forms the basis of the current maintenance programme, but serves as a guide to the next inspector as to potential problem areas. A file containing previous reports should be taken to the site during inspections.

5.2.1 Inspection Methods

Several methods of bridge inspection are currently in use. These should be supplemented by modern equipment and methods which are more accurate and non-destructive. What ever method of testing is used, it should cover all areas where unsound timber is apparent and at points where decay commonly occurs, such as near the ends, and at points where dampness is retained.

In piles decay generally occurs in the centre at the top where wales and braces join the piles, and slightly below ground level where rot may be from the outside as well as at the heart. In trusses decay occurs most frequently between chords and chord flitches and at the lower ends of compression members.

Decay in decking generally occurs under the kerbs, or on the underside of the decking where it bears on it's supports.

a. Visual

The bridge should be examined for any indication of deterioration or damage. The examination should be thorough and carried out from levels appropriate to all members - scaffolding may be required to carry out this work effectively under the bridge. All members should be examined. Record any signs of decay, insect attack, physical damage or deterioration. Note signs of potential problems for re-examination at the next inspection.

b. Hammer Testing

Hammering a timber member gives an indication of any internal deterioration. The presence of either rot or termite attack shows through a hollow sound. A 2kg hammer is recommended and suspect or potentially suspect timbers should be hammered at 450mm centres. However, this method is not conclusive and should be supplemented by physical examination in suspect areas.

c. Boring

Current practice is to test bore timbers with a 12mm hand auger. The effort required indicates the soundness of the timber. The material from the borehole can also indicate the condition of the timber as well as the presence of termites or marine borers.

All holes are potential moisture traps - horizontal as well as vertical. Holes should be filled with a diffusing preservative (Section 4.4.2.3) , and sealed with a preservative impregnated softwood plug.

d. Shigometer and Conditiometer

These two instruments measure the presence of decay in timber by change in resistance. A fine hole (approximately 3mm) is bored into the timber and a probe inserted. A meter records the resistance between two points at the end of the probe, thus showing not only decayed timber, but also potential decay. After use the hole should be sealed with a preservative impregnated softwood plug. At the next inspection the hole can be drilled out and reused.

This method is preferred to test boring as the hole is smaller and can be reused.

e. Ultrasonics

Two forms of ultrasonic testing are available. This form of testing is non-destructive and has the advantage of speed and accuracy, and portability.

There is an ultrasonic tester called PURL (Pole Ultrasonic Rot Locater) that is used on timber power poles with great success. A transmitter is attached to the timber member and its pulses recorded by a receiver placed at various locations. A light flashes to show sound wood, but remains off at deterioration. By moving both transmitter and receiver the exact section of the deterioration can be plotted.

The "Resotest/Polescan" is similar but uses a meter marked "good" or "reject" .

Both systems have been found to depend for speed and accuracy on the experience of the tester.

The ultrasonic system can also be used in a similar manner to hammering, to quickly run along the members and locate any possible areas of decay. They have been found to be much more accurate than hammer testing.

f. X-Rays

The Forestry Commission are able to locate and identify any deterioration by the use of X- rays. However the equipment is bulky, and the testing is slow and expensive. Unless there are significant developments in this field, its application will be limited to specific locations where all other methods are unsuitable.

5.3 RECORDING

The recording of data from inspections forms the basis for all maintenance activity - current and future. Recording should be meticulous and detailed. Negative reports (i.e. no sign of deterioration or damage) should be included.

Reports should be in a form that can be easily interpreted by future inspectors. Consequently they should be quantitative wherever possible and supplemented by photographs. It is very hard to describe a state of deterioration (e.g. end grain or paint) in a manner that can be interpreted in one or five years time. Photographs are the correct solution.

Reports should be on standard forms. These forms should be prepared for each individual bridge, but based on the standard diagrams attached. These are sufficiently detailed to allow full recording of all deterioration. Attempts to reduce the drawing to have several spans on one sheet should be avoided -use one sheet per span. Similarly, piers and abutments should be drawn at a sufficiently large scale to allow detailed recording. As there are less details (packers, splices, etc.) in piers and abutments, these rarely need dissected drawings.

The bridge should be inspected with five objects in mind:-

a) To observe the effectiveness and failures of the regular maintenance work.

b) To observe any defects which have been identified in previous inspections and record any variations.

c) To locate any previously unidentified defects.

d) To observe any potential problems.

e) To record the effect of any unusual events that has occurred during the last year that has affected the structure.

5.3.1 Quantitative Recording

The testing of timber, by boring, ultrasonics or resistance should be recorded in a uniform manner.

The direction of the test should be indicated by two letters. The first is either H or V to indicate whether the test is horizontal or vertical. The second letter indicates the direction of drilling as follows:-

U Upwards for vertical tests and upstream for horizontal tests

D Downwards for vertical tests and downstream direction for horizontal tests

A Towards Abutment A for horizontal tests

B Towards Abutment B for horizontal tests

Whenever the condition for the timber changes during testing the depth of the test is measured in millimetres, the length for the condition encountered is calculated and recorded to the nearest 10mm. The condition of the timber is indicated by adding one of the following letters after each length recorded:-

S Sound timber and, if used on its own, indicates that the timber is sound throughout

P A pipe

R Rot

Sample Test Record

Position	Direction	Timber Condition
1	HU	100S, 100P, 100S
1	HA	120S, 60P, 120S
2	HU	S
3	HU	90S, 120P, 90S
3	HA	80S, 140P, 80S
4	HU	S
50	VU	100S, 200R, 0S
50	HU	60S, 180R, 60S

5.3.2 Damage Reports

Damage from floods, fire, vandalism, traffic or any other source should also be recorded on the same forms. This acts as a discipline to recording, and also ensures that future maintenance problems arising from this damage are effectively understood.

5.4 MAINTENANCE PROGRAMMES

Regular inspection and maintenance procedures should be observed to ensure that preventative measures are undertaken before deterioration occurs. As preservatives are expected to need replacement at three-year intervals, the following programme is based on this cycle.

Three main periods are proposed:-

- Annual
- Three yearly
- Nine yearly

Paint usually will require replacement at nine yearly intervals, which serves as a good period for a complete overhaul of the bridge and its protection system.

Table 2 on page 5.11 shows details of work required at each period. The following sections explain the intention behind the requirements of Table 2.

5.4.1 Annual Inspection and Maintenance

5.4.1.1 Inspections

The annual inspection is intended as a check that no problems are arising during the three yearly maintenance cycle. It is basically a check up on problem areas exposed in the regular inspections, or known through experience. Additionally, checks are made on functional items that are subject to damage or malfunction (e.g. scuppers, loose bolts, etc.). It is not envisaged that any testing will be carried out during this inspeciton, except for any locations that are causing particular concern. A check on scour around piles should be carried out.

5.4.1.2 Maintenance

Annual maintenance is mainly concerned with keeping the bridge in a functional condition. Based on, or associated with, the inspection, bolts should be tightened, drains cleaned, any seriously damaged members replaced, paint damage repaired. Any vandalism or other damage that has not been repaired at the time of occurrence (see Section 5.4.2) should be fixed.

The entire bridge should be washed using a high pressure jet. Care should be taken to penetrate recesses and all areas where dirt and rubbish can accumulate. These areas will hold water and allow rot to commence.

The site should be cleared of debris or growth that may be a hazard to the bridge.

5.4.2 Three Yearly Inspections and Maintenance

5.4.2.1 Inspections

A full bridge inspection should be carried out every three years. As well as the check on function that is carried out annually the bridge should be examined for deterioration. This serves as a check on the preventative maintenance measures, and also locates any other developing areas. This inspection is not intended to replace the annual inspection, but is additional to it, and both are carried out at the same time.

The inspector should take all previous three yearly reports to the site to provide a history of the peculiarities of the bridge. After a visual check of all previous reported problem areas, and also those known to cause problems (splices, end grain, joints, etc.), a hammer or ultrasonic test should be run along each timber member to seek new areas of decay. Any such areas located should be drilled, or any previously tested should have plugs drilled out, and tested with the Shigometer or Conditiometer, and results recorded. Areas of visual decay should be photographed. The inspection should be carried out on all members - including underneath the deck.

5.4.2.2 Maintenance

Preservatives are expected to have a useful life of at least three years. The intention of this three yearly maintenance programme is to renew these preventive measures.

All diffusive preservatives in holes should be renewed (see Section 4.4.2.3) and holes recapped. Any new test holes or areas indicated by the inspection as needing preservative should be similarly treated.

Caps should be removed and gel preservative renewed before replacing. All other joints should have paint l removed, and be flooded with copper naphthenate oil, using stirrup pump or , brushes. Repainting can be carried out \ after at least three weeks has elapsed.

All requirements of the annual maintenance programme should be carried out.

5.4.3 Nine Yearly Inspections And Maintenance

5.4.3.1 Inspections

There is no difference between a regular three yearly inspection and a nine yearly inspection. See Section 5.4.2.1 for details of this full inspection.

5.4.3.2 Maintenance

The paint coat is expected to perform satisfactorily for a period of nine years.

The bridge should be cleaned of all unsound paint by abrasive blast cleaning (see 4.4.7(a)).

By supporting each truss individually (see section 6.3), all truss joints -including those between flitches - should be opened sufficiently to allow full penetration of copper naphthenate (CN) oil.

All other preservatives (in holes or caps) should be renewed and the bridge repainted, (see 4.4.7 (b)). A full three yearly and annual maintenance programme is obviously additional to the above work.

TABLE 2

SITE & GENERAL

Members	Annual Maitnenance A A	Three Yearly Maintnenance (additional at A) B	Nine Yearly Maintenance (additional to B) C
-	Remove debris and rubbish	-	Remove all damanged paint by abrasive blast cleaning.
	Clear growth in area that contributes to a fire hazard		Support truss as necessary for detail work as listed in individual sections.
	Check condition of approach pavement and protective barriers or fences – advise appropriate authorities		Repaint
	Clean bridge superstructure and was with high pressure jet		
	Check bridge camber and adjust		

TRUSSES

Members	Annual Maitnenance A	Three Yearly Maintnenance (additional at A) B	Nine Yearly Maintenance (additional to B) C
All Timber Chords	Check for damage and repair or replace Check all caps-repair as necessary and refill with preservative Check for paint damage and repair	Fill or refill all prepared hols with diffusing preservative Refill all caps with preservative gel Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Lower Timber Chords	Examine and report on signs of weakness so that consideration can be give to strengthening with wire ropes or under-trussing to prevent partin of the chord		
Steel Chords	Check for damage and repair or replace Check for pain t damage and repair	-	-
Splices and Joints	Check for damage and repair or replace Check ror paint damage and repair – before repair flood with CN* oil	Refill all caps with preservative gel Flood all hoints with CN* oil	Loosen all joints and splices and coat with CN* oil
Timber Webs	Check for damage and repair or replace	Fill or refill all prepared holes with diffusing preservative	Loose all joints and splices and coat with CN* oil

	Check for paint damage and repair	Flood all joints with CN* oil	
Hangers	Check for damage and repair or replace	-	Loosen all joints and coat timber surfaces with CN* oil
Lateral Stays	Check for damage and repair or replace	-	Loosen al joints and coat timber surfaces with CN* oil
Bolts	Check condition Tighten and replace as necessary	Flood all bolts holes with CN* oil	-
All Timber Members	Protect and treat, if required, for termites in accordance with M.R. Form No. 326		

***CN = Copper Napthenate**

DECK AND DECK SHEETING

Members	Annual Maitnenance A	Three Yearly Maintnenance (additional at A) B	Nine Yearly Maintenance (additional to B) C
Transvers Girders or Longitudinal Girders	Check all caps – repair as necessary and refill with preservative	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Timber Decking	Check for damage and repair or replace Check for loose bolts and tighten as necessary	Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Timber Sheeting	Check for damage and repair or replace Check for loose bolts and tighten as necessary	Flood all joints with CN* oil Check condition of seal coat and repair as necessary	Loosen all joints and splices and coat with CN* oil unless both decking and sheeting are preservative impregnated
Timber Kerbs	Check for damage and repair or replace Check for paint damage and repair Check for loose bolts and tighten as necessary	Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Timber Handrail	Check for damage and repair or replace Check for paint damage and repair	Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil

	Check for loose bolts and tighten as necessary	
Bolts	Check condition. Tighten and replace as necessary. Where bolts are counter-sunk into the deck, the counter-sunk holes are to be cleared of dirt or other debris before the head of the bolt is gripped with a box spanner for tightening. Any lock washers under the deck which have lost their grip should be replaced.	Flood all joints with CN* oil
All Timber Members	Inspect and treat, if required, for termites in accordance with M.R. Form No. 326.	

***CN = Copper Napthenate**

TIMBER PIERS

Members	Annual Maitnenance A	Three Yearly Maintnenance (additional at A) B	Nine Yearly Maintenance (additional to B) C
Headstocks or Capwales	Check for damage and repair or replace Check all caps – repair as necessary refill with preservative Check for loose bolts and tighten as necessary	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Piles	Check for damage and repair or replace Check all caps – repair as necessary refill with preservative Remove all debris Check for scour Check for damage to any groundline bandages	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Refill or replace all groundline bandages Inspect by driving all substructure in permanent water deep enough to warrant the employment of a diver. Repeat inspection programmes after any flood where scouring is suspected of being significant. Underwater inspection programmes normally should be prepared well in advance so that an economical	

		itinerary for the diver can be prepared.	
Bracing	Check for damage and repair or replace Check all caps – repair as necessary refill with preservative Check for loose bolts and tighten as necessary	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Flood all joints with CN* oil	Loosen all joints and splices and coat with CN* oil
Bolts	Check condition Tighten and replace as necessary	Flood all bolt holes with CN* oil	
All Timber Members	Inspect and treat, if required, for termites in accordance with M.R. Form No. 326.		

***CN = Copper Napthenate**

TIMBER ABUTMENTS

Members	Annual Maitnenance A	Three Yearly Maintnenance (additional at A) B	Nine Yearly Maintenance (additional to B) C
Headstocks or Capwales	Check for damage and repair or replace Check all caps – repair as necessary refill with preservative Check for loose bolts and tighten as necessary	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Flood all joints with CN* oil	
All Timber Members	Inspect and treat, if required, for termites in accordance with M.R. Form No. 326.		
Piles	Check for damage and repair or replace Check all caps – repair as necessary refill with preservative Remove all debris Check for scour Check for damage to any groundline bandages	Fill or refill all prepared holes with diffusing preservative Refill all caps with preservative gel Refill or replace all ground bandages	
Sheeting	Check for damage and repair or replace Coat all visible end grain with CN* oil unless pressure treated		

Bolts	Check condition Tighten and replace as necessary	Flood all bolt holes with CN* oil

***CN = Copper Napthenate**

5.4.4 Special Maintenance

There will be events that will damage the bridge, or provide conditions for rapid deterioration, that will occur between periods of regular maintenance. Consequently, the bridge should be inspected immediately to determine if action must be taken, and to what extent immediate action is necessary. Some possible events and the likely form of activity are listed below.

5.4.4.1 Floods

Floods can cause damage to the bridge from: impact of floating debris. Debris can also be caught in the elements of the bridge. , Additionally the increased stream flow can result in severe scour around piers, and under or behind abutments.

Debris damage must be assessed, and the need for repair or replacement determined from the loss of section. Ideally, all debris should be removed as soon as possible, particularly any sediment in joints and corners which can act as moisture traps.

A check should be made for any scour around piers or abutments. In deep water the services of a diver will be required. The usual method of repair is to place large stones or gabions in the eroded space. Care should be taken in dumping very large stones to avoid damage to the structure, and the filling should be balanced so that there is never any undue pressure on one side of a pile or footing. In the course of time sand and mud will fill the spaces between the stones.

5.4.4.2 Fire

Bridge timbers can be burnt to ash in a fire, or may only be charred. A fire may be hot enough to melt iron or steel. After any fire timber members should be checked for structural adequacy of the reduced timber section. Steel or iron members (including bolts) should be examined closely for loss of galvanising, any mel ting , distortion or cracking caused by either fire or firefighting. Any members so affected should be replaced.

5.4.4.3 Traffic

Vehicles may strike structural members during passage across the bridge.

Timber members should be assessed for the extent of damage. Loss of cross section due to gouging should be assessed for its effect on structural adequacy. Joints should be carefully checked, as impact can cause failure of bearing surfaces or bolted connections. Deep scours that do not affect structural adequacy can be rebuilt with epoxy, but should first be coated with copper naphthenate.

Steel members should be checked for damage lor deformation. Bent compression members should be straightened as the bending can cause extreme loss of strength. Again connections should be carefully checked.

5.4.4.4 Vandalism

Vandalism can take many forms. The general rule should be to check the effect f on loss of section in members, of the likelihood of damage to some preservatve, thus reducing the resistance to decay. For instance damage to paint could allow moisture penetration beneath the paint 1 coat and admit fungal decay.

5.4.5 Safety

During all maintenance operations safety must have top priority. Observe all rules for safety of workmen, traffic and the bridge.

SECTION 6 REPLACEMENT.

INTRODUCTION

There will be times when members in timber truss bridges should be replaced, either due to damage or failure of the preventative maintenance system. At this time consideration should be given to replacement of inadequate members with materials or products that will have longer life or better reliability. Change in detail and the use of preservatives can also extend the life of individual members and reduce maintenance costs.

This section deals with the major considerations. For further detail on methods of member replacement refer to Appendix D containing relevant extracts from DMR Manual No.6 "Bridge Maintenance".

Heritage Considerations

Some bridges will be identified as important historically. These will be listed on the Register of the National Estate, or by the National Trust, and generally would be rare examples of a type. These bridges should not be altered during replacement of members. Both materials and methods of construction or attachment should, if possible, reproduce the original.

6.1 MATERIALS

6.1.1 Cast Iron and Wrought Iron

Members or details made of these materials can be replaced with steel of the same section.

6.1.2 Timber

6.1.2.1 Timber Species

MR Form 140 "Specification for Timber for Bridges" lists acceptable species and the quality required.

6.1.2.2 Ordering

Good quality timber can be obtained by advertising locally in the areas where the species required is grown (generally the North Coast). However, more competitive prices may be obtained by ordering through Supply Section.

It is desirable to allow as long a period for suppy as possible, as this will result in the best timber. It is preferable to allow six months. This should be adequate as soon as sufficient stocks are taken into storage (and seasoned) to cover the ordering period.

6.1.2.3 Stocks

With the use of preservatives, the need for large stocks will be reduced. However, as the use of seasoned timber is essential, sufficient stocks should be maintained to allow the timber to season in the yard for at least 12 months. Allow also for the increased timber stocks required to cover the fact that a longer period is to be allowed for supply (see 6.1.2.2).

6.1.2.4 Storage

Timber should be stacked clear of the ground, et be well supported to prevent permanent set. Stack timber to leave an air gap at least 50mm wide around all pieces.

6.1.2.5 Preservative

Timber for decking, sheeting or abutment sheeting should be ordered cut to length whenever possible, and pressure impregnated with PEC. (See 4.4.2.1) Predrilled bolt holes would be desirable.

6.2 SPLICING OF TIMBER MEMBERS

To reduce the cost of timber replacement it is sometimes acceptable practice to splice new sections into existing timbers. This practice should be limited to top chords, capwales, headstocks, braces and piles. Bottom chords in old PWD and McDonald trusses should only be spliced with engineering advice, as the strength of the member is dependent on continuity. Splices are a potential area for decay as they provide additional end grain surfaces. The extra cost in replacement of the full length of the timber will normally be justified in saving of preservative costs.

Splices in top chords can be located anywhere. Only well-seasoned timber should be used, joints should be butted, and good bearing faces prepared on both old and new timbers. Cover plates and bolting are only nominal.

Capwales and headstocks should only be spliced in spans between piles where the capwale or headstock is not supporting any load. Splices should be halved and bolted.

Braces can be spliced anywhere. Timbers should be halved and bolted with at least M20 bolts each side of the splice ~ as the brace is usually in tension.

Piles may be spliced at any location, but it should be remembered that piles can be subject to uplift. The use of a halved and bolted joint is preferred. Good fit is important and well-seasoned timber is required to maintain continued bearing on both surfaces.

All splices should be thoroughly treated with copper naphthenate prior to installation.

6.3 REPLACEMENT OF CROSS GIRDERS

There are benefits available from the replacement of timber cross girders using steel sections and consideration should be given to the following points.

1) Sagging is much reduced and hence the tendency to misalignment of top chords is practically eliminated,

2) The increased strength of girders of comparable size permits bridges to be widened from single to double lane. The trusses usually have adequate capacity,

3) Durability is improved and hence maintenance costs reduced,

4) The employment of rectangular hollow sections does not alter the appearance.

6.4 TEMPORARY SUPPORTS

It is usually necessary to support the bridges temporarily for replacement of members. Temporary support may be by use of Bailey bridging, tomming to the ground, or methods which are not as common, such as undertrussing.

6.4.1 Tomming

Care should be taken in tomming a truss bridge that the truss action is not affected. For instance a support at the centre can change tension members to compression members and vice versa. Such changes can result in catastrophic failure - for instance a hanger rod can carry virtually no compression. Tomming at any location other than piers should be carried out under engineering supervision.

