DEVELOPMENT AND APPLICATION OF STRESS LAMINATED TIMBER BRIDGE DECKS IN AUSTRALIA

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SUMMARY

Since that 1990, a major research and development program has been undertaken at the University of Technology, Sydney (UTS), which has successfully established Stress Laminated Timber (SLT) bridge deck Technology in Australia, resulting in the construction of some 40 prototype bridges nation wide. This R & D program has linked laboratory testing with field application and has lead to development of limit states design procedures, construction and maintenance specifications and training courses for Engineers and construction personnel.

This paper presents an overview of both the R & D programs and applications of stress laminated timber technology in Australia, with an emphasis on the implications of “built-up” technology for timber bridges with spans exceeding 9m. Work undertaken to date indicates that this new technology is structurally efficient and economically viable and has resulted in the construction of several prototype bridges which will presented as case studies.

INTRODUCTION

Australia, like many other countries today suffers from the problem of an ageing infrastructure, with state road and local government Authorities now facing the consequences of many years of inadequate maintenance funding for transport infrastructure, particularly bridges. Many of these bridges were built in the late 1800’s and the early 1930’s, using native hardwood timbers, which are strong, durable and were at the time of construction, in relatively abundant supply.

On the East Coast of mainland Australia there are an estimated 10000 timber bridges having spans greater than 6m, with about 80% of these under the control of local councils. Whilst routine maintenance of these bridges has been undertaken, it has often been inadequately funded. Most of these are over 60 years old and were designed for loads of 18 tonnes, compared with the 44 tonne design load now required. The prevailing attitude amongst Engineers towards timber bridges has been one of “patch and replace”. This attitude has been further compounded by ignorance and distrust of timber, due to lack of formal education in Timber Engineering design. Timber has been generally perceived as a “temporary” and unreliable material - despite the fact that most of these timber bridges have performed satisfactorily for well over 60 years!

The reality of this problem was finally acknowledged in the late 1980’s when state road authorities recognised and faced the following facts:

1. the replacement rate of timber bridges was (and still is) about 1% to 2% per annum.
2. the introduction of compulsory asset maintenance systems meant that the timber bridges asset had to be valued. The current value of timber bridges in the eastern states is about $10 billion! Even if this was logistically possible, the cost is prohibitive.
3. the low rate and high cost of replacement means that even if funds were available to replace all timber bridges, most of these will still need to be in service for another 40 to 50 years.

Thus the need to maintain and rehabilitate the existing bridge asset is both pressing and urgent. Stress laminated timber decks are perceived by Engineers from State Road Authorities as one possible solution for addressing this problem of extending the life and / or upgrading the load carrying capacity of existing timber bridges. It is also arguable that SLT represents the most efficient and environmentally sustainable technology for rehabilitation and upgrading of the nation’s timber bridge asset.

BENEFITS OF SLT DECK SYSTEMS

The significance of stress laminated timber plate bridge decks as an alternative technology for the refurbishment of short-span bridges derives from a number of factors, which include the following:

(i) Frequently, defective decks can be replaced by considerably lighter prefabricated SLT decks on existing substructures. The reduced dead loads provide for increased live-load capacities.

(ii) the use of engineered timber products produced under controlled conditions results in a significant increase in structural reliability

(iii) SLT decks can be constructed from sizes and lengths of timber commercially available from softwood plantations or re-growth hardwood forests,

(iv) The structural integrity, durability and serviceability of SLT decks far exceed the corresponding qualities of conventional timber construction,

(v) With appropriate construction procedures the use of SLT decks can minimise the duration of road closures and the need for traffic diversions,

(vi) significant cost benefits can be derived using this system, with total replacement costs of SLT decks typically being about 60% - 75% of the cost of an equivalent replacement in steel or concrete.

3 R&D Program for Plate Decks

In order for such new technology to gain acceptance, a thorough research and development testing program was considered necessary, in order to characterise the structural performance of SLT decks using Australian timber species and provide a technical undergirding of design procedures.

3.1 Background

In an effort to avoid "re-inventing the wheel", the R&D program has focused on a "technology transfer" of the current state of the art from overseas into an Australian context. The R&D testing commenced at the University of Technology, Sydney (UTS) in 1990 and has continued until 1998.