Size of toms and bracing should be chosen to suit the load to be carried. As a guide a typical truss bridge may have a dead load of 2kPa and a maximum live load reaction from each lane would be as shown in Table 12. Footings or sole plates must be of adequate size to ensure that settlement will not occur. A safe bearing capacity on the ground could be assumed to be 100kPa on any material other than swampy river flats.

6.4.2 Bailey Bridging

This is the almost universal method of temporary support in current use. The materials are readily available, easy to erect, and adequate (through combinations) for virtually any load. Erection and use should be in accordance with the Bailey Handbook.

However, some consideration should be given to the method of attachment of Bailey bridging to the timber bridge, and the effect of the supporting , method on the timber truss.

The Bailey truss should always be supported directly from the ground, either by packing to the bridge, piers or abutments, or by temporary tomming. If the panel of the Bailey truss does not occur directly over a support, packing and corbelling can usually be managed in the depth between the top of the pier/abutment, and the Bailey panel point. If tomming or pigstys are required, the loads should be calculated from the figures given in Section 6.4.1.

The method of support of the timber truss should ensure that the load is carried uniformly across the bridge - i.e. at all panel points of the timber truss. Bolts to the Bailey should be 4M3O for Dare and De Burgh trusses, and 4M24 for Allan, McDonald and Old Public Works Department trusses per timber truss panel point for one lane bridges. Bolts should be tightened uniformly to ensure that the load is evenly distributed i.e. tighten each group of bolts a little at a time in sequence.

The top of the Bailey should be tied to the top of the timber truss for stability.

6.4.3 Other Methods

There are other methods of temporary support for truss bridges that are virtually never used these days, but may be useful in particular cases. These can be found in DMR Manual No.6 -1962 - "Bridge Maintenance", of which relevant sections are included in Appendix.

6.5 <u>DECK TIMBERS</u>

Deck timbers including sheeting are subject to wear from traffic, while impact results in loosening of bolts and shattering of ends.

6.5.1 Replacement Timbers

Replacement timbers should be pressure impregnated with PEC (See 4.4.2.1), as this will prevent rot at seatings on supporting members. If cut to length before treatment end grain will also be protected which is a great advantage.

Timber for decking should be well seasoned to reduce gaps formed by shrinkage. Blackbutt, Ironbark, Grey Box and Tallowwood have all been found to be excellent. Brush Box is unsatisfactory and should not be used. Only 75mm sheeting should be used, experience shows that splitting is virtually eliminated.

Replacement of timbers should be carried out in sections, whenever appropriate. The increased life achieved by providing a uniform wearing surface justifies the replacement of a few extra timbers. Decisions on timber replacement should be made with a view to the deck lasting without member replacement during the nine-year cycle.

Deck planks which show signs of failure due to any defect should be replaced immediately, using new planks from stock in hand. In the absence of stock, second salvaged planks may be used, with immediate action being taken to restore the stock situation.

Under no circumstances should running planks be used. The bridge should be sheeted through out the full width.

6.5.2 Concrete Decking

The use of concrete decking provides abetter wearing surface, a longer life deck and an "umbrella" over the rest of the bridge to prevent moisture penetration and decay. However, a problem with concrete decks lies in their permanency, and the resultant difficulty of replacing supporting members. While this may not be such a problem where preservatives are in use, there is always the possibility of damage due to overload, or failure of the maintenance system. Alternatives to a permanent concrete deck include the use of a concrete overlay on the timber deck, or precast decking.

It is difficult to make concrete deck joints water tight, and failure to achieve this can lead to timber rotting underneath them.

6.6 DISPOSAL OF OLD TIMBER

Timber removed from the bridge, which is not reuseable should be either burnt or dumped. Reuseable timber may be used for repairs of other bridges, disposed of to the Council in whose area the bridge is situated, or sold to the highest bidder.

6.7 RECORDS

Replacements should be recorded on standard record sheets, to build an effective maintenance history. Again all costs should be recorded and dissected as suggested in Section 5.1.4.

SECTION 7 STRENGTHENING

INTRODUCTION

It is unlikely that any strengthening will be required on existing bridges. If necessary, it is probable that only the bottom chord will require strengthening as a temporary measure pending the replacement of a bridge on a major highway. However, there is one element of all truss bridges that requires some action- the lateral stability of the top chord.

7.1 BOTTOM CHORD STRENGTHENING

The weakness of timber in tension, particularly when subject to rot, can result in an overstressed bottom chord.

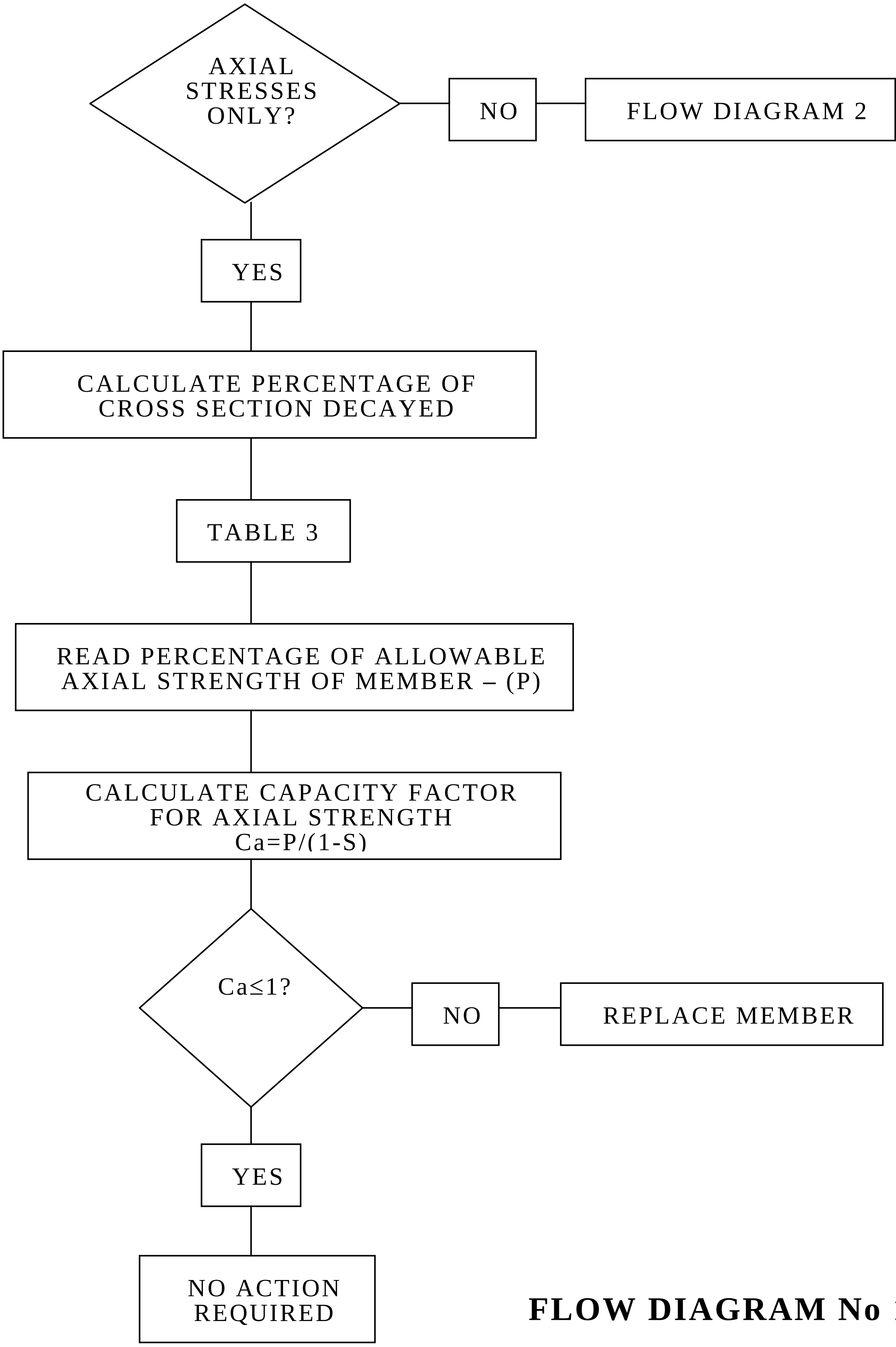
A method of strengthening, using an undertruss of mild steel rods and timber bearers, is given on DMR Plan B47A. This can be adopted if the bridge is intended for early replacement. In an emergency, and as a temporary measure, strengthening may be carried out using wirerope ties.

The bottom chord can also be strengthened by bolting steel plates to the sides. However this is only effective if there is no slip in the bolt holes - a most difficult objective. The steel will be effective with loose holes only should the timber fail. In this case the steel area needs to be approximately 12% of the timber area in the bottom chord.

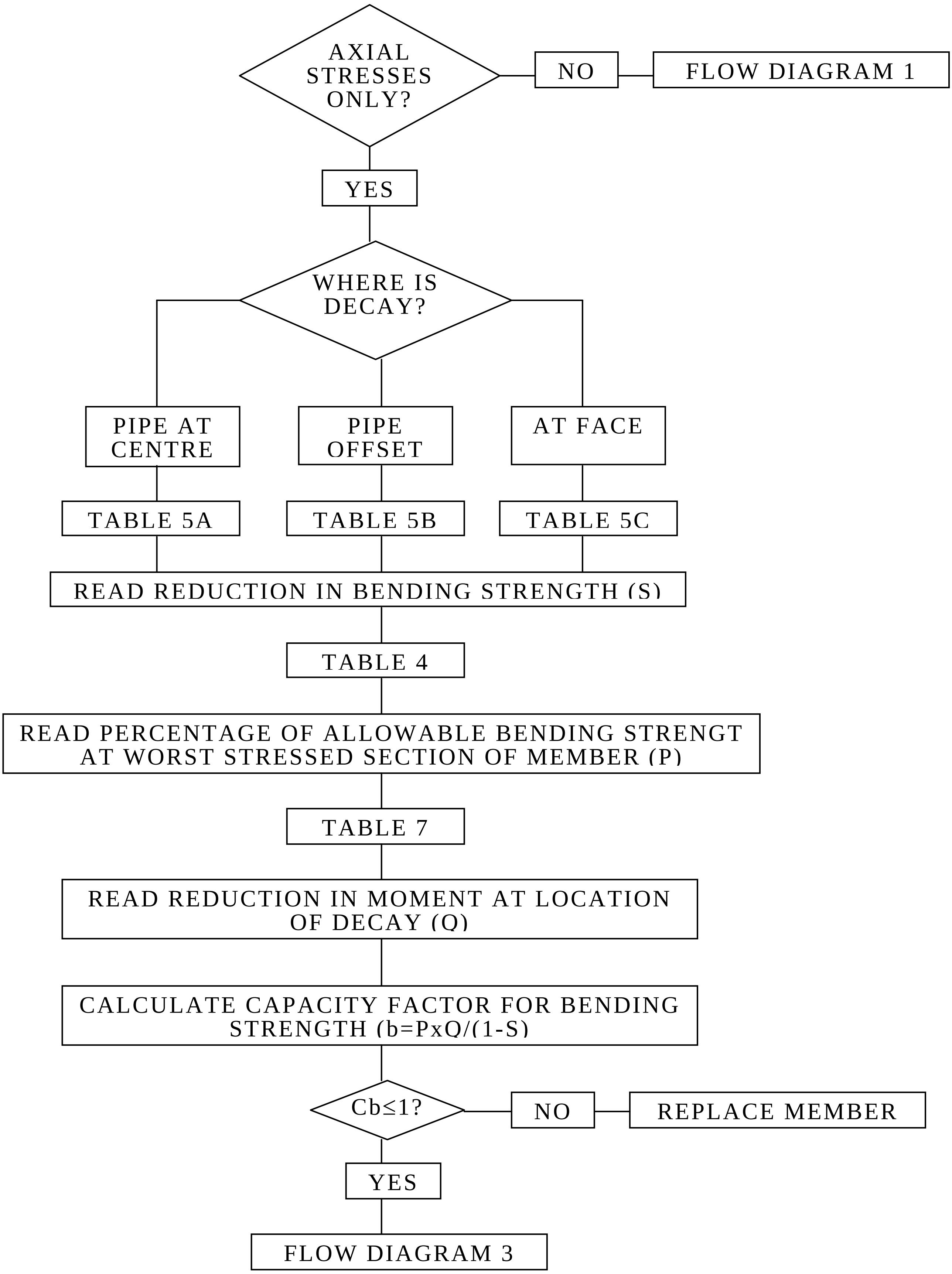
The bottom chord can also be strengthened by bolting timber members on the side of the existing bottom chord. Again this is only effective if there is no slip in the bolt holes, or should the existing bottom chord fail. If used, timbers should be bolted to both sides of the bottom chord. The timber size for each side should be equal in depth to the depth of the chord and have at least half the thickness.

7.2 TOP CHORD LATERAL STABILITY

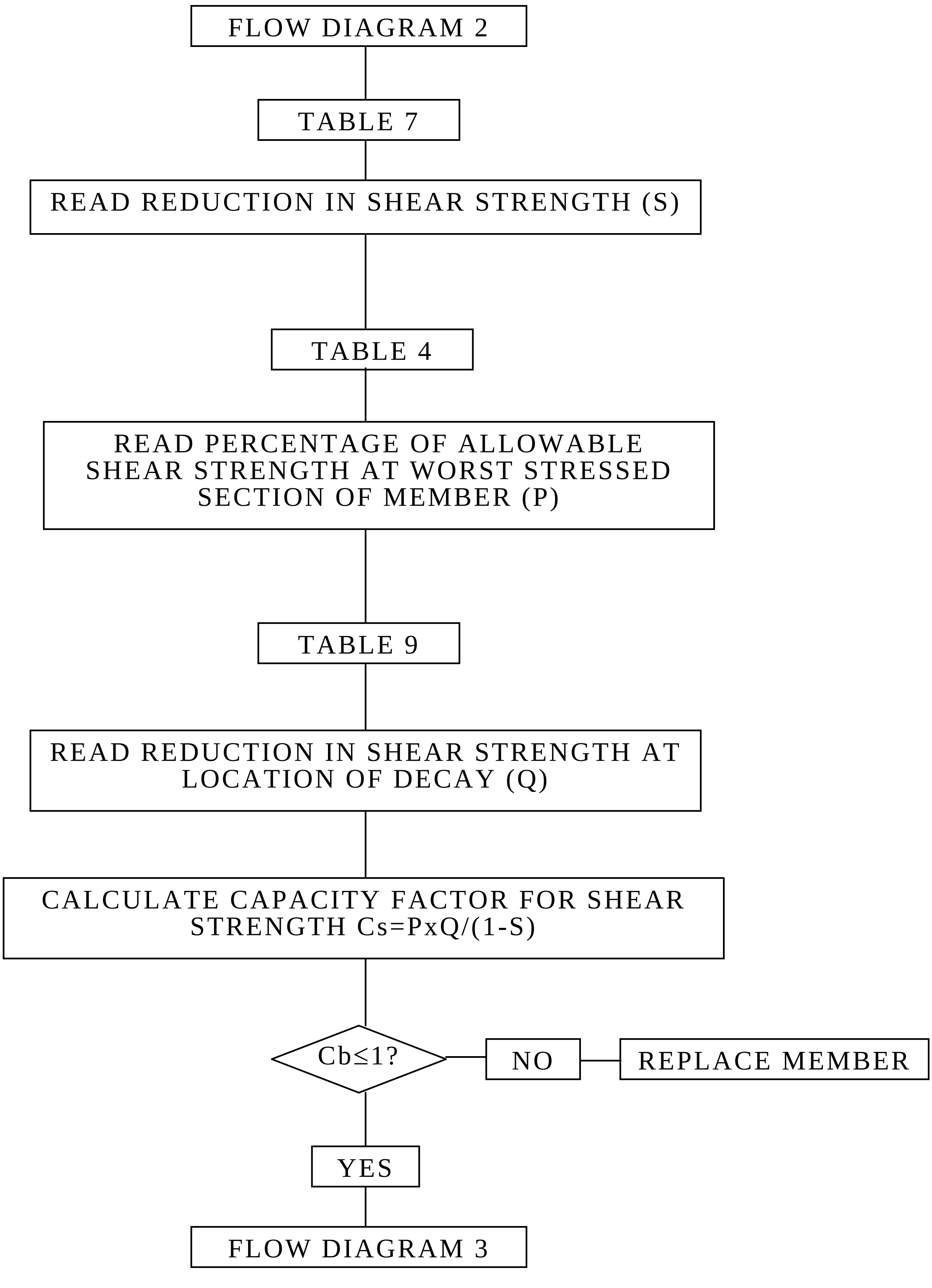
The steel angles which have been used to provide stability to top chords are too slender and are allowing excessive lateral movements. Movements are also induced by deflexions in the cross girders. Where heavy loads are experienced and trouble with top chord stability has developed, these should be replaced with heavier members - either tubes or angles. Fixings should be increased to use heavy end plates and four bolts. Cranking of the member, as is current practice, should be eliminated. Ideally, the new frame should be supported under the trusses independently of the cross girders.



FLOW DIAGRAM No 1



FLOW DIAGRAM No 2



FLOW DIAGRAM No 3

USE OF TABLES 3 TO 8

The ability of a member to withstand the imposed axial bending and shear stresses can be assessed by calculation of a load/capacity factor:

Ca = 1/capacity factor for axial stresses

Cb = 1/capacity factor for bending

Cs = 1/capacity factor for shear

Where $C = \frac{(P \times Q)}{(1 - S)}$ < 1 for a satisfactory member,

And P = percentage of allowable strength $\frac{(\text{Table 3 or 4})}{(100)}$

Q = reduction in required strength due to position of defect $\frac{(\text{Table 7 or 9})}{(100)}$

S = reduction in strength due to section loss $\frac{(\text{Table 5, 6 or 8})}{(100)}$

1. AXIAL STRESS

For example, the web of a 27.4m Allan truss has 20% of its cross-sectional area decayed.

From Table 3, Pa = 0.60,

In this case Sa = 0.20

Qa = 1.00 (location independent)

$$Ca = \frac{(0.60\ x\ 1.00)}{(1 - 0.20)} = 0.75 < 1.0$$

Member has satisfactory strength.

2. BENDING & SHEAR STRESS

For example, a 27.4m Allan truss has a cross-girder in which a pipe extends from one end to 1.1m beyond its point of support. The pipe is 150mmm in diameter and is centred 125mm from the underside of the member. The cross-girder is 380 x 250 and spans 5.7m.

a) <u>Bending</u>

The critical location for bending is the inner end of the pipe, 1.1m from the support.

From Table 4, Pa = 0.75

From table 5, Sb = 0.17 (b/d = 0.67, D/d = 0.4 and pipe located 1/3rd from underside, hence Table 5b)

So, $C_b = \dfrac{(0.75 \ x\ 0.64)}{(1 - 0.17)}$ = 0.58 < 1

b) <u>Shear</u>

The critical location for shear is at the point of support.

From Table 4, P_s = 0.45

From Table 8, S_s = 0.19

From Table 9, Q_s = 1.00

So, $C_s = \dfrac{(0.45 \ x\ 1.00)}{(1 - 0.19)}$ = 0.56 < 1

Member has satisfactory strength and maintenance can be confined to arresting decay and providing protection against further deterioration.

TABLE 3 – 21.3M ALLAN TRUSS

Percentage (P) of allowable strength in axially stressed members. Bridge loaded with NAASRA Standard Vehicle Load. (D = Double Member).

Refer to Figure 13 for member layout.

Member	Size	P(%)
Web – LOU1, L'OU'1	300mm x 150mm	30
Web – LIU2, L'IU'2	200mm x 115mm	65
Web – L2U3, L'2U'3	200mm x 115mm	40
Web – L3U'3	200mm x 100mm	15
Web – L'3U3	200mm x 200mm	15
Top Chord – U1U2, U'1U'2	300mm x 150mm	20
Top Chord – U2U3, U'2U'3	300mm x 150mm	25
Top Chord = U3U'3	300mm x 150mm	30
Btm Chord – LOL1, L'OL'1	300mm x 125mm	20
Btm Chord – L1L2, L'1L'2	300mm x 125mm	30
Btm Chord – L2L3, L'2L'3	300mm x 125mm	35
Btm Chord – L3L'3	300mm x 125mm	35

TABLE 4 – 21.3M ALLAN TRUSS

Percentage (P) of allowable strength in members stressed in bending orbending and axial load. Bridge loaded with NAASRA Standard Vehicle Load.

See also Table 5.

Refer to Figure 13 for member layout.

Member	Size	P (%) due to	
		Bending	Shear
Stringer - S1	235mm x 150mm	95	85
- S2	260mm x 150mm	80	75
- S3	273mm x 125mm	85	85
Cross Girder - CG	380mm x 250mm	75	45

TABLE 3 – 27.4M ALLAN TRUSS

Percentage (P) of allowable strength in axially stressed members. Bridge loaded with NAASRA Standard Vehicle Load (D = Double Member).

Refer to Figure 14 for member layout.

Member	Size	P (%)
Web – LOU1, L'OU'1	355m x 165m	25
Web – L1U2, L'1U'2	200m x 155m	100
Web – L2U3, L'2U'3	200m x 155m	80
Web – L3U4, L'3U'4	200m x 155m	60
Web – L4U'4	200m x 100m	35
Web – L'4U4	200m x 200m	20
Top Chord – U1U2, U'1U'2	355m x 165m	15
Top Chord – U2U3, U'2U'3	355m x 165m	20
Top Chord – U3U4, U'3U'4	355m x 165m	20
Top Chord – U4U'4	355m x 165m	25
Btm Chord – L0L1, L'0L'1	300m x 125m	20
Btm Chord – L1L2, L'2L'3	300m x 125m	30
Btm Chord – L2L3, L'2L'3	300m x 125m	35
Btm Chord – L3L4, L'3L'4	300m x 125m	45
Btm Chord – L4L'4	300m x 125m	40

TABLE 4 – 27.4M ALLAN TRUSS

Percentage (P) of allowable strength in members stressed in bending and axial load. Bridge loaded with NAASRA Standard Vehicle Load. See also Tables 5 & 8.

Refer to Figure 14 for member layout.

Member	Size	P (%) due to	
		Bending	Shear
Stringer - S1	235mm x 150mm	60	85
- S2	260mm x 150mm	50	75
- S3	270mm x 125mm	50	85
Cross Girder - CG	375mm x 250mm	75	45

TABLE 3 – 27.7M DARE TRUSS

Percentage (P) of allowable strength in axially stressed members. Bridge loaded with NAASRA Standard Vehicle Load (D = Double Member).

Refer to Figure 19 for member layout.

Member	Size	P (%)
Web – LOU1, L’OU’1	330m x 150m	50
Web – L1U2, L’1U’2	225m x 125m	85
Web – L2U3, L’2U’3	200m x 115m	95
Web – L3U’3, L’3U’3	200m x 115m	20
Top Chord – U1U2, U’1U’2	330m x 150m	25
Top Chord – U2U3, U’2U’3	330m x 150m	40
Top Chord – U3U’3	330m x 150m	45

TABLE 4 – 27.7M DARE TRUSS

Percentage (P) of allowable strength in members stressed in bending or bending and axial load. Bridge loaded with NAASRA Standard Vehicle Load.

Refer to figure 19 for member layout.

Member	Size	P (%) due to	
		Bending	Shear
Stringer - S	300mm x 300mm	40	35
Cross Girder - CG	380mm x 330mm	80	45

TABLE 5a

Reduction in bending strength due to piping at centre of section. Applicable to bending stresses in Table 4.

Refer to Figure 7a for explanation of symbols.

B/d	% Reduction in bending strength for different pipe sizes. R% = 100 D/d					
	10	20	30	40	50	60
1.0	-	-	-	2	4	8
0.9	-	-	1	2	4	8
0.8	-	-	1	2	5	-
0.7	-	-	1	2	-	-
0.6	-	-	1	3	-	-
0.5	-	-	1	-	-	-

TABLE 5b

Reduction in bending strength due to piping at the 1/3 point of section. Applicable to bending stresses in Table 4. Refer to figure no. 7b for explanation of symbols.

B/d	% Reduction in bending strength for different pipe sizes. R% = 100 D/d					
	10	20	30	40	50	60
1.0	-	2	5	11	19	30
0.9	1	3	6	12	21	34
0.8	1	3	7	14	24	-
0.7	1	3	8	16	-	-
0.6	1	4	9	19	-	-
0.5	1	5	11	-	-	-

TABLE 6

Reduction in bending strength for loss of timber on one face.

See Figure no. 7c

X %	Reduction in Bending Strength (%)
10	19
20	36
30	51
40	64
50	75

TABLE 7*

Percentage of maximum bending moment for different positions on a simply supported span (L) from a concentrated axle load.

Applicable to total load.

Position	% of maximum moment simple supported span
0.1L	36
0.2L	64
0.3L	84
0.4L	96
0.5L	100

*NOTE: This table is not applicable to continuous spans. Refer to Engineer.

TABLE 8

Reduction in shear strength due to piping. Applicable to shear stresses in Table 4.

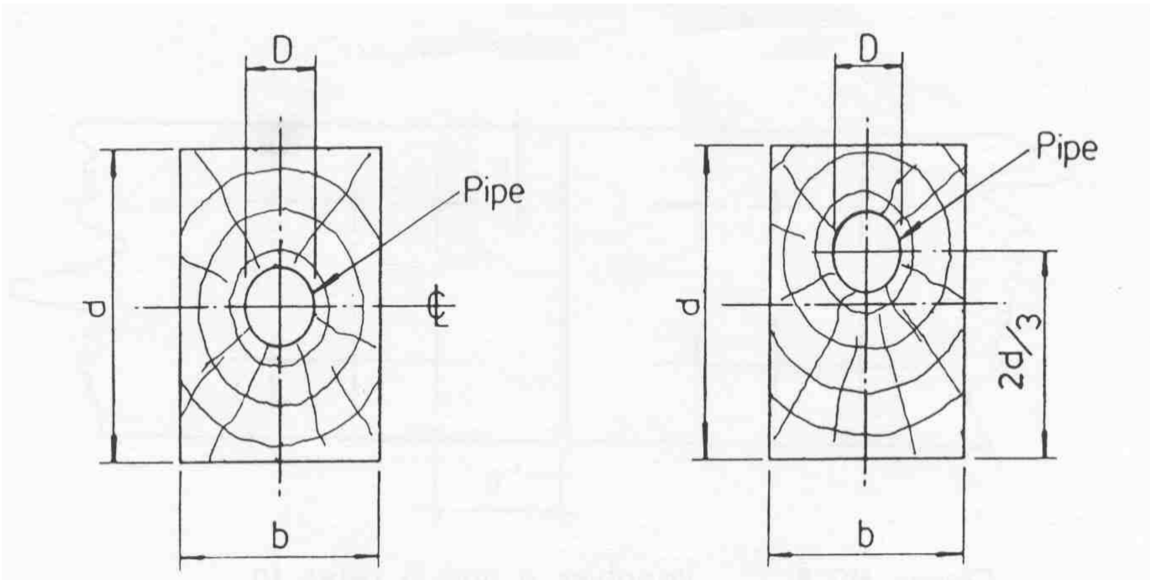
Refer to Figure 7a for explanation of symbols

% Reduction in shear strength for different pipe sizes. R% = 100 D/d						
B/d	10	20	30	40	50	60
1.0	1	3	7	13	20	28
0.9	1	4	8	14	22	31
0.8	1	4	9	16	25	-
0.7	1	4	10	18	-	-
0.6	1	5	12	21	-	-
0.5	2	6	14	-	-	-

TABLE 9

Percentage of maximum shear for different positions on a simply supported span (L) from a concentrated axle load.

Position	% of shear simply supported span
0.0L	100
0.1L	90
0.2L	80
0.3L	70
0.4L	60
0.5L	50



(a) (b)

Figure no. 7(a & b) Location of pipe in timber section at (a) middle and (b) 2d/3 from bottom.

Refer to Table no. 5

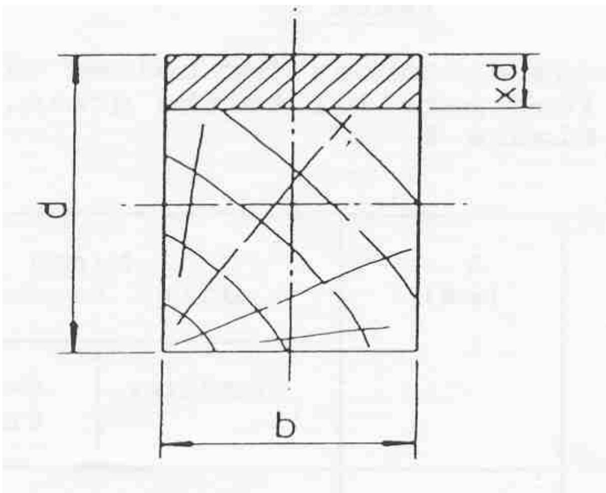


Figure no. 7 (c) Reduction in timber section on top or bottom face.

Refer to Table no. 6

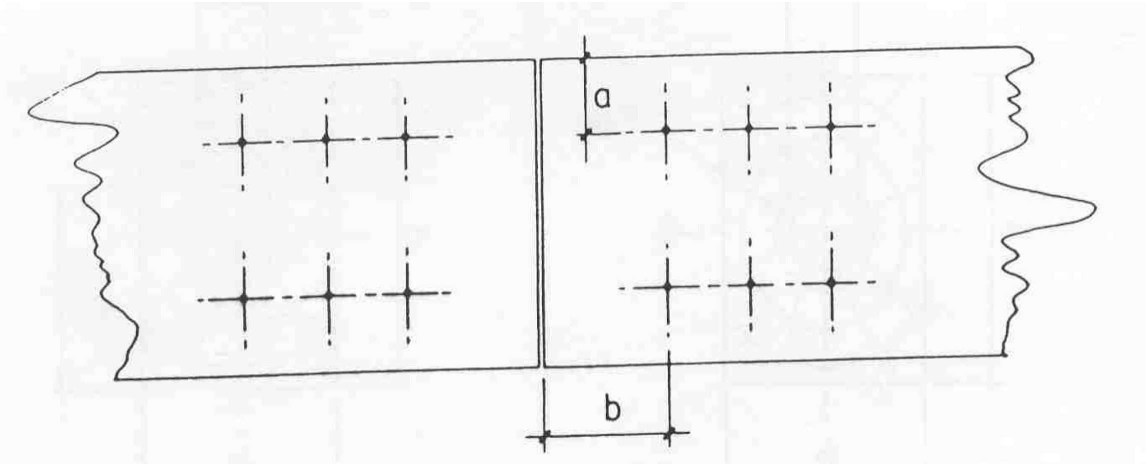


Figure no. 8 Variables a and b refer to minimum edge distance for bolts.

Refer to Table no. 10 for values to a and b.

TABLE 10

Minimum edge distances for bolted timber joints with the load parallel to the grain.

Refer to Figure 8.

Bolt Diameter (mm)	A (mm)	B (mm) Joint Loaded in	
		Tension	Bending or Compression
12	25	100	60
16	35	130	80
20	40	160	100
24	50	200	120
30	60	240	150

TABLE 11 – 27.4M ALLAN TRUSS

Permissible reduction in area in bearing for axially loaded members.

Refer to Table 3 for member sizes and Figure 14 for member layout.

Member	Permissible Reduction in area (%)
Web – LOU1, L’OU’1	85
Web – L1U2, L’1U’2	70
Web – L2U3, L’2U’3	75
Web – L3U4, L’3U’4	85
Web – L4U’4	95
Web – L’4U4	95

TABLE 11 – 21.3M ALLAN TRUSS

Permissible reduction in area in bearing for axially loaded members

Refer to Table 3 for member sizes and Figure 13 for member layout.

Member	Permissible Reduction in area (%)
Web – LOU1, L’OU’1	80
Web – L1U2, L’1U’2	75
Web – L2U3, L’2U’3	80
Web – L3U’3	95
Web – L’3U3	95

TABLE 12

Maximum Live Load Reaction for Standard NAASRA Vehicle (T44 Truck or Lane)

Span		Maximum LL Reaction per lane (kN)
ft	m	
65	19.825	358
70	21.350	363
75	22.875	368
84	25.620	375
90	27.450	378
100	30.500	384
105	32.025	386

APPENDIX A

TIMBER CHARACTERISTIC

APPENDIX A

PROPERTIES OF STRUCTURAL TIMBERS

Standard Trade Common Name[a]	Box Grey	Box Grey Coast	Gum Grey	Gum Spotted	Ironbark Grey	Tallow wood	Turpentine
Strength Group:							
Green	S2	S2	S2	S2	S1	S2	S3
Seasoned	SD3	SD2	SD2	SD2	SD1	SD2	SD3
Lyctus Susceptibility[b]	R	S	R	S[f]	R	S	R
Durability Class (fungi and termites)[c]	1	1	1	2,3	1	1	1
Shrinkage[d]	M	M	H	M	H	M	H
Density at 12% Moisture Content kg/m^3	1120	1100	1060	990	1090	990	940
Reference No[a]	120	121	252	280	304	655	688

Footnotes to Appendix A:

a The Standard Trade Common Names are those given in AS 02 or AS1148, as appropriate. Reference should be made to AS 02 for botanical names and States where the species occurs.

b S = susceptible
R = resistant

c 1 = highly durable
2 = durable
3 = moderately durable
4 = non-durable

d H = high shrinkage 9over 8 percent)
M = medium shrinkage (5 to 8 percent)
L = low shrinkage (less than 5 percent)
Values are for tangential shrinkage from green to 12 percent moisture content. For further information on shrinkage properties of timbers see CSIRO Technological Paper No 13, Shrinkage and Density of Australian and Other Woods, or refer to State and Commonwealth Forestry Departments.

e Wide sapwood.

RELATIONSHIP BETWEEN STRENGTH GROUPS AND STRESS GRADES FOR SEASONED TIMBER

Strength Group	Stress Grade			
	No1 Structural	No 2 Structural	No 3 Structural	No 4 Structural
SD1	F43	F34	F27	F22
SD2	F34	F27	F22	F17
SD3	F27	F22	F17	F14
SD4	F22	F17	F14	F11
SD5	F17	F14	F11	F8
SD6	F14	F11	F8	F7

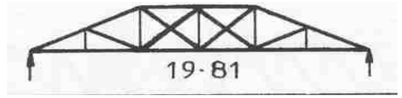
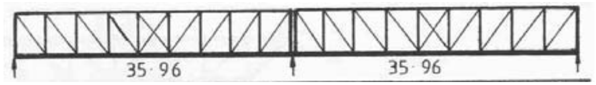
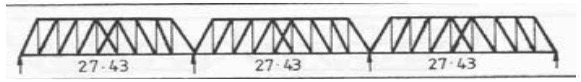
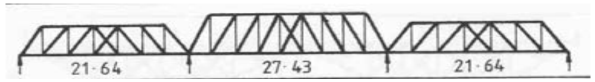
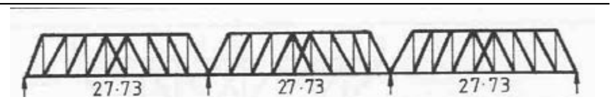
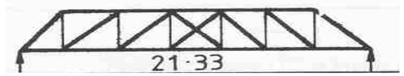
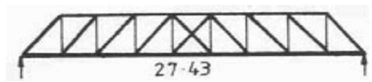
APPENDIX B

TIMBER TRUSS BRIDGE IN N.S.W.

1986

APPENDIX B

TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
390	161		Pearces (Tunks) Ck	1892	19.96	Timber	McDonald	
413	181	St Albans Br	MacDonald R	1902	166.12	Stl/Tim	De Burgh	
965	-	Victoria Br	Stonequarry Ck	1897	83.36	Timber	Allan	
1015	54		Abercrombie R	1919	106.37	Timber	Allan	
1185	216		Turon R	1897	106.68		Allan	
1199	233	Guntawang Br	Cudgegong R	1919	73.76	Timber	Allan	
1203	233	Yamble Br	Cudgegong R	1910	188.26	Conc/Tim	Dare	

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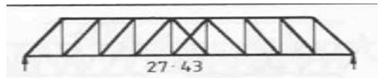
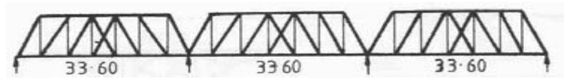
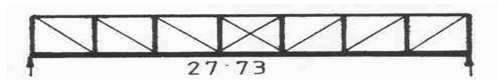
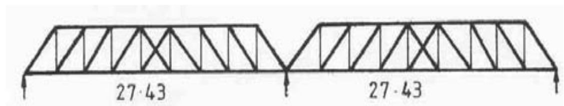
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
1301	-	Rankins Br	Macquarie	1920	172.51	Timber	Allan	
1302	-	McKanes Br	Coxs R	1893	56.08	Brick	McDonald	
1304	-	Beryl Br	Wyaldra Ck	1927	71.62	Conc/Tim	Allan	
1472	101	Coorei Br	Williams R	1904	114.6	Timber	Dare	
1481	102	Morpeth Br	Hunter R + Rly	1898	281.63	Stl/Tim	Allan	
1482	102	Hinton – Hinton Br	Paterson R	1904	178.61	Stl/Tim	Allan	
1527	128	Beckers Br	Webbers Ck	1901	45.41	Timber	De Burgh	
1535	128	Vacy Br	Patterson R	1898	64.92	Timber	Allan	

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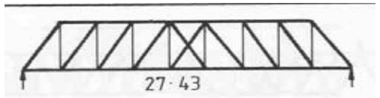
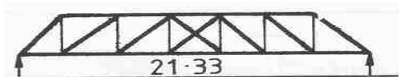
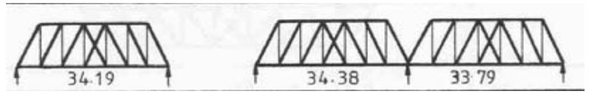
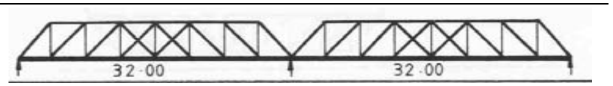
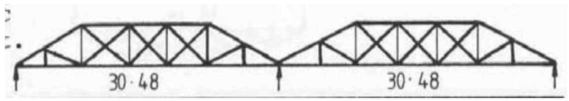
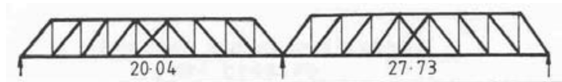
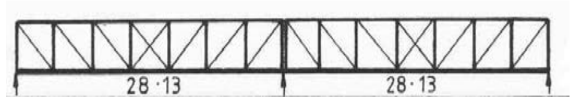
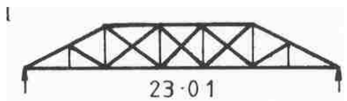
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
1564	208	Upper	Wybong Ck	1924	63.7	Timber	Allan	
453	225		Mill Ck	1929	21.33	Brk/Conc	Allan	
1683	301	Woodville-Dunmore Br	Paterson R	1899	130.45	Stl/Tim/ Conc	Allan	
1737	503	Bulga Br	Wollombi Brook	1910	129.23	Tim/Conc	Dare	
1752	567	Clarencetown Br	Williams R	1878	115.82	Stl/Tim	Old Public Works Dept	
1779	-	Yarrawa Br	Goulburn R	1927	149.73	Conc/Tim	Allan	
1784	-		Glennies Ck at Middle Falbrook	1904	75.43	Stl/Tim	De Burgh	
1917	75	Comara Br	Five Day Ck	1893	72.05	Timber	McDonald	

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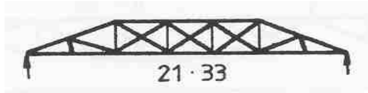
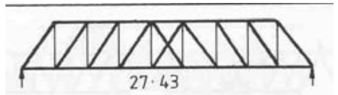
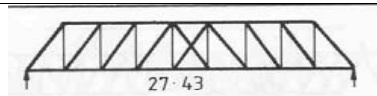
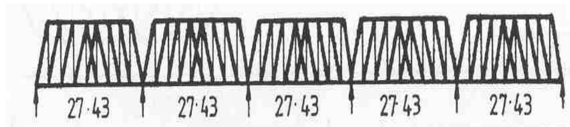
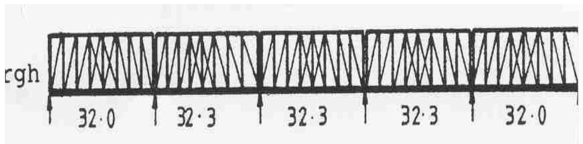
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
1477	101	Monkerai Br	Karuah R	1877	98.45	Timber	Old Public Works Dept	
1950	109	Duffs Br	Dingo Ck	1926	69.49	Timber	Allan	
1951	109	Marlee Br	Dingo Ck	1902	71.01	Timber	Allan	
1958	112	Killawarra Br	Manning R	1899	192.93	Timber	Allan	
2082	-	Barrington Br	Barrington R	1918	83.21	Timber	Allan	
2266	16		Clarence R	1902	297.48	Timber	De Burgh	

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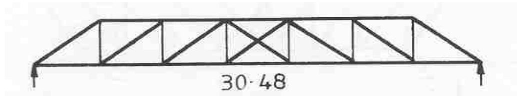
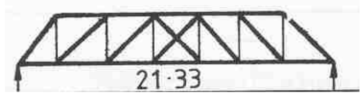
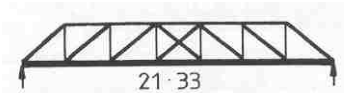
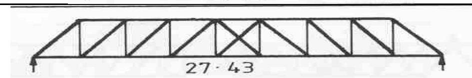
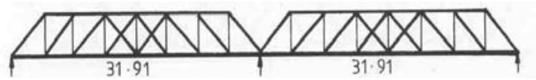
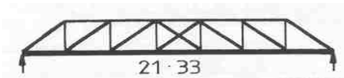
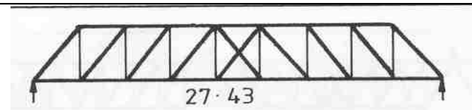
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
2366	83	Bean Tree Br	Richmond	1927	100.58	Timber	Alan	
2445	143		Rous R (Tweed R Nth Arm) at Kynnumboon	1927	71.32	Timber	Allan	
2501	150		Minneys Ck	1936	34.44	Conc/Tim	Dare	
2509	151		Orara R	1922	108.5	Timber	Allan	
2531	151		Sportsman Ck	1911	91.74	Conc/Stl/ Tim	Dare	
2540	152		Palmers Channel	1925	70.1	Timber	Allan	
2564	361		Tooloom Rivulet (Duck Ck)	1934	37.49	Timber	Dare	
2581	399		Tweed R	1916	43.89	Timber	Allan	