Up to 1995, this work was funded by a consortium of joint venture stakeholders, with about 75% of the total $2.5 million spent on the project coming from the NSW state government road authority and the remaining 25% being provided from Forestry and timber industry sources. Since 1995, an additional $0.6 million has been made available through a collaborative Australian Research Council grant for the development of longer spanning systems, other than plate decks.

This consortium comprised the RTA, State Forests of New South Wales, Pine Australia, the University of Technology, Sydney (UTS) and, in the initial stages (from 1990 to 1992), Western Woods Products Association through the "AUSTIM 90" bridge initiative program.

3.2 Scope of Project

At the outset of the Australian SLT initiative, strategic objectives were defined which established the scope, basic direction and desired outcomes of the project. These objectives related to a number of stages encompassing the following:

1. technology transfer from North America and Europe
2. definition, specification of testing procedures and undertaking laboratory testing
3. analysis, interpretation and reporting of test results
4. field implementation through construction and monitoring of demonstration prototype bridges
5. implementation through preparation of design, construction and maintenance documentation for SLT bridges, coupled with appropriate education and training programs
6. development of new construction methods and techniques
7. research and development of SLT systems other than plate decks, suitable for longer spanning applications

The fundamental purpose of this project has been to develop a reliability based, 'engineered system' for timber bridge decks, which would be accepted and used by structural engineers in both the public and private sectors. At the outset, it was recognised that the technology should be applicable to both new and replacement bridge decks, conforming with AUSTROADS and Standards Australia bridge design codes, for use by both State and local government authorities.

3.3 Testing Program

The testing program for plate decks commenced in 1990 and has included testing of kiln dried hardwoods, Australian Pine (mainly radiata), LVL (made from Radiata pine laminates) and imported Douglas Fir. The Douglas Fir testing had particular importance, as it provided a means of correlation with results from the North American testing programs. This work encompassed the following:

Component Testing:

- "Ingrade" determination and verification of characteristic strength properties for MoR and MoE from both four point bending and non destructive testing methods.
- Interlaminate shear behaviour.
- Compression perpendicular to face grain tests.
- Creep and moisture effects (focusing on prestress losses) and the interaction of mechano-sorptive effects on stress laminated timber decks.

Partial Deck Testing:

- Serviceability testing of large scale (either half sized and full sized) single lane width decks in the laboratory at UTS. The purpose of these tests has been to quantify the general serviceability performance and confirm the orthotropic plate properties, which have then been used in the development and correlation of analytical models.
- Comparative studies of effective plate stiffness (in the longitudinal direction) for both static and dynamic loads have been undertaken as a part of this serviceability testing.

- Additional tests (under laboratory conditions) to investigate dynamic response effects, natural frequency vibration and dampening effects, as well as fatigue and cyclic load responses. These have quantified load history effects of SLT decks and confirmed that the effects of accelerated cyclic loading and fatigue on structural performance and material properties are negligible.

Orthotropic Plate Testing:

- Unlike similar tests undertaken in North America, the UTS tests were specifically set up on large scale plates (typically 3.6 x 3.6 metres square).
- The results of these tests were used to derive the transverse stiffness, overall longitudinal stiffness of the laminate system and the shear modulus properties of orthotropic plates made from hardwood, Radiata Pine and Douglas Fir.

Ultimate Load Tests:

- Ultimate load tests of two full scale, single lane decks under laboratory conditions, have been reported elsewhere [1]. These tests were undertaken in order to obtain further serviceability data for a variety of loading conditions (for use in determination of expressions for distribution widths), prior to being loaded to destruction using a single wheel path with a T44 standard axle configuration about midspan.
- By testing to destruction, not only was it possible to quantify the ultimate strength of these types of decks, but also the failure mechanisms associated with the ultimate strength limit state were identified.
- This provided some unexpected benefits, for not only do SLT decks satisfy the AUSTROADS serviceability and ultimate design limit states, the post critical behaviour of the stress laminated deck once failure is deemed to have occurred, demonstrated that the residual load carrying capacity of these decks is quite extraordinary.
- Both decks tested were observed to carry in excess of three times the basic serviceability load after "failure" had occurred, due in part to the inherent ability of an SLT deck to redistribute load around areas of localised failure.