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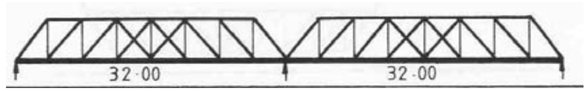
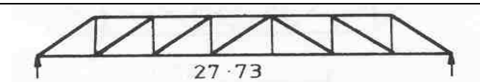
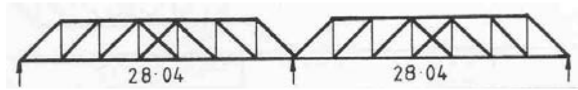
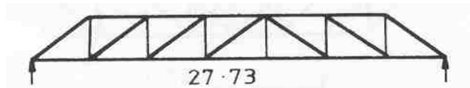
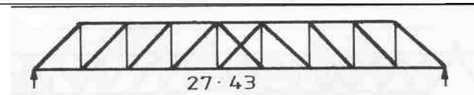
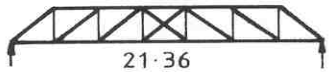
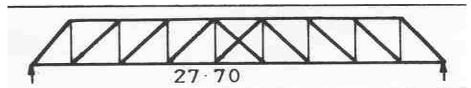
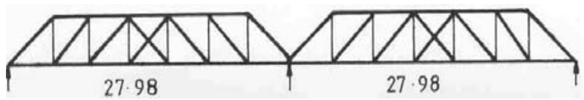
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
2594	544	Colemans Br	Leycester Ck	1907	90.67	Stl/Tim	Dare	
2675	1141		Richmond R at Kyogle	1912	98.75	Timber	Allan	
2678	-		Oxley R at McKenzies Crossing	1923	105.15	Tim/Conc	Allan	
2680	-	Briner Br	Upper Coldstream R	1908	114.6	Timber	Allan	
2810	16		Sandy Ck	1897	81.68	Timber	Allan	
3071	232	Boonangar Br	Barwon R	1928	44.8		Allan	
3088	367		Barwon R	1914	61.56	Timber	Allan	
3138	-	Pallamallawa Br	Gwydir R	1908	92.98	Timber	Allan	

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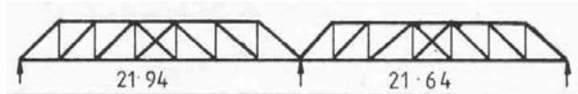
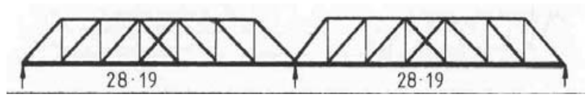
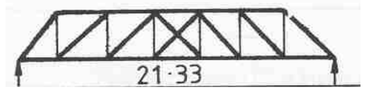
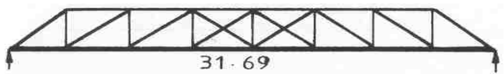
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
3244	222		Murray R at Tooleybuc	1925	89.3	Stl/Tim	Allan	
3247	226	Cobram Br	Murray R at Barooga	1902	186.84		De Burgh	
3248	244	Carrathool Br	Murrumbidgee R	1922	115.51	Stl/Tim	Allan	
3256	319		Murray R at Barham	1905	99.65	Stl/Tim	De Burgh	
3315	386	Coonamit Br	Wakool R	1929	128.01	Timber	Dare	
3320	410	Coopers Br	Lachlan R at Willanthry	1918	52.73	Timber	Allan	
5638	78	Hampden Br	Murrumbidgee R	1895	196.59	Stl/Tim	Allan	
5719	197	Howlong Br	Murray R at Howlong	1908	93.26	Timber	Dare	

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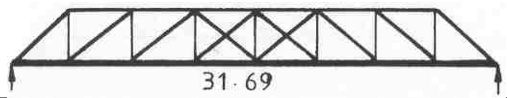
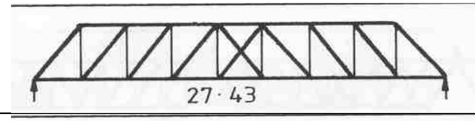
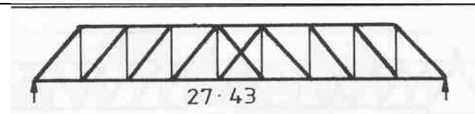
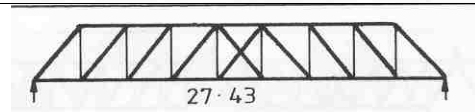
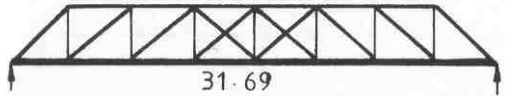
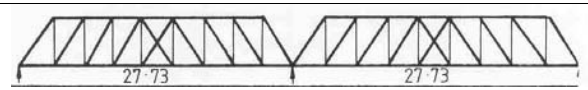
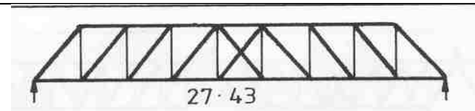
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
3443	-	Bendemeer Br	McDonald R	1904	92.04	Timber	Dare	
3772	74		Wollombi R	1897	55.47	Timber	Allan	
3778	74		Gara R	1928	55.77	Timber	Allan	
3791	75		Styx R	1900	44.19	Timber	Allan	
3796	105		Pages R at Gundy	1908	87.47	Timber	Dare	
3801	105		Hunter R at Belltrees	1919	119.17	Timber	Allan	
3802	105		Stewarts Brook	1921	40.53	Timber	Allan	

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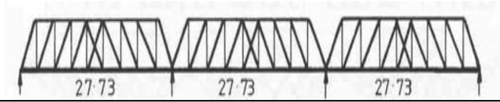
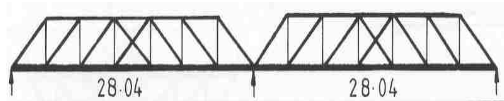
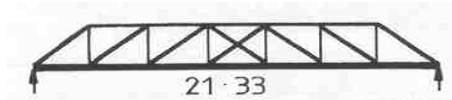
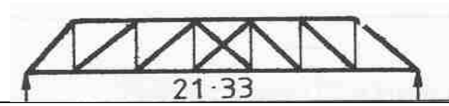
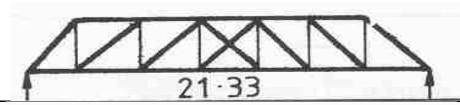
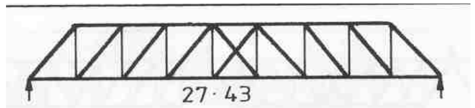
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
4799	18	Ewimbin Br	Barwon R	1920	155.75	Timber	Dare	
4860	68	Dangar Br	Barwon R	1930	119.48	Timber	Dare	
4991	437		Birrie R near Goodooga	1929	61.26	Timber	Dare	
4994	437		Gulgoa R at Brenda	1922	63.39	Timber	Allan	
3215	67		Murray R at Swan Hill	1896	116.35	Stl/Timb	Allan	
3220	80	Hillston Br	Lachlan R	1920	39.01	Timber	Allan	
3237	94	Gee Gee Br	Wakool R	1929	72.54	Timber	Dare	
3803	105		Hunter R at Lower Razor	1924	69.79	Timber	Allan	

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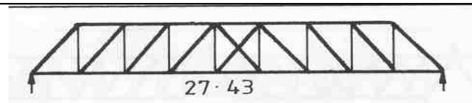
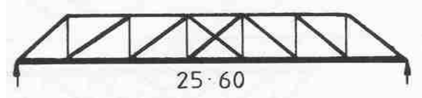
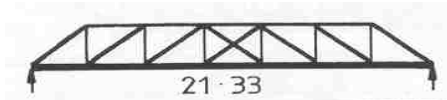
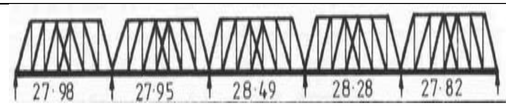
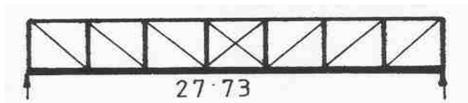
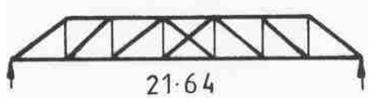
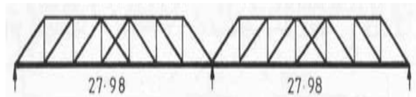
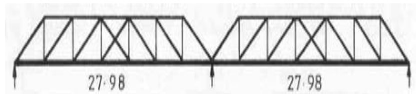
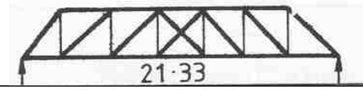
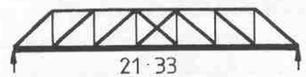
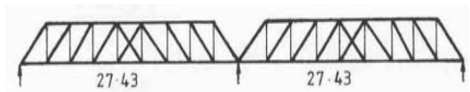
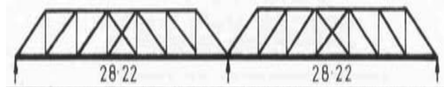
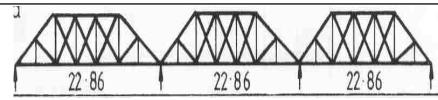
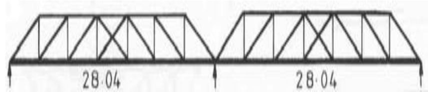
TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
3804	105		Hunter R at Upper Razor	1924	92.35	Timber	Allan	
3806	105		Hunter R at Bells Crossing	1929	47.85	Concrete	Dare	
3864	127	Collins Br	Namoi R	1903	52.42	Timber	Dare	
4075	6		Lachlan R at Cowra	1893	319.12	Stl/To,b	McDonald	
4175	11	Gooloogong Br	Lachlan R	1904	246.27	Timber	De Burgh	
4515	310	Wadell Br	Belubula R	1901	52.12	Timber	De Burgh	
4603	423		Lachlan R at Murrin	1920	54.25	Timber	Allan	

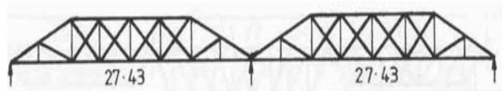
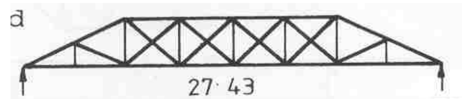
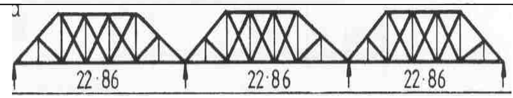
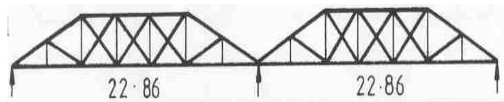
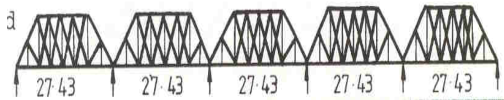
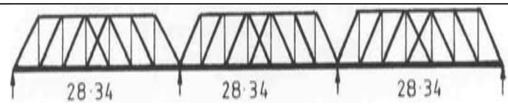
<u>APPENDIX B</u>

TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
4608	572		Macquarie R at Narromine	1906	159.71	Timber	Dare	
4645	1165		Macquarie R at Minore	1916	111.86	Conc/Timb	Dare	
4657	-		Goobang Ck at	1926	61.87	Timber	Allan	
4658	-	Warroo Br	Lachlan R	1909	62.78	Timber	Dare	
4659	-	Patons Br	Lachlan R at Colletts	1926	128.01	Timber	Allan	
4660	-	Scabbing Flat Br	Macquarie R	1910	150.74	Stl/Timb	Dare	
5948	-	Junction Br	Tumut R	1892	105.05	Timber	McDonald	
5949	-	Eurolie Br	Murrumbidgee R	1929	95.7	Timber	Dare	

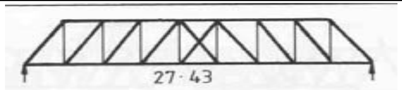
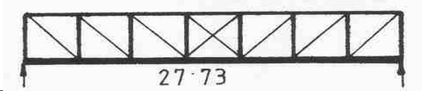
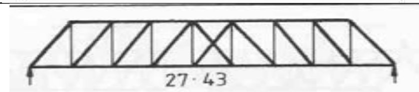
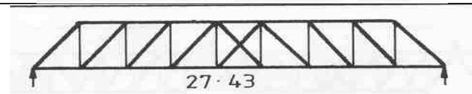
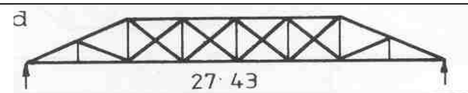
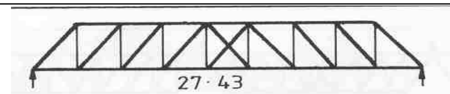
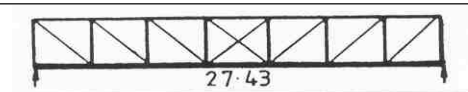
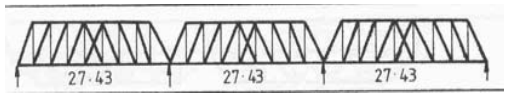
<u>APPENDIX B</u>

TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
6061	19		Bombala R at Bombala	1893	88.39	Timber	McDonald	
6064	19		Bombala R at Cunninghams Pt	1893	111.55	Timber	McDonald	
6067	19		Bombala R at Bibbenluke	1889	108.2	Timber	McDonald	
6129	91		Coolumbooka Ck	1893	86.25	Timber	McDonald	
6154	272	Tarraganda Br	Bega R	1894	335.58	Timber	McDonald	
6237	-	New Buildings Br	Towamba R	1921	101.19	Timber	Dare	

<u>APPENDIX B</u>

TIMBER TRUSS BRIDGES IN NSW

Bridge No.	Road No.	Name	River	Approx Date Built	Overall Length (m)	Sub structure Material	Truss Type	Line Diagram (Approach spans not shown)
6380	52	Fairfield Br	Yass R at Gundaroo	1899	64.0	Timber	Allan	
6396	54		Crookwell R	1903	28.95	Timber	De Burgh	
6463	79	Thornes Br	Mulwaqree R	1920	100.88	Timber	Allan	
6506	92	Charleyong Br	Mongarlowe R	1901	89.3	Timber	Allan	
6578	248	Acramans Br	Boorowa R	1892	68.58	Timber	McDonald	
6633	278	Wee Jasper Br	Goodradigbee R	1923	66.49	Timber	Allan	
6675	-	Lansdowne Br	Mulwaree Ponds	1902	97.53	Conc/Timb	De Burgh	
6678	-	Rossis Crossing Br	Wollondilly R	1898	106.07		Allan	

APPENDIX C

STANDARD RECORDING DRAWINGS

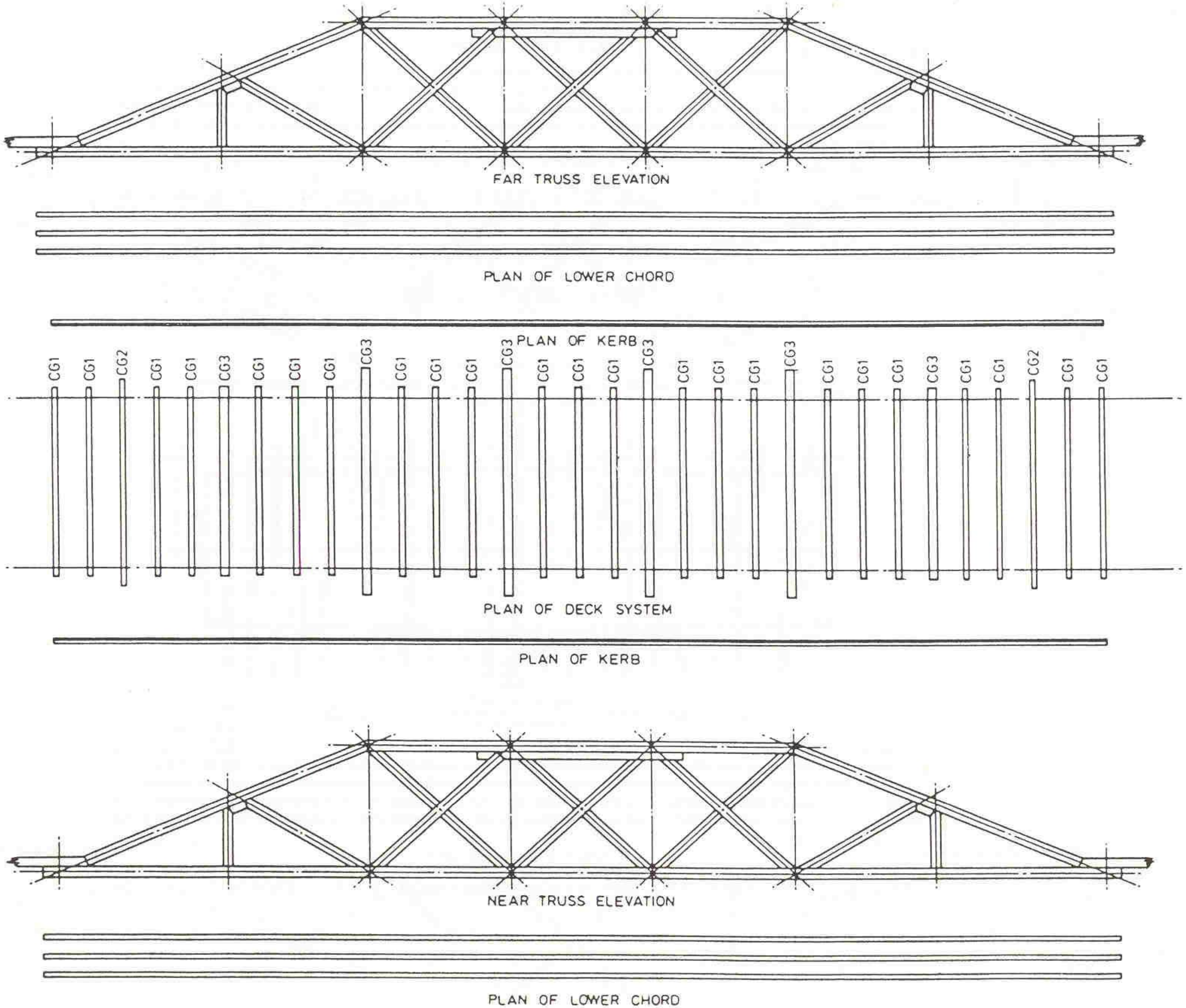


Figure 9.

30·48 m OLD PUBLIC WORKS DEPARTMENT TRUSS SPAN

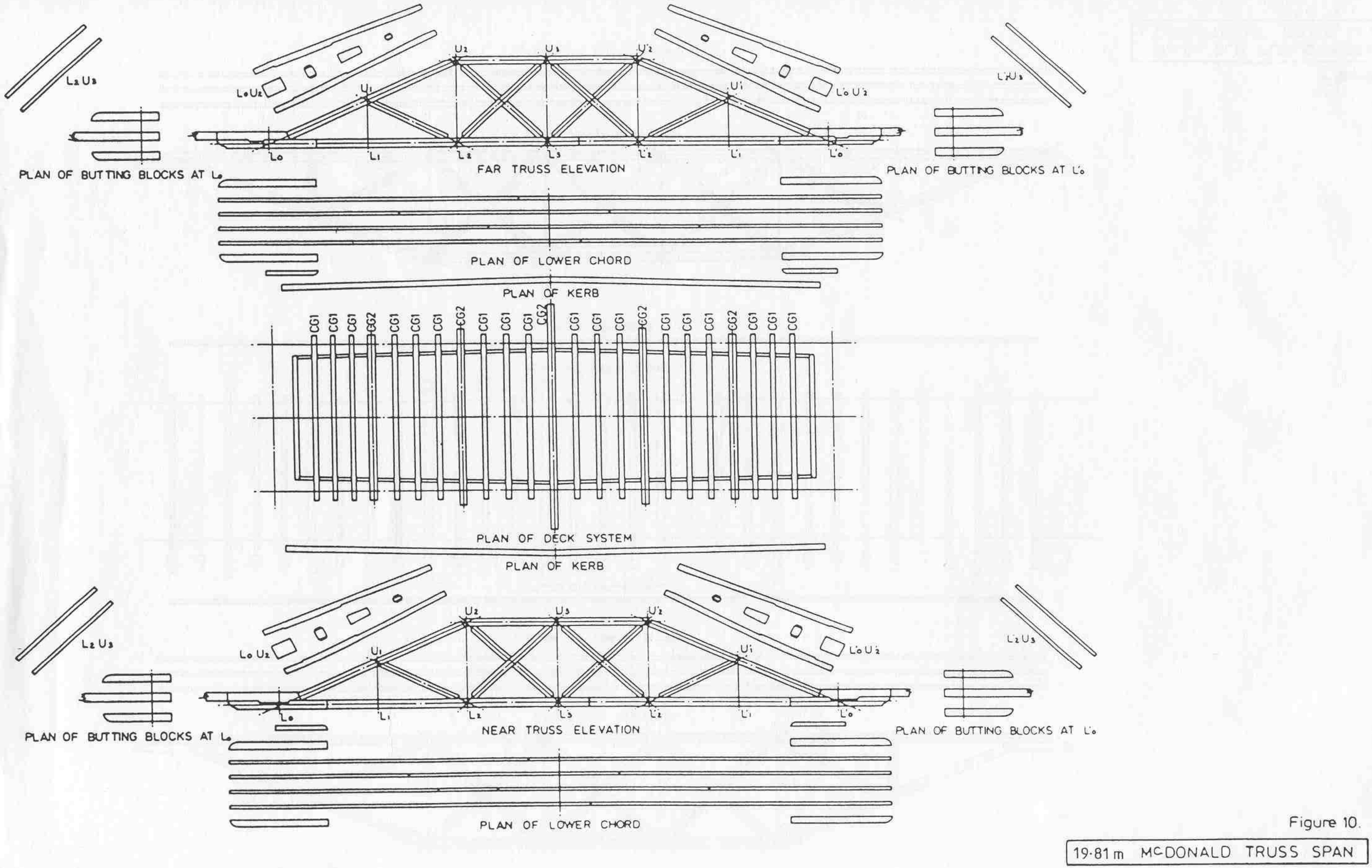


Figure 10.

19·81 m McDONALD TRUSS SPAN

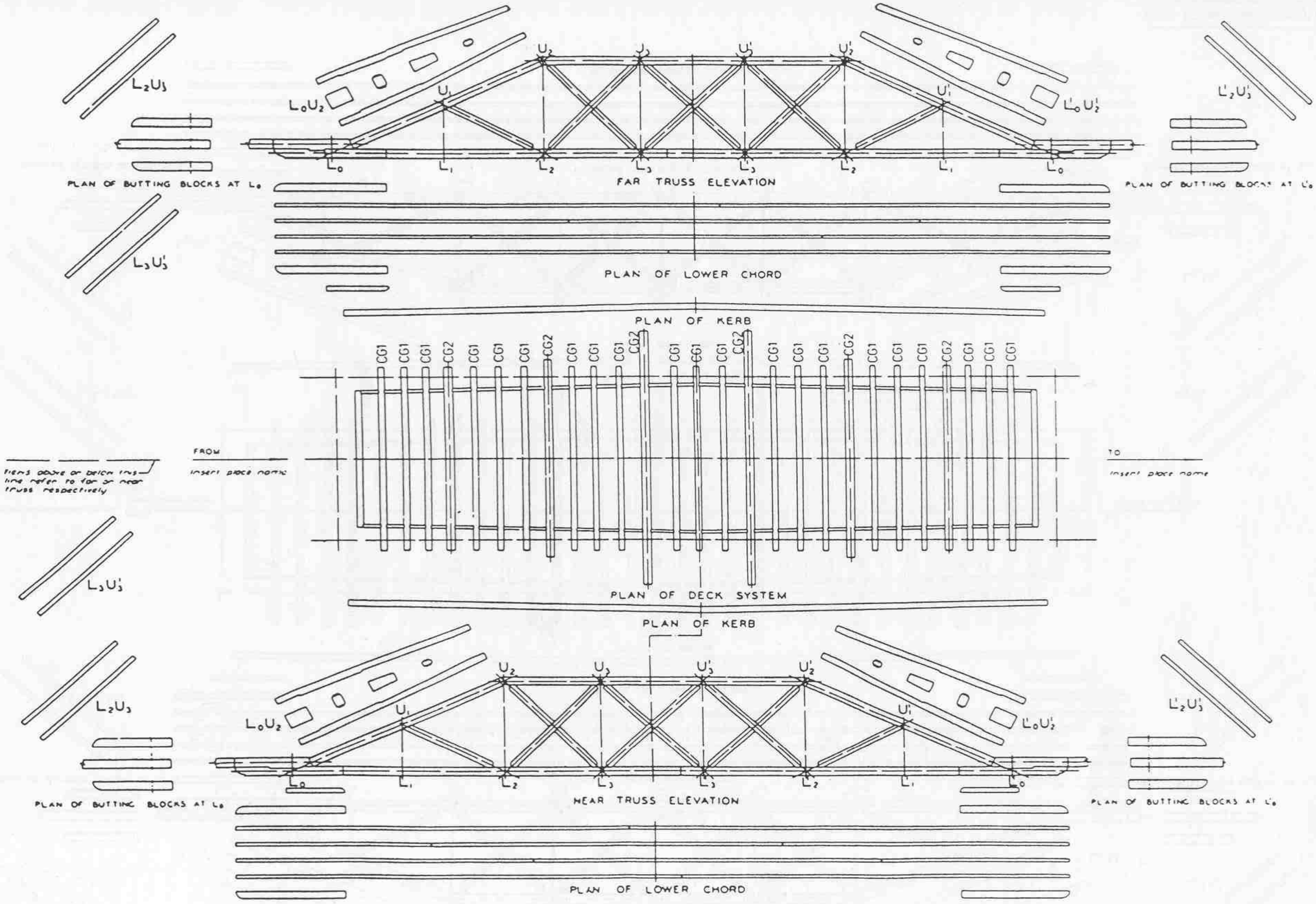


Figure 11.

22·86m McDONALD TRUSS SPAN

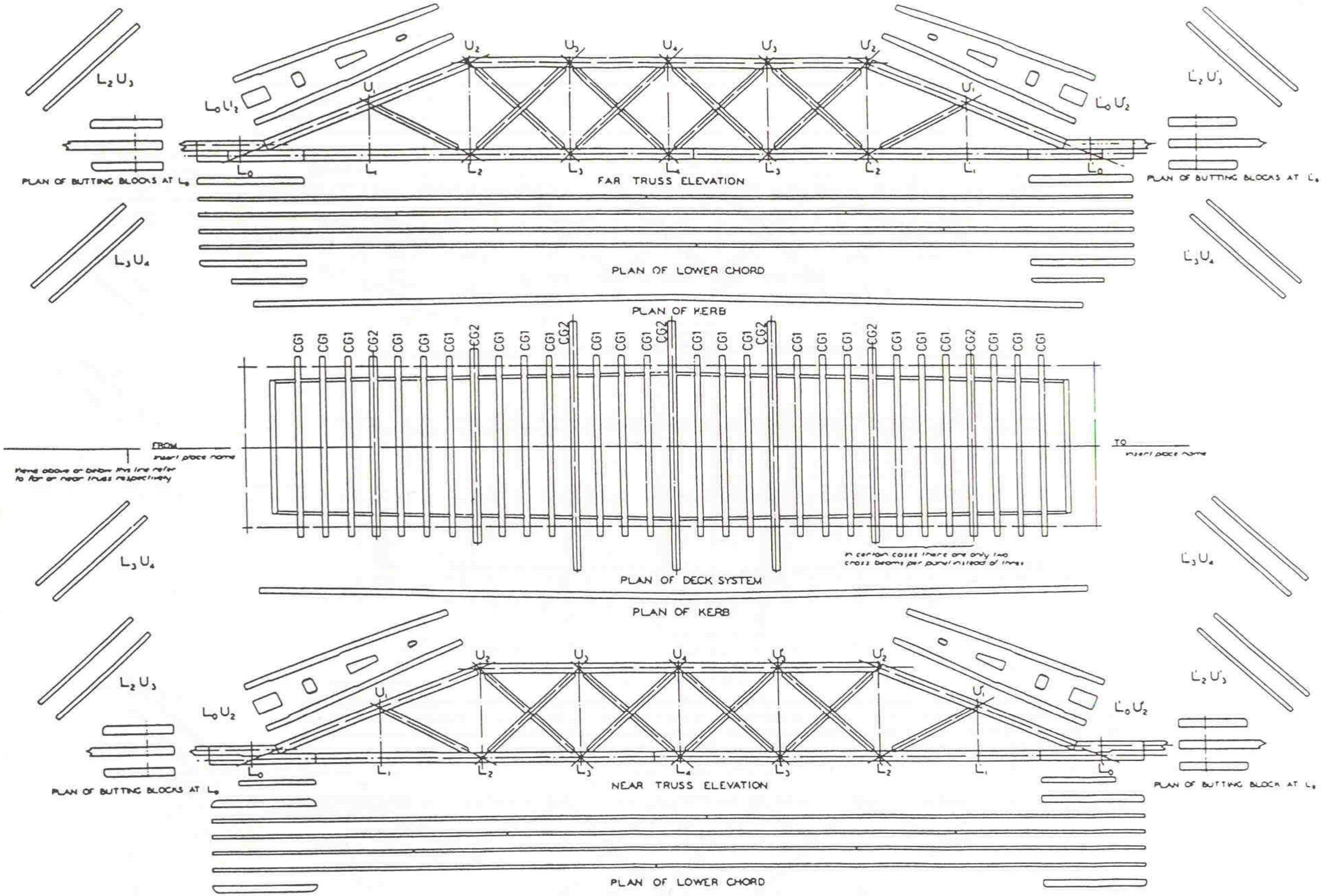


Figure 12.

27·43 m McDONALD TRUSS SPAN

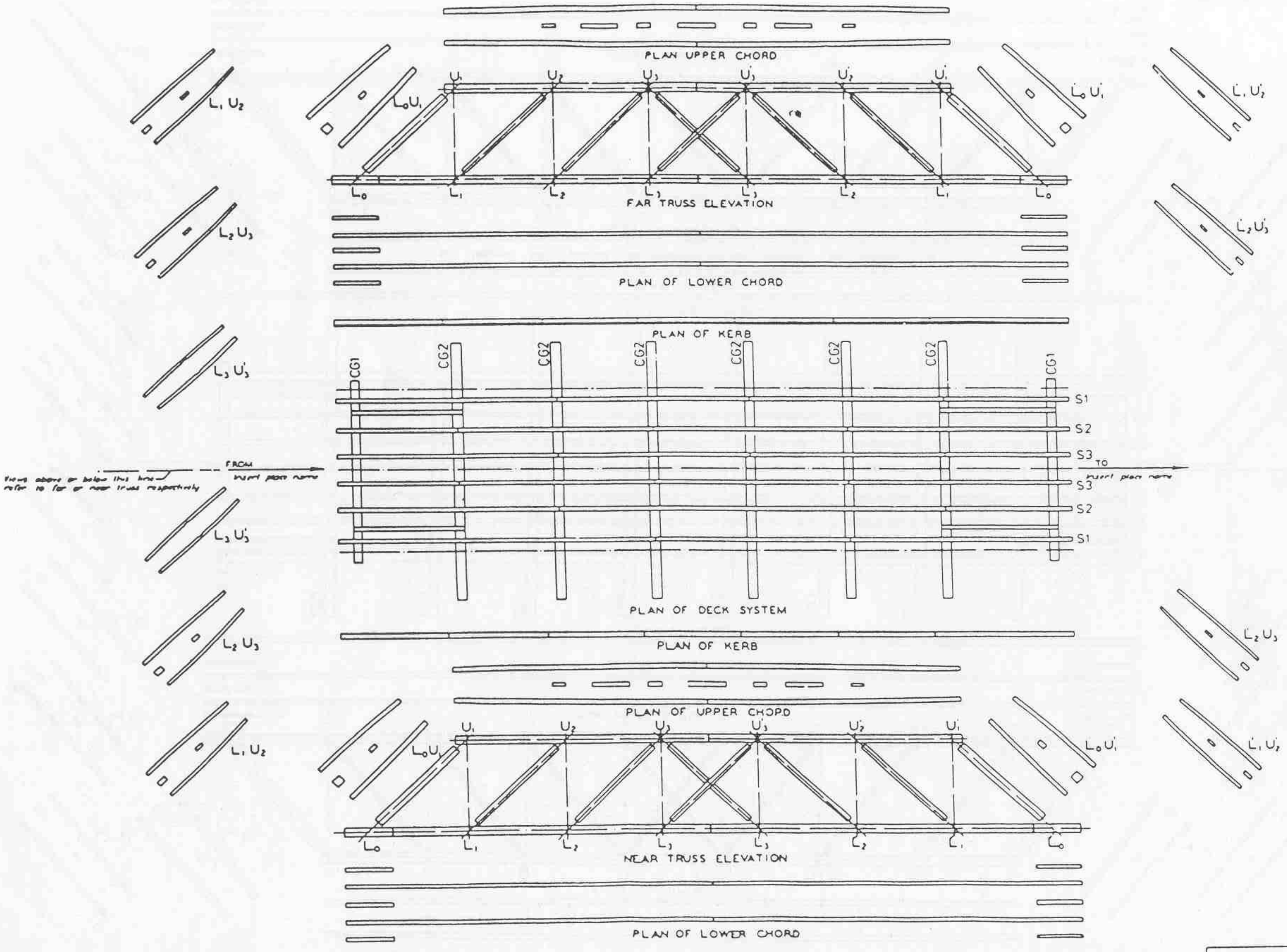


Figure 13.

21·33 m ALLAN TRUSS SPAN

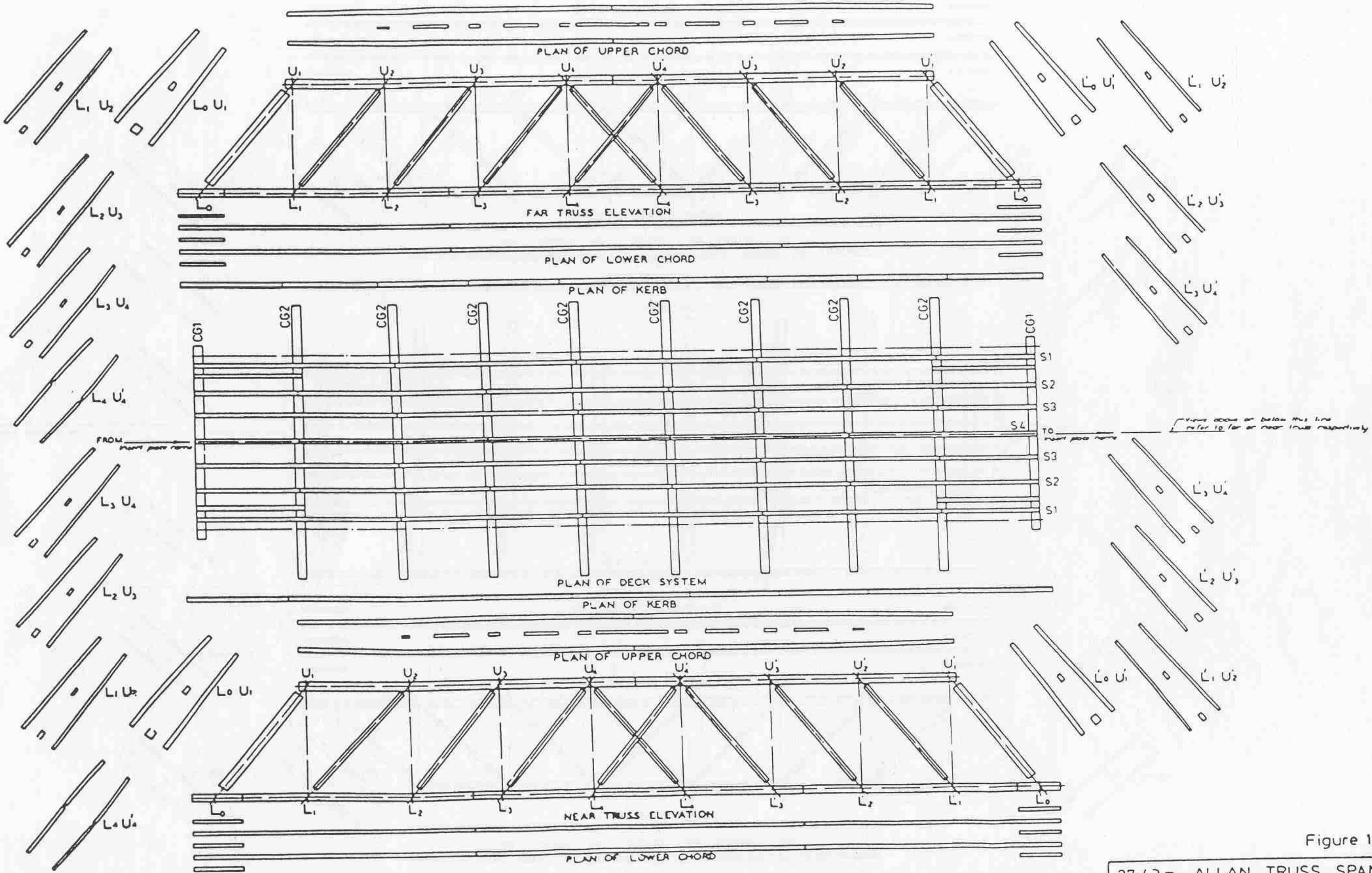


Figure 14.

27·43 m ALLAN TRUSS SPAN

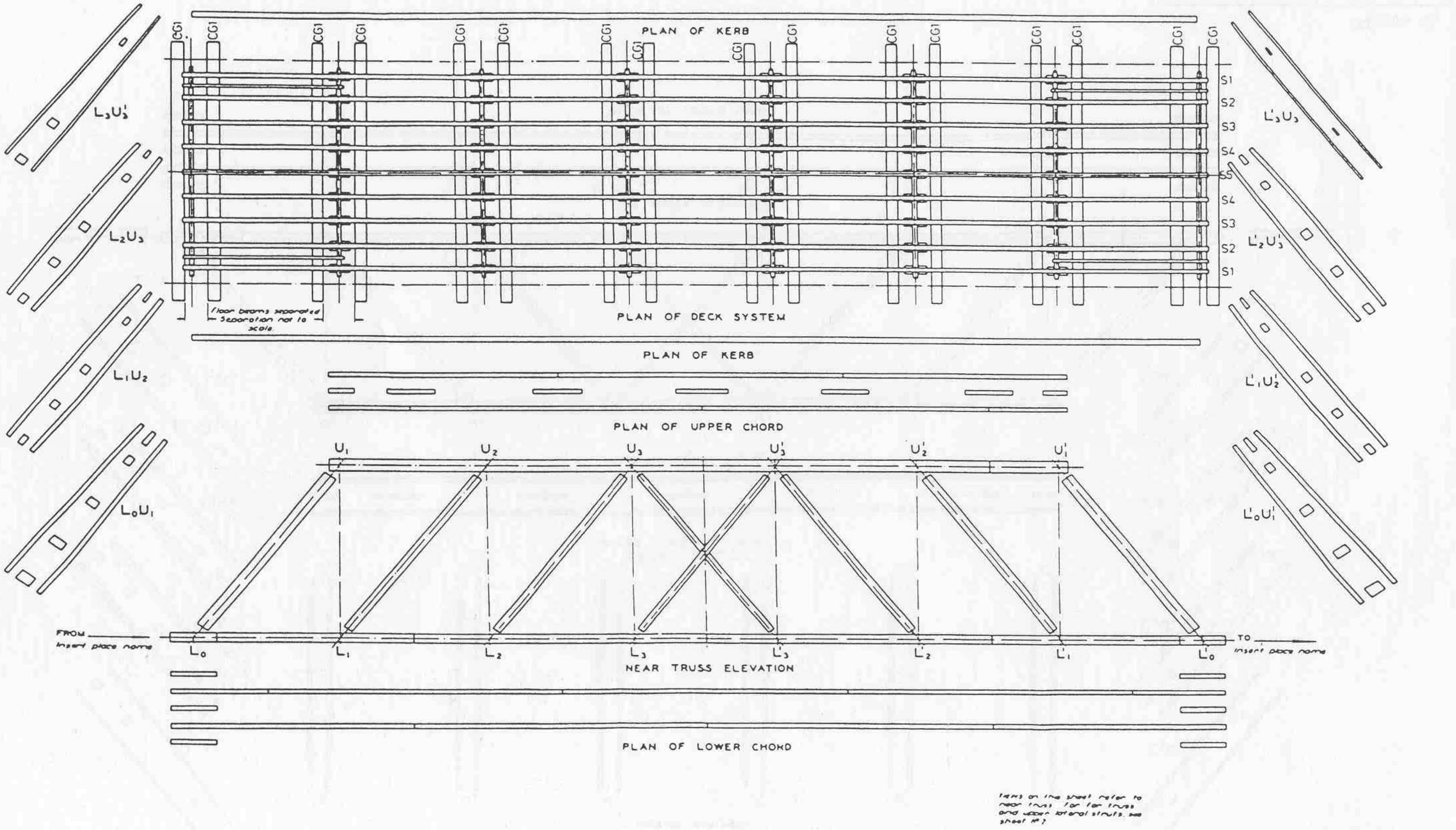


Figure 15.