Effects of Treatment & Surface Finish:

- The issues of in-service durability and long-term performance have also been investigated. Moisture submergence tests and comparisons of various appropriate protective systems and treatment systems have been undertaken at UTS in order to quantify moisture susceptibility and dimensional stability of softwood and hardwood laminates.

4 FIELD APPLICATIONS

All parties involved in this project recognised the importance of linking laboratory development with field implementation and monitoring and because of this fact, the latter has been an integral part of the R&D project. This has essentially focused on a number of plate decks that have been put into service throughout Australia.

4.1 Prototype Bridges

The first prototype bridge in Australia was the Eltham bridge in Victoria, opened November 1991, followed in December 1991 by construction of the first hardwood deck, over Yarramundi Lagoon at Agnes Banks on a rural link road west of Sydney. These bridges have been very successful prototypes and have paved the way for construction of numerous other prototype bridges over the past six years [2].

Since these two early initiatives, some 40 bridges have been built in Australia. Details of the first prototype bridges and the associated research and development work have been reported elsewhere [3] Monitoring and load testing of many these bridges is being undertaken as a part of a continuing R & D program.

Clearly, stress laminated timber for use in plate bridge decks is an established technology in Australia - particularly with the completion of design procedures and associated documentation [4].

4.2 The Need for Longer Spanning Decks

Subsequent full scale laboratory testing has validated the stress laminated concept for simple plate structures spanning up to about 9 metres. Design, construction and maintenance procedures have now been developed, establishing the general use of this technology in Australia. The first limit states design code and commentary for plate decks was published in 1995 [4].

However, it has been found both in Australia and overseas, that the application of stress laminated orthotropic plate decks are limited to bridges of up to about 9m span. Approximately 60% of timber bridges in Australia exceed this span limit and as such, a definite need exists to construct spans in the 11m to 15m range, for the rehabilitation and maintenance of the existing timber bridge asset. Also, in some situations, there are considerable advantages in being able to reduce the number of pier supports by increasing the span of the deck superstructure.

5 R&D PROGRAM FOR “BUILT-UP” DECKS

In order to extend the useful application of SLT technology, a research initiative was commenced early in 1995 at UTS to undertake fundamental research and development of cellular bridge decks using stress laminated timber technology. This program complements and links with similar work on “T” and “box” beam decks undertaken in the United States at the Forest Products Laboratory (Madison) and the University of West Virginia, as a part of the USDA Timber bridge initiative [5].

These “built-up” decks utilise material which is readily available from the timber industry and for which reasonable quality assurance and reliability of material properties is available, making the material acceptable for use in timber bridge structures.

5.1 Project Description

The research work in Australia has been funded collaboratively by the Australian Research Council and industry. This R&D project has involved both full scale serviceability and ultimate load testing (up to 12.2m) as well as an examination and analytical investigation into fundamental behaviour of cellular and “T” beam structural forms constructed from timber elements. Several prototype bridge decks spanning up to 12.2m have been constructed and research is currently being completed to extend this technology to applications with clear spans of 25 to 30m.

The focus of Australian research for built-up decks has been the cellular deck. This deck form, whilst similar in concept to the box beam, essentially differs in that it uses more closely spaced and thinner web members, with the webs typically being made from LVL in thickness’ from 45 to 65mm and spaced at centres not exceeding 500mm. Additional research into load distribution of “T” beam decks has also been undertaken, but the majority of the research program has involved testing cellular decks.

Details of the cellular concept developed by the author and tested at the University of Technology, Sydney, are shown in figure 1. The test decks are full scale, single lane bridge decks, spanning up to 12.2m (40ft). These are almost identical to the four prototype bridges that have been constructed in Australia since 1994, details of which have been presented elsewhere [2]. The most recent of these structures has been shown to be very cost effective, despite the fact that the cellular technology is being currently used at the lower end of its potential span capacity. In all cases, the decks span up to 12m and are based on the 600mm deep prototype decks developed at UTS.