33·60m ALLAN TRUSS SPAN

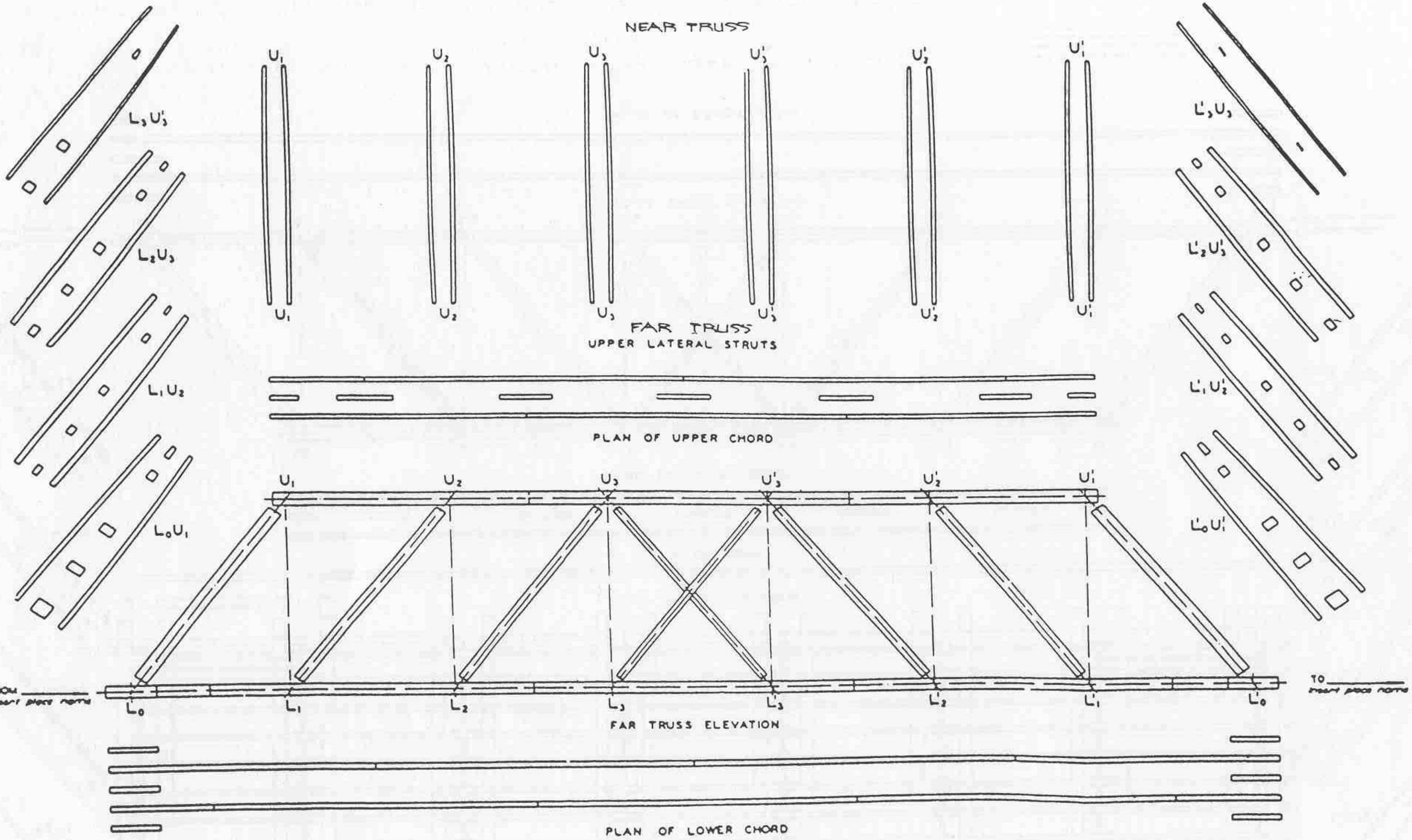


Figure 16.

33.60 m ALLAN TRUSS SPAN

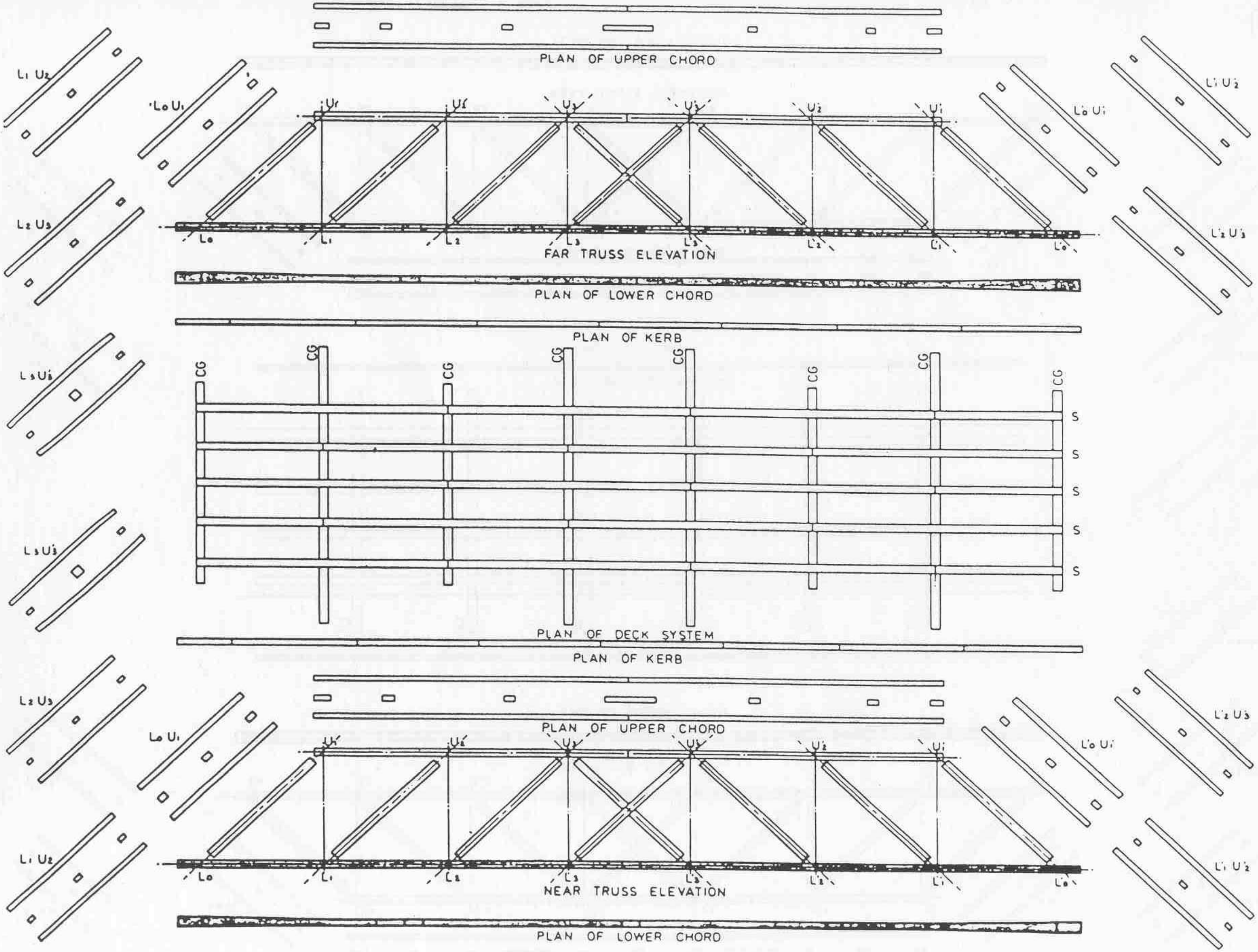


Figure 17

21·33m DARE TRUSS SPAN

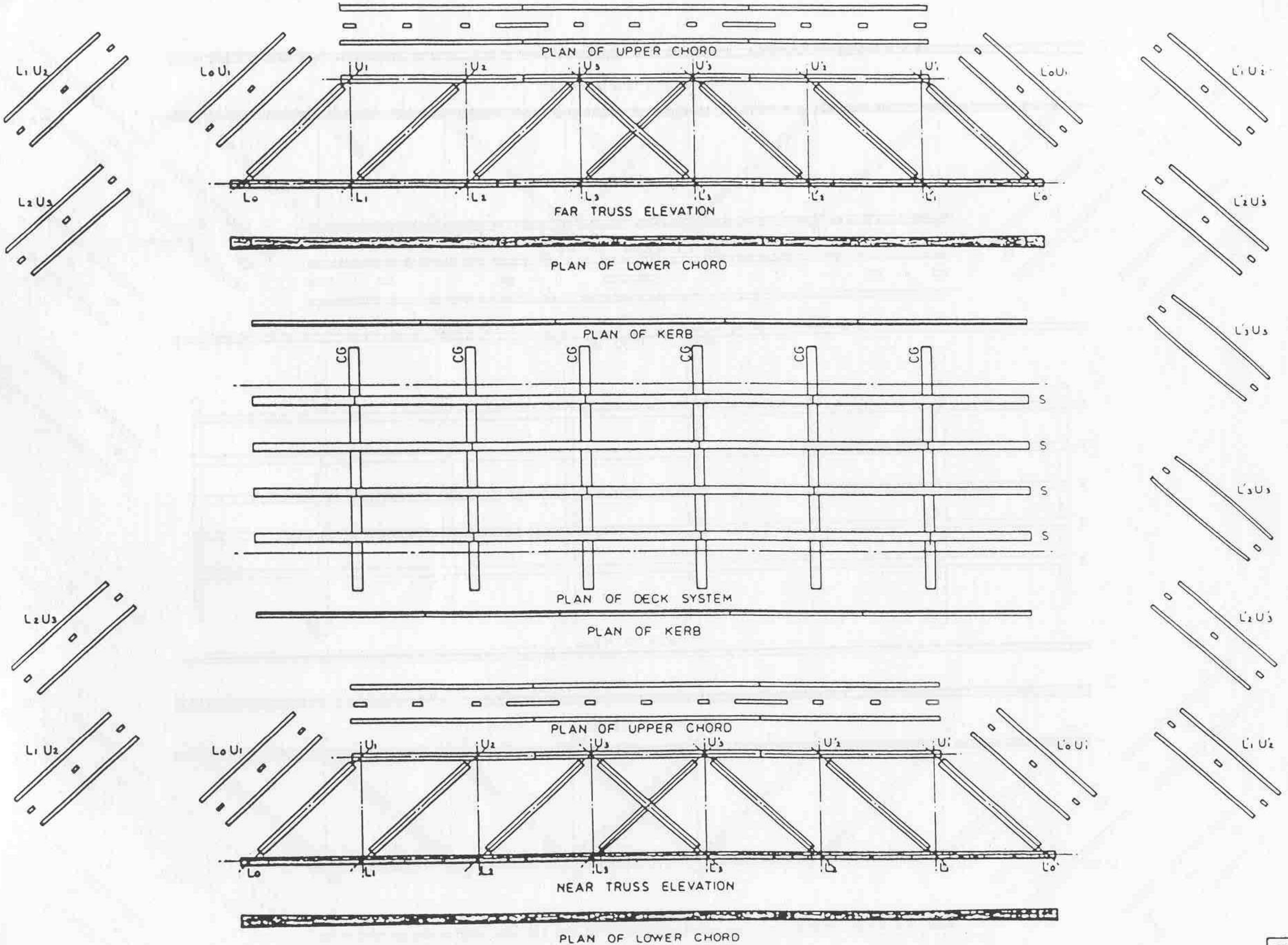


Figure 18.

25·60 m DARE TRUSS SPAN

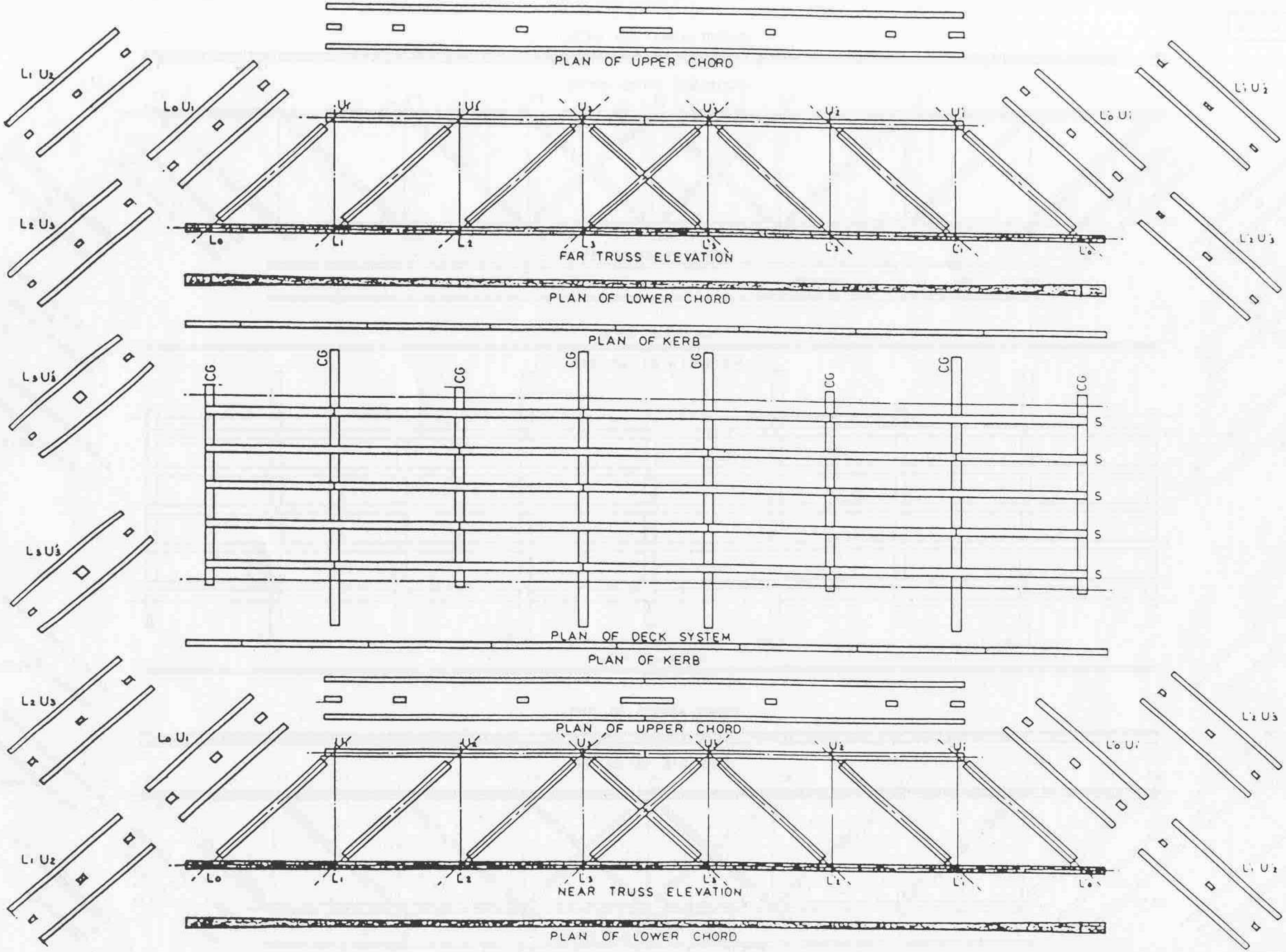


Figure 19

27·73 m DARE TRUSS SPAN

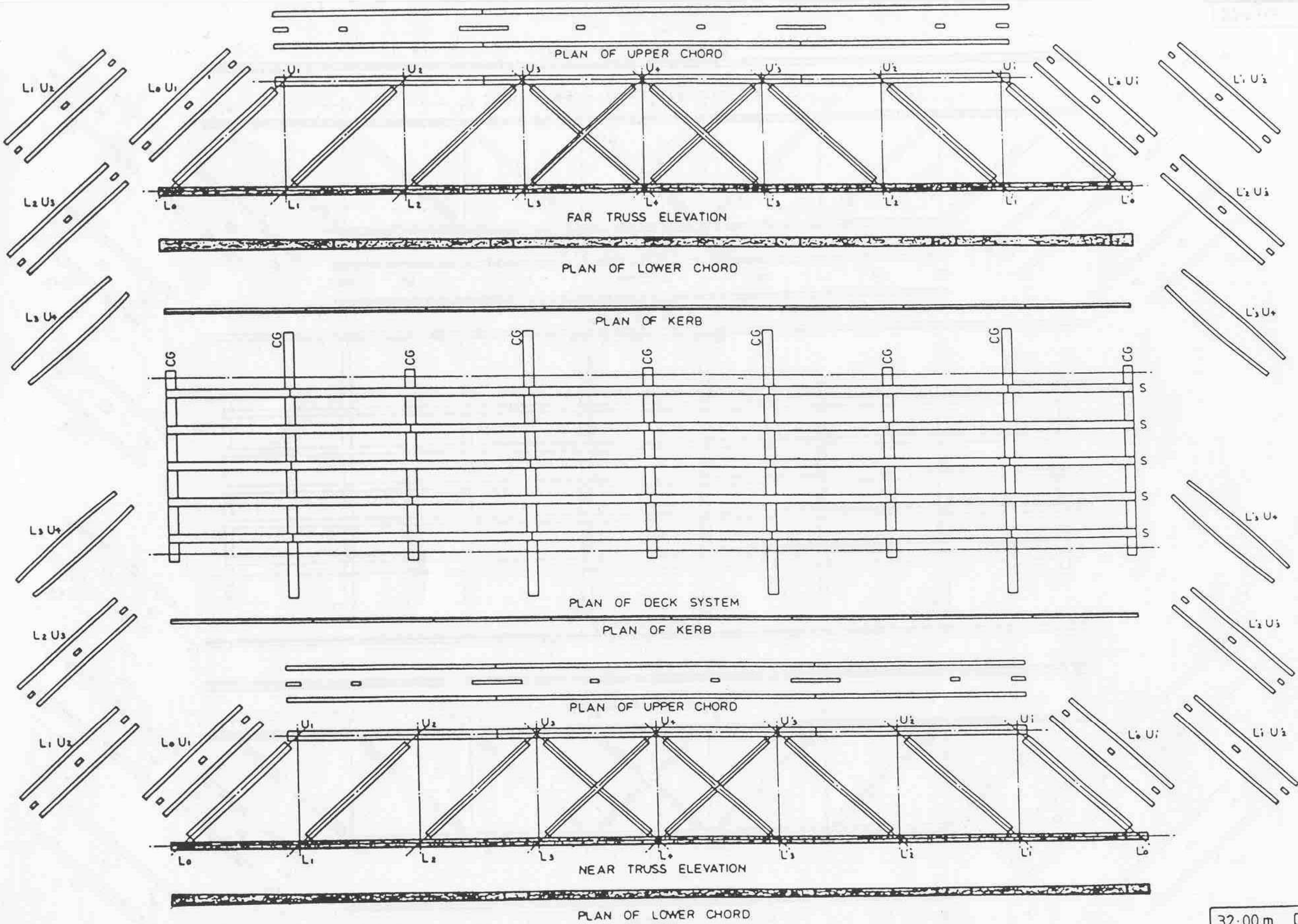


Figure 20.

32·00 m DARE TRUSS SPAN

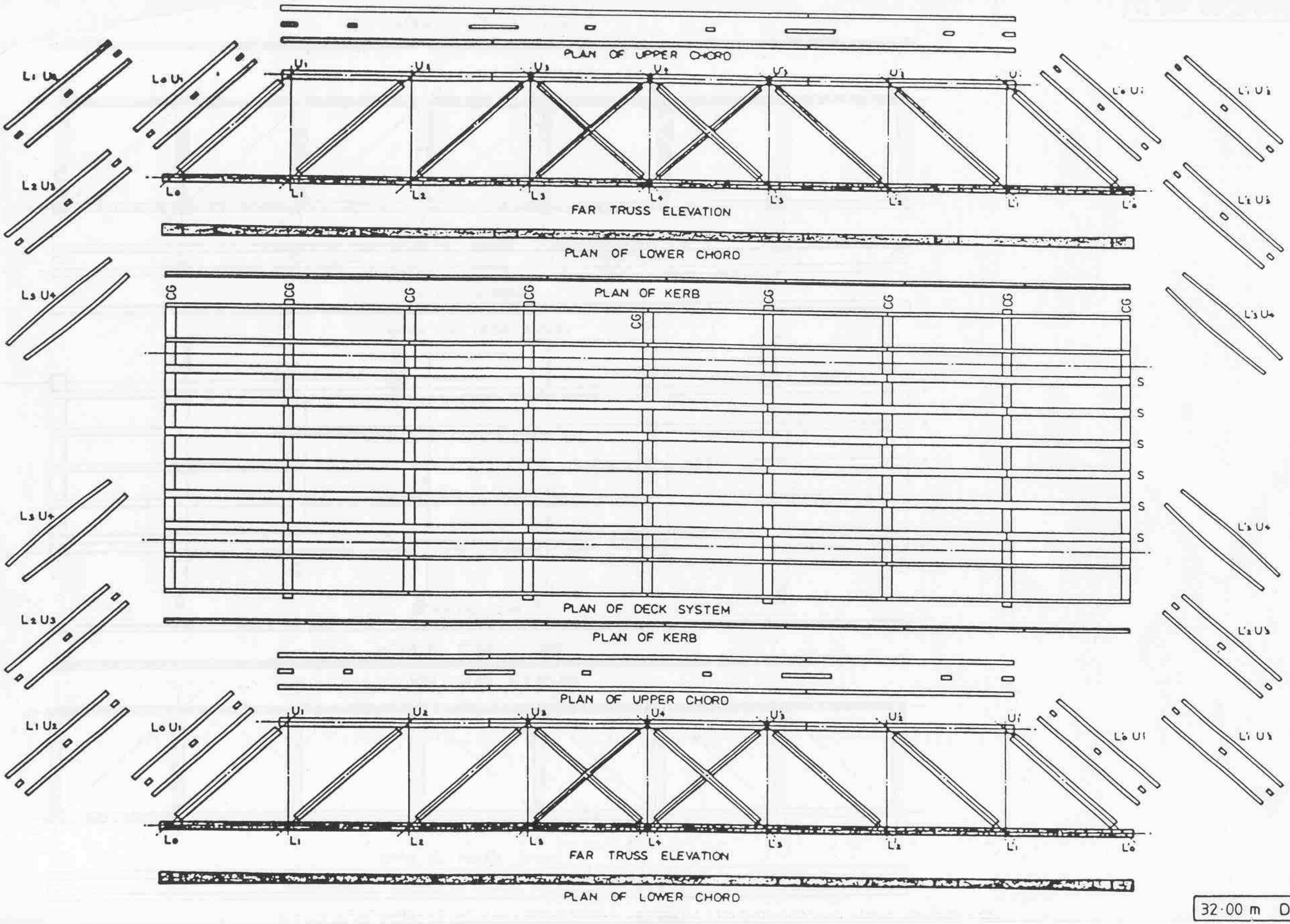


Figure 21.

32·00 m DARE TRUSS SPAN

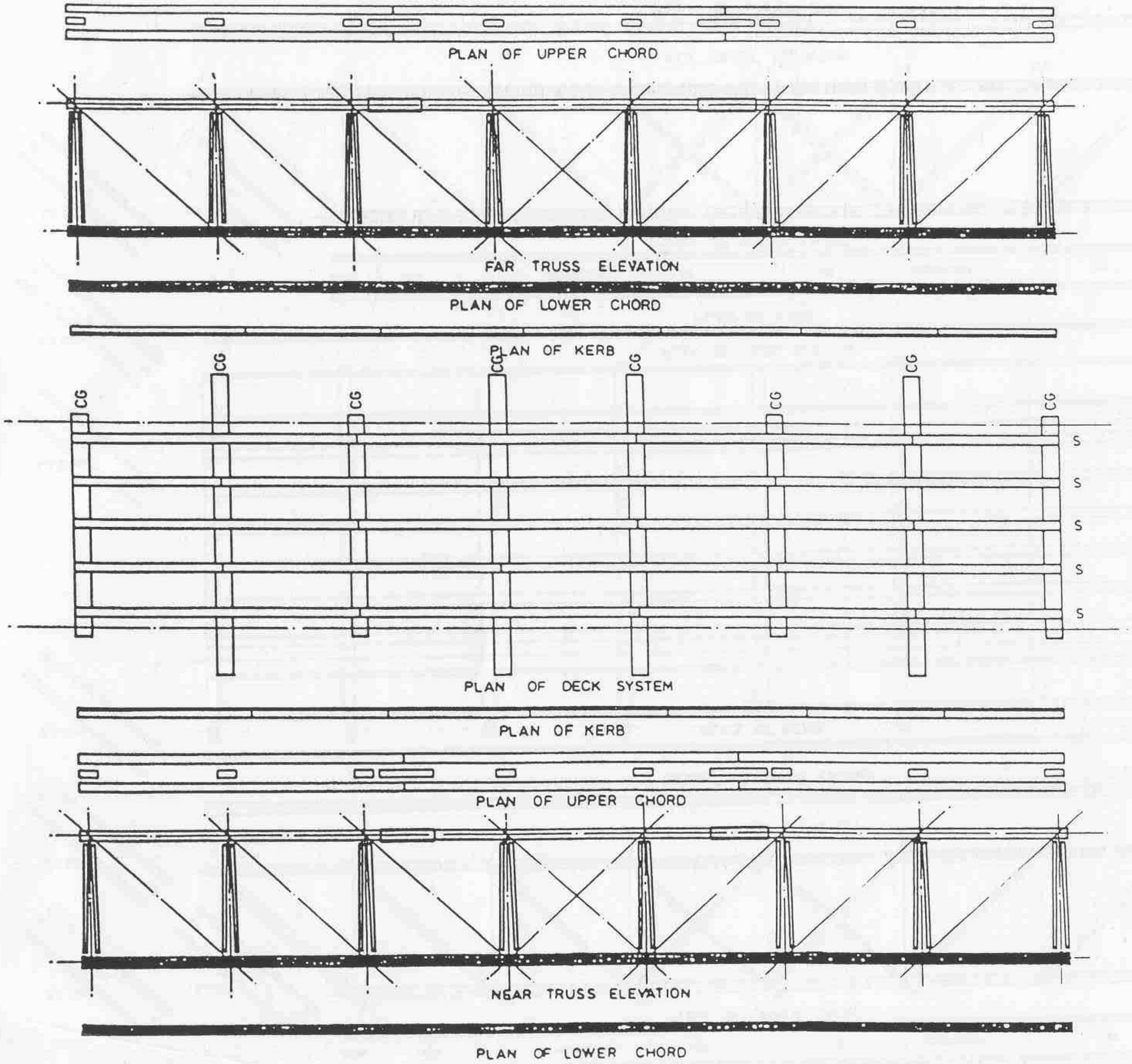


Figure 22.

27·73m DE BURGH TRUSS SPAN

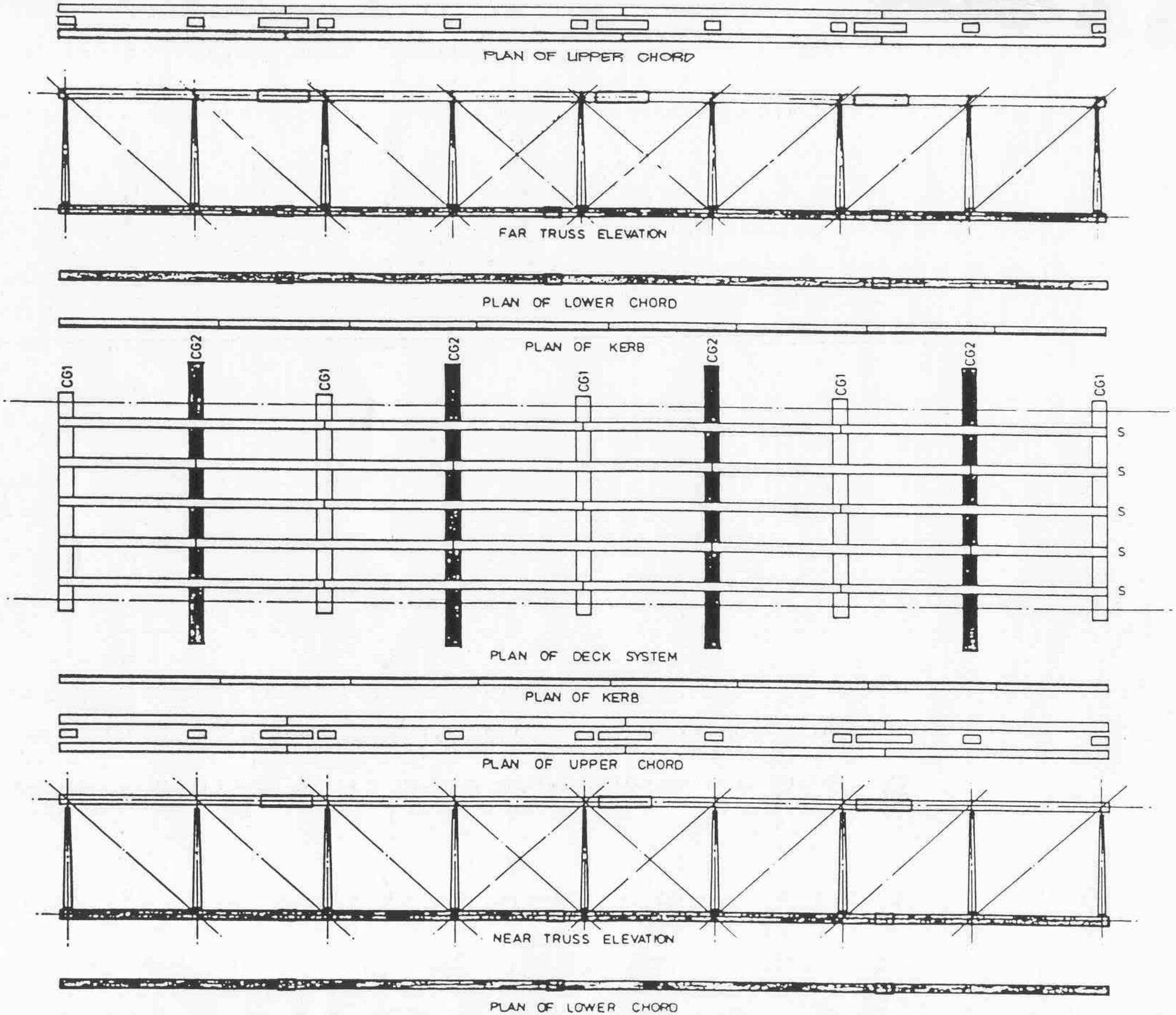


Figure 23.

31·70m DE BURGH TRUSS SPAN

APPENDIX D

EXTRACT FROM MANUAL NO. 6 – BRIDGE MAINTENANCE

REPAIR OF TIMBER TRUSS BRIDGES

REPAIR OF TIMBER TRUSS BRIDGES.

(i) Scope

The following instructions apply to:-

1st (Truss A). The old form of "McDonald" truss constructed prior to 1886, having single principals, and single suspension bolts passing through the chords. Spans 60 to 100 feet.
2nd (Truss B). "McDonald". The double principal truss with double suspension bolts at haunches (not passing through the chords, but through links resting on the chords) and with wedges at feet of braces; in use after 1886. Spans 65, 75 and 90 feet.
3rd (Truss C). "Allan". The truss of "Howe" type introduced in 1894 having open top and bottom chords, double principals, braces parallel to principals – no wedges at feet of braces, and cross girders only at suspension bolts. Spans 70 and 90 feet.
4th (Truss D). "de Burgh". Introduced in 1899. Composite truss, with timber vertical struts and timber upper chord, steel lower chord, and wrought iron diagonal tie-rods.
5th (Truss E). "Allan". Introduced in 1904. Composite truss, with timber upper chord and diagonal struts, steel lower chord, and wrought iron vertical tie-rods.

(ii) General

The requirements of clause 8 (a) of this Manual apply equally to timbers in Truss bridges.

All bolts in the piers are to be kept screwed up, additional washers being used if necessary. If the timber in any portion of the bridge has shrunk so much as to render 1 ½ in. of washers necessary, the bolt is to be removed and replaced by a shorter bolt, the old bolt being kept for use elsewhere. The unsightly practice of using wooden packing pieces as washers in not to be adopted except as an emergency measure. Where the struts in piers have shrunk so as to cease to butt at the ends, hardwood or iron wedges in pairs are to be driven from opposite sides, so as to bring the strut into operation again.

The suspension bolts in the older trusses being lighter than those now in use, and not having so good a bearing on the chords and principals, may be unequal to the task of restoring the camber to the truss. In screwing up, therefore, shores should be placed under the chord, which can then be wedged up while the suspension bolt is tightened. If the bolts are damaged they are to be replaced by new bolts 25 per cent heavier.

If the height from the bed of the river is so considerable as to make shoring a troublesome and expensive operation, a chain may be passes round the chords set up with union screws or a pair of bolts used similar to the haunch bolts in the "B" type of truss, so as to relieve the suspension rod while it is being tightened. Shoring is preferred. In the older designs of truss bridges no iron wedges were used at the foot of diagonal members. In screwing up, hardwood wedges or iron plates are to be used to fill the space left by Shrinkage.

The method of screwing up certain of these types of timber truss bridges is shown in the clauses, which follow.

(iii) Truss Type "A"

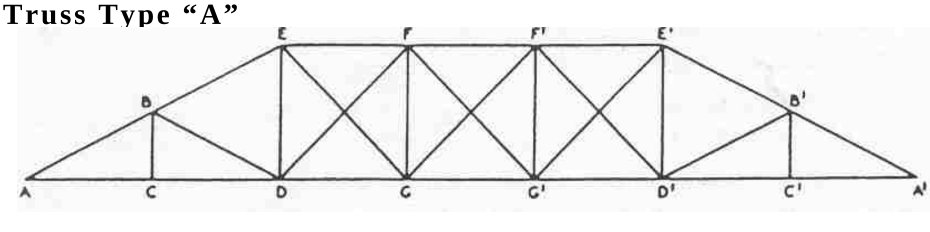


Fig 1

At the junction (see Figure 1) E or E^1 of the top chord EE^1 and principals AE and A^1E^1, the shoulder shoes are in most cases fitted with wrought-iron washer plates, through which the suspension bolts pass. As the timber in top chord shrinks from under them these plates become bent, in some cases breaking the cast-iron shoulder shoe. The surface of the washer plate being no longer level, nor at right angles to the suspension bolt, the plate acts as a washer on the cant, and bends the suspension bolt under the nut. Tending to break it off. The weight should be taken off the suspension bolt either by shoring or by using a temporary suspension (as described above). The bent washer plate should then be cut through with a cold set where it joins the shoulder shoe. This will permit it to drop on to the top chord where it will lie level. The cutting should be carefully done, a heavy hammer being held at offside of plate to lessen the jar during operation. The nuts at the ends of the suspension bolts below the bottom chord should then be slackened off an inch or two, and those above tightened until the upper nuts are filled with new thread from below. It may be found necessary to drift the bolt up with a heavy hammer from below, but generally, screwing at top will be found sufficient. All bolts in butting blocks, chords, cross girders, etc., should be kept screwed up; but the suspension bolts and the iron wedges at ends of struts should not be touched unless a loss of camber is observed.

In every other respect the operation of restoring camber is similar to that detailed below for the "B" type of truss.

In the even of iron wedges becoming loose they should be lightly driven by the man in charge; but the operation of restoring the camber to the truss should not be undertaken without the express approval of the Divisional Engineer.

(iv) Truss Type "B"

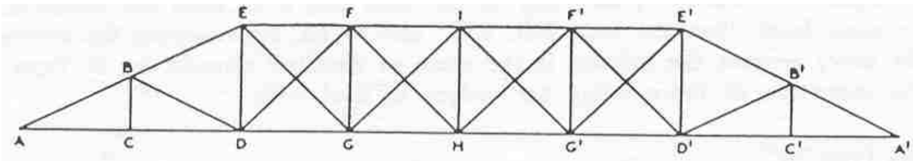


Fig 2

Figure 2 represents a 90-ft. truss; but the following instructions are also applicable to 75 and 65 feet trusses.

The camber in each truss should be 2 in. in the 90 feet 1¾ in. in the 75 feet, and 1½ in. in the 65 feet truss when first erected, and the chords should never be allowed to approach a straight line.

Having ascertained that the point D is low, the bolts connecting the tee iron stiffener (which runs from end of cross girder at D to top chord at E) should be removed, as it is evident that the bottom chord cannot be taken up so long as those bolts remain in. The wedges at the feet of the members BD, DF should be examined and, if not already loose, may be loosened with a hammer; the suspension bolt DE should then be tightened until slightly more than the necessary camber is obtained at point D.

If the point D^1 is low, the same operation is gone through with the suspension D^1E^1, and the members B^1D^1, D^1F^1.

The correct level having been thus obtained at points D and D^1, the wedges at the feet of members DF, D^1 should be driven up solid until any sag in the top chord at point F and F^1 is removed.

Levels should now be taken at points G and G^1. If the point G^1 is low, the wedges at the feet of members G^1E^1, G^1I must be loosened, and the suspension bolt G^1F^1 tightened until the necessary camber is obtained at point G^1. In the same way if point G is low. The wedges at the feet of, members GE, GI must be loosened and the suspension bolt GF tightened until the necessary camber is obtained at point G.

The above operations with regard to points G and G^1 should, if both points are low, be performed simultaneously.

The wedges at the feet of members G^1I, GI should now be driven up solid, until any sag in the top chord at point I is removed.

If the point H is found to be still low, the wedges at the feet of members, HF, HF^1 should be loosened and the suspension rod HI tightened until the necessary camber is obtained at point H.

The wedges at the feet of members GE, G^1E^l should now be driven up solid; then those at the feet of members HF, HF^l and then those at the feet of members DB, D^lB^l.

There should now be no sag in the top chord, and not more than ½ in. camber between the points E and E^l.

A line should be stretched along the principals AE, A^1E^l and the struts DB, D^1B^l should be wedged up until the principals have an upwards camber of ¼ in.

Levels should now be taken at points C and C^l and the correct height obtained at those points by tightening the suspension bolts CB, C^1B^l.

A final observation may now be taken of the levels of the various points along the chord; and if the camber is correct the locknuts of suspension bolts may be finally tightened, and the bolts in butting blocks looked to, and the operation is complete.

No staging is required to support the truss during the operation.

(v) Truss Type "C"

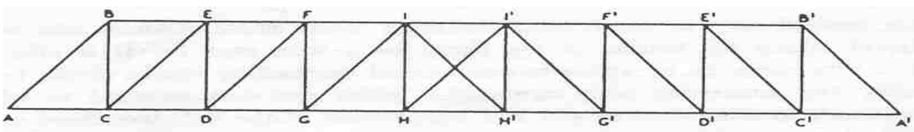


Fig 3

The main points of difference between this truss and Trusses A and B are the double chords separated only by packing pieces at intervals, the absence of wedges at feet or braces, the fact that the braces are parallel and that there are no cross girders resting upon the chords excepting where suspension bolts occur .

The absence of wedges at foot of braces in the type now under consideration makes the task of screwing up much easier.

The camber at each point of truss is shown on drawing of bridges, and is to be obtained from the Divisional Engineer before screwing up.

Levels having been taken at each cross girder on lower chord A to A^l (see Fig. 3) , the camber is restored by screwing up the bolts BC, B^lC^l until the points C and C^l are at correct level, then the bolts ED, E^1D^l and so on, approaching the centre of the truss. In every respect the process is the same as detailed already for B Type Trusses with the exception of there being no wedges to deal with.

(vi) Truss Type "D"

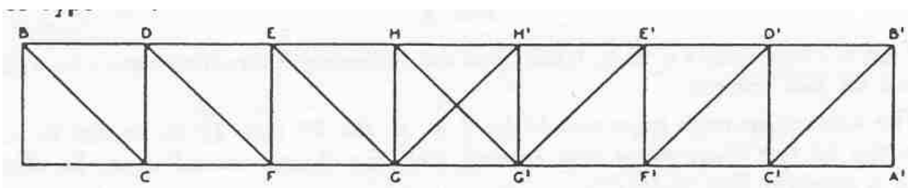


Fig 4

(vii) Truss Type "E"

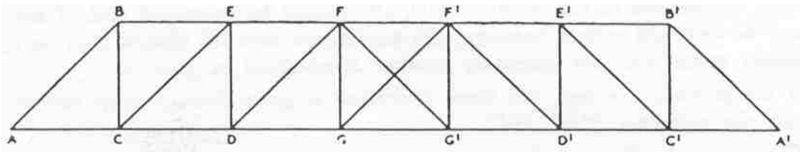


Fig 5

In types D and E the method of restoring camber is the same as for Truss C, the tie-rods at the haunches being the first to screw up, working thence towards the centre.

In cases where more than one suspension rod is used at each panel point, care should be exercised to have each rod take its share of the load.

METHODS OF SUPPORTING TIMBER TRUSSES DURING REPLACEMENT OF MEMBERS.

(i) Choice of Methods.

During replacement of truss members, it is necessary to have support under the lower chord at various positions. The most convenient and economical of the methods of support described hereunder are to be used, or other suitable methods approved by the engineer .

(ii) Underpinning.

Where practicable, "shoring" or "tomming" from the ground is the easiest method of supporting trusses when replacing top chords and principals. In its simplest form, it consists of one or more toms supporting crossheads under the lower chord, the necessary adjustment of height being obtained by means of fox wedges at the base. The toms can be erected on driven or silled foundations as occasion demands. Replacement girders or similar members can frequently be used as crossheads; if such are not available, bush timber can often be obtained.

In some cases vertical toms cannot be used on account of a water crossing or too great a clearance above ground. Diagonal struts from the bases of the piers may sometimes be employed, but care should be taken in this case to check the stability of the piers. Such struts should generally not be taken from the piers above ground line unless the piers are of very substantial design or are provided with adequate lateral support.