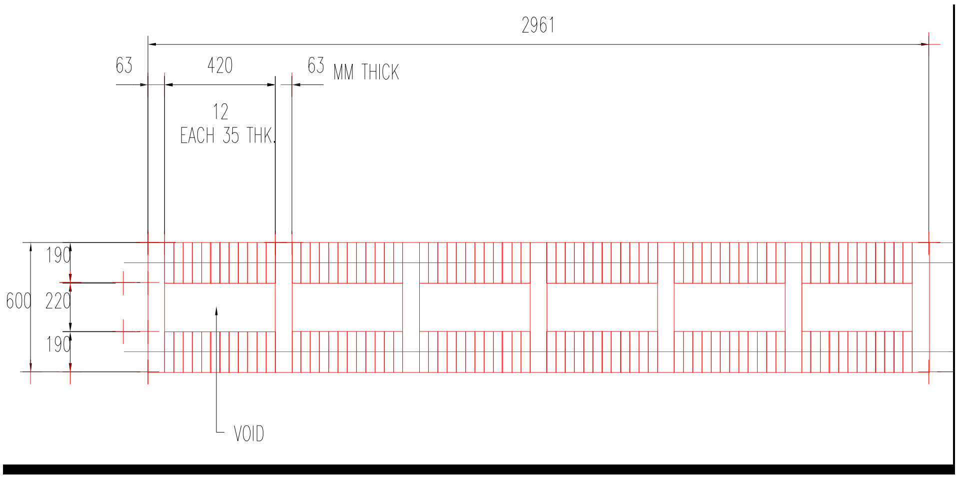

Figure 1 - Section detail of the UTS cellular deck, utilising Radiata pine flanges and pine LVL webs

5.2 Testing Program

A 2 year testing program on individual component cells was completed in 1998. The typical section geometry is shown in Figure 2, with depths of 600mm, 900mm and 1200mm and prestress levels of 1200, 1000, 700, and 500 kPa. Additional load tests have been undertaken on the 600mm deck for prestress levels of 300kPa (static loads) and 500 kPa for cyclic load tests. These series of tests not only characterise the material and component system behaviour for bending, shear, and torsion, but also focus on quantifying the slip interaction mechanism between web and flange laminates.

This slip mechanism is believed to be the critical limiting factor for effective serviceability structural performance and the cause non-linearity at high load levels for cellular sections. The same slip mechanism is believed to be the governing factor for the “T” beam bridges currently in use in North America and a series of “T” beam tests has also been completed as a part of the current R & D program at UTS.

The main set of component test cells (as shown in figure 2) have been manufactured using flange laminates which have been finger jointed to avoid the inclusion of butt joints, which were included in the full scale, single lane deck tests.

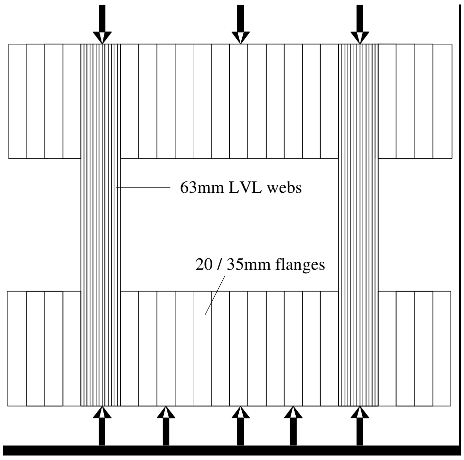

Figure 2 - Typical Section of cell component beam used in Component Tests.

Arrows indicate positions of vertical deflection measurements

This form of construction has been incorporated to deliberately remove the discontinuity effects of the butt joints and to directly relate slippage to the release of strain energy in the deck. In addition to the non butt jointed cells, three additional 600mm deep cells incorporating butt joints at patterns of 1 in 4, 1 in 3 and 1 in 2 have been tested to quantify the effects of butt joints on deck stiffness and the slip mechanism.

5.3 Discussion of Results

Test results from the 600mm deep deck indicate that a strong correlation exists between web to flange (horizontal) slip, the commencement of non-linear load deflection behaviour and the onset of any permanent deflection in the deck (vertical slip) after removal of the loads [6].

The prestress level has a marked effect on the "stiffness" of the deck and the commencement of the slip mechanisms discussed above. On the basis of the preliminary analysis of data obtained from the component tests for both cells and "T"s, it is strongly recommended that the prestress pressure in cellular decks should not be allowed to fall below 700kPa, with an absolute lower bound level of 500kPa. Below 500 kPa the structural behaviour of the deck changes markedly, both in terms of stiffness and ultimate strength. At 300 kPa, non linear behaviour can be observed as a result of interlaminate slip, at service loads