(iii) Wire Rope Tie.

This method may be used when replacing lower chord flitches, and consists, essentially, of taking the tension in the chord by a wire rope tie. It is effected by passing two wire ropes 2 3/8 in. circumference around the butting blocks of the truss, or the cap-sills, and connecting with turnbuckles which are then adjusted to take the tension necessary to allow the removal and replacement of the defective chord member. Sketch "B" shows one method of attaching the ropes.

(iv) Wire Rope Support.

A typical arrangement of this method is shown in sketch "C". It is an alternative to underpinning, and is specially useful over water, or where the truss is high above ground.

The anchorages should be placed at suitable distances from the hardwood posts at or below ground level. In pile piers, where the piles have been spliced, the anchorage bearers should be placed below the splice. Struts should be inserted between the bearers and the bridge to prevent their being pulled upward. For effective use of the turnbuckles, the free ends of the wire rope should be pulled back by tackle or hand winch before securing with wire cramps.

(v) Temporary Undertrussing.

This is similar to the "Wire Rope Tie" method, and a typical arrangement is shown in sketch "D" for McDonald type trusses. Care should be taken that the trussing blocks on the bottom chord are so placed as to permit the removal and replacement of the defective chord section.

(vi) Additional Temporar;y Truss.

In this method, the load of the bridge is temporarily transferred to a temporary truss erected alongside the truss to be repaired. Sketch "E" shows how a Bailey truss was used at Jindabyne during repairs to the lower chord of a McDonald truss. In this case the cross girders were hung from the Bailey truss to take their load off the lower chord of the bridge truss and the top chord and bracing was propped off the cross girders. There was no interruption to traffic during the period of the repairs.

(vii) Precautions to be Taken in All Cases.

When a truss is temporarily supported during repairs, traffic should be confined to the side of the span remote from the truss under support, and its speed should be reduced to walking pace. Because of this, and for general safety, the time of temporary support should be reduced to a minimum. This can be facilitated by doing all possible work on replacement members before releasing the existing members.

Old ferry ropes are suitable for use where wire ropes are indicated. Such rope is usually 2¾ inches circumference of 6 x 7 galvanised steel wire. One turn will safely carry a live load of four to five tons. Should heavier vehicles commonly use the bridge under repair, a second rope should be provided.

It is essential that wire ropes slip round all supports freely. Accordingly, bearers should be shaped, grooved and well greased. Vibrating the ropes also assists them to slip.

Theoretical determination of the stress in a rope, from observations of sag and vibrations, is not reliable owing to give in timbers and like factors. If slipping of the ropes on all bearers has been made as free as possible, tightening of the tensioning turnbuckles or nuts, to the capacity of an average man using a spanner with a 2-ft. purchase, will stress the ropes to their safe load.

REPLACEMENT OF MEMBERS OF TIMBER TRUSSES.

Where the chord members of a truss are made up of two or more flitches, replacements can often be made, one flitch at a time, without temporary external support for the truss. However, unduly heavy live loads cannot be allowed on the bridge during the time of repairs, and in any case, moving loads must be restricted to a walking pace on the side of the bridge remote from the truss under repair.

When all flitches in one section of a chord are in very bad order, or the chord is in one piece, support for the truss during replacement is necessary.

Where the whole length of a flitch is in bad condition and has to be replaced it will probably be impracticable to obtain new flitches long enough to retain the existing joint arrangement and extra joints will be required. The maximum length obtainable without undue difficulty can be assumed as 30 ft. As the new arrangement of joints will depend on the location and extent of deterioration in the existing timber, a sketch should be prepared of the proposed arrangement and forwarded to Head Office for checking well in advance of the commencement of the repair work.

The replacement of diagonal member does not necessitate external support for the truss.

Various methods of support which have been successfully used are described in Section 10.

Whenever repairs have been made on a truss, proper tightening up is to be carried out and camber restored as detailed in Section 9.

The following describes the precautions which need be observed in carrying out replacement of members and other repairs to timber trusses.

Truss Type "A" – (McDonald Truss, Early Type).

(i) *To remove principal* – Solid Member AE or A^1E^1

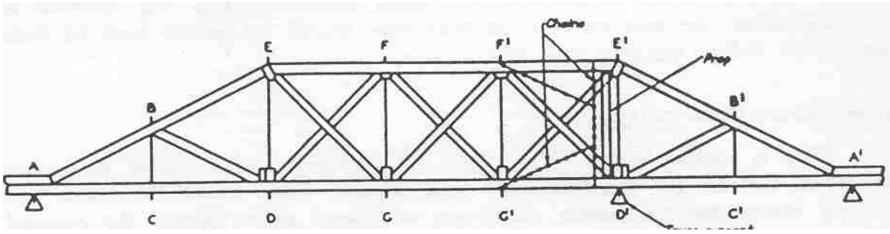


Fig 6

(a) Place prop between top and bottom chords near panel point D^1.

(b) Tie together top and bottom chords with chain and union.

(c) Tie diagonals E^1G^1 and D^1F^1 to top and bottom chords respectively with chains so that "free" ends cannot slip.

(d) Support truss under panel point D^1.

(e) Place prop between top chord and kerb on opposite side of bridge.

(f) Remove and replace principal A^1E^1.

(g) Dismantle in order (e), (c), (b), (a) and (d).

(ii) *To splice portion of principal.*

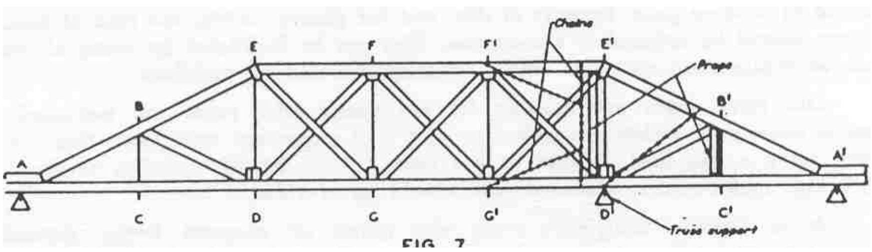


Fig 7

(a) *(b), (c), (d)* and *(e)* as above.

(f) Prop solid portion from lower chord.

(g) Remove and replace defective part.

(h) Dismantle *(f), (e), (c), (b), (a)* and *(d)*.

(iii) *To remove a dia8onal - For example, member FG1.*

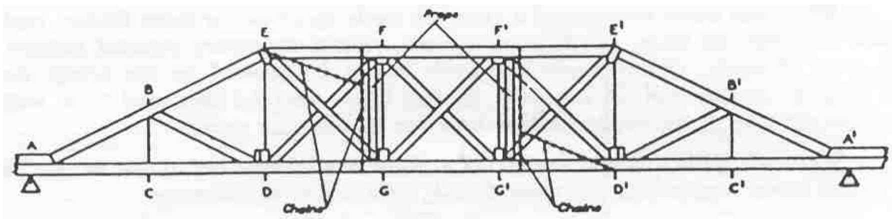


Fig 8

(a) Place props between top and bottom chords at panel points G and G^1.

(b) Tie top and bottom chords together with chain and unions.

(c) Tie braces in adjacent panels, i.e., members DF and G^1E^1 to top and bottom chords respectively, with chains to prevent slip.

(d) Remove and replace diagonal.

(e) Dismantle *(c)*, *(b)*, *(a)*.

(iv) *To remove top chord*

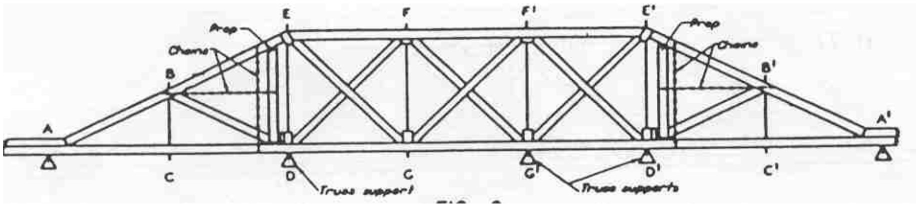


Fig 9

(a) Place props between tops of principals and lower chord at panel points D and D^1 and securely tie with chains and union screws to ends of truss, say panel points Band B^1.

(b) Tie tops of principals to lower chord with chains and unions.

(c) Support bottom chord at panel points D and Dl and alternate ones.

(d) Place props between tops of principals and kerb on opposite side of bridge.

(e) Tie tops of principals across bridge.

(f) Brace all diagonals to maintain alignment.

(g) Remove and replace top chord.

(h) Dismantle in order *(f)*, *(e)*, *(d)*, *(b)*, *(a)* and *(c)*.

(v) *To remove outside flitch in lower chord* – For example flitch in panel GG1.

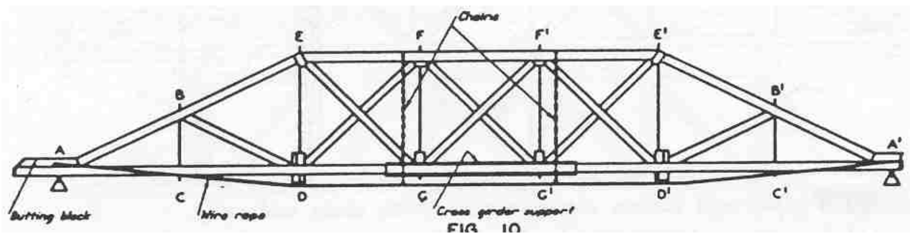


Fig 10

(a) Support cross girders and deck by chain from top chord over faulty section.

(b) Tie bottom ends of principals around butting blocks with wire rope and union to take tension off lower chord.

(c) Remove and replace flitch.

(d) Dismantle *(a)* and *(b)*.

(vi) *To remove inside flitch of lower chord.*

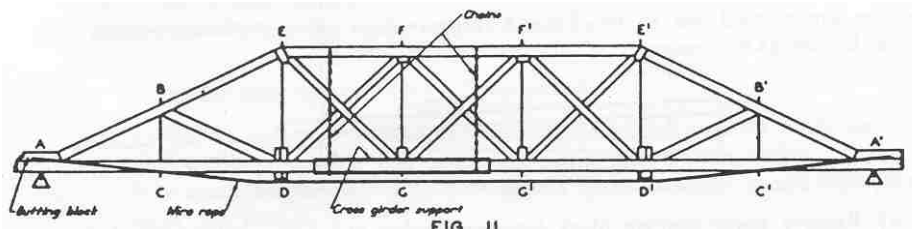


Fig 11

(a) Tie ends of truss with wire rope and unions to take tension out of lower chord.

(b) Replace bearing plate at lower end of double suspension rods by separate plates having gap between them sufficient for the defective flitch to drop through. Tie suspension rods together immediately above lower chord to prevent their spreading.

(c) Remove deck load from faulty part of chord by placing girder under cross girder and supporting from top chord by chains and unions.

(d) Loosen and drive splicing bolts in lower chord from faulty flitch but not free from other flitches. Wedge flitches apart, drop out faulty flitch and replace, using new splicing bolts and plugging up old holes.

(e) Replace original bearing plates under suspension bolts.

(f) Dismantle *(c)* and *(a)*.

(vii) *To remove a cross girder* – for example girder at G.

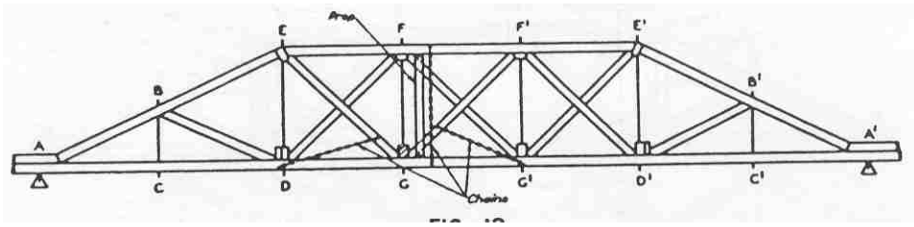


Fig 12

(a) Place prop between top and bottom chords near panel point G.

(b) Tie top and bottom chords together with chain and union near same panel point.

(c) Tie diagonals butting against girder (i.e., EG and GF[1]) to lower chord.

(d) Take out suspension rod.

(e) Remove and replace cross girder.

(f) Replace suspension rod.

(g) Dismantle in order *(c)*, *(b)* and *(a)*.

(viii) *To remove butting block*

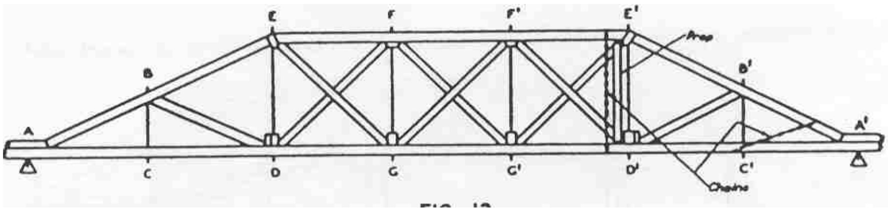


Fig 13

(a) Place prop between top and bottom chords at panel point D.

(b) Tie top and bottom chords together with chain and union.

(c) Tie principal to lower chord with chain and union to prevent slip of "free" end.

(d) Remove and replace faulty portion of butting block.

(e) Dismantle in order *(c)*, *(b)*, *(a)*.

Truss Type "B" – (McDonald Truss, Late Type).

Repairs are carried out as for Type A except when replacing section oly at bottom of a principal.

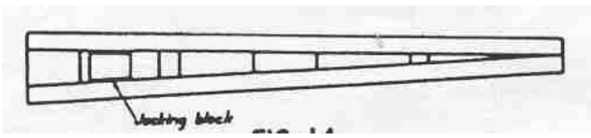


Fig 14

(a) Remove lower spacing block between flitches and bolt a new piece of timber in between to sound portion leaving room for jack between lower end and butting block.

(b) Jack up end of truss to free timber from butting block.

(c) Cut off faulty portions of members and replace with new timber.

(d) Release jack, remove central temporary piece and replace original spacing block.

Truss Type "C" – Allan Truss (Howe Type)

(i) ***To remove principal –*** for example, member A^1B^1

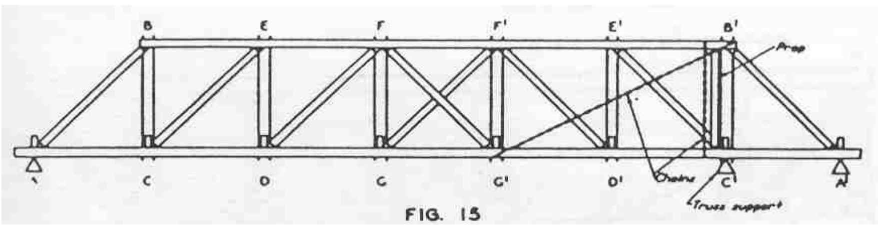


Fig 15

(a) Place prop between top and bottom chords at C^1B^1.

(b) Tie top and bottom chords together with chain and union at C^1B^1.

(c) Tie top chord (at B^1) back with chain and union to lower chord.

(d) Support truss under low chord at C^1.

(e) Place prop from top chord to kerb on opposite side of bridge.

(f) Tie top chords across bridge.

(g) Remove and replace principal.

(h) Dismantle (*f*), (*e*), (*c*), (*b*), (*a*) and (*d*).

(ii) *To splice portion of principal –*

Lower end

(a) Remove spacing blocks between flitches and bolt a long piece of new timber to flitches above faulty section.

(b) Jack up truss to free ends of flitches from butting blocks.

(c) Cut off faulty sections, one side at a time and splice on new pieces.

(d) Release jack and remove temporary spacer.

(e) Replace spacing blocks to original design.

Top end – Proceed similarly to jacking between new timber and top chord.

(iii) *To remove whole of top chord.*

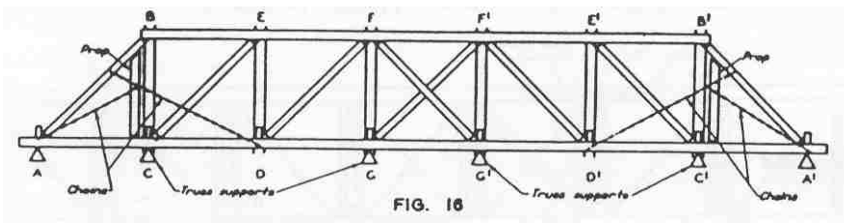


Fig 16

(a) Support truss under lower chord at first and last panel points (i.e., C and C^1) and every alternate intervening panel point. The stiffness of the lower chord will hold the intervening panel points.

(b) Place props between tops of principals and lower chord, and tie props to butting blocks.

(c) Tie principals to lower chord.

(d) Place props between tops of principals and kerbs on opposite side of deck or against check blocks attached to deck.

(e) Tie tops of principals across bridge to prevent overturning.

(f) Brace diagonals longitudinally to maintain alignment.

(g) Remove and replace chord.

(h) Dismantle (*f*), (*e*), (*d*), (*c*), (*b*) and (*a*).

(iv) *To remove part of one flitch of top chord.*

(a) If life is only to be extended five to six years, unstress flitch by placing new timber alongside and bolting to sound part of old timber.

If a short length only is to be removed from otherwise sound truss proceed as in (*a*), then –

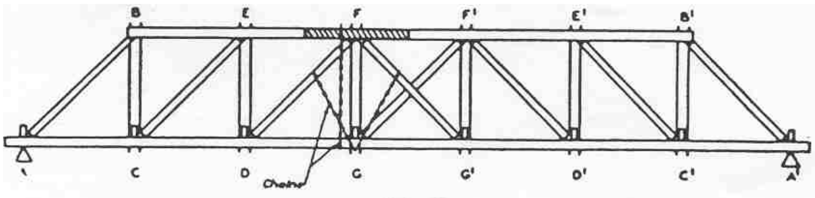


Fig 17

(b) Tie together top and bottom chords with chains and unions, using wooden blocks to give clearance to slide in new piece.

(c) Tie back diagonals to top and bottom chords.

(d) Remove suspension rods.

(e) Remove and replace faulty timber.

(f) Replace suspension rods and dismantle (*c*), (*b*), (*a*).

Truss Type "D" – de Burgh Truss (Pratt Type) (Through Truss only).

(i) *To remove whole of top chord*

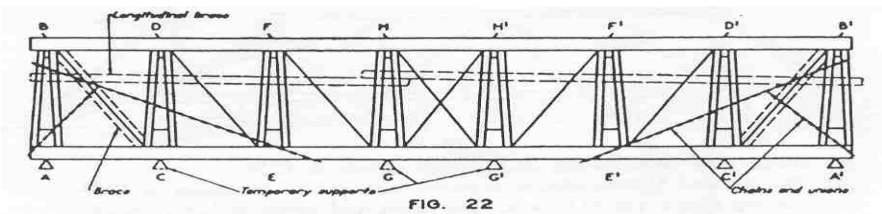


Fig 22

(a) Support truss under lower chord at first and last panel points (i.e. C and C^1) and every alternate intervening panel point. The stiffness of the lower chord will hold the intervening panel points.

(b) Brace top of end verticals from foot of adjacent verticals and tie brace back to ends of truss at A and A^1.

(c) Tie end verticals to lower chord at E and E^1.

(d) Place props between tops of end verticals and kerbs on opposite side of deck or against deck blocks attached to deck.

(e) Tie tops of end verticals across bridge or to check blocks to prevent over- turning.

(f) Brace verticals longitudinally to maintain alignment.

(g) Remove and replace chord doing each flitch in turn between splices. Tee iron braces should also be removed and replaced in turn to help maintain alignment.

(h) Dismantle (*f*), (*e*), (*d*), (*c*), (*b*) and (*a*).

(ii) *To remove part or whole of one flitch of top chord.*

Where a complete flitch is to be removed support truss at lower chord panel points under length of flitch to be removed.

Where a short length is to be removed proceed as follows:-

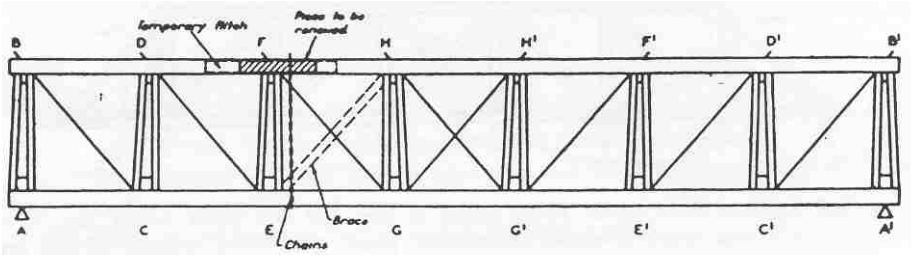


Fig 23

(a) Place temporary timber flitch alongside portion of flitch to be removed and bolt to sound limber beyond. (Where this is not possible, e.g., for portion of flitch commencing from B or B^1 support truss at lower chord panel points under portion of flitch to be removed.)

(b) Tie top and bottom chords together with chains and unions using timber blocks to give clearance to slide in new piece.

(c) Where necessary to slacken off diagonals to remove portion of flitch, brace panels in opposite direction to diagonals.

(d) Remove and replace faulty section of flitch.

(e) Dismantle (*c*), (*b*) and (a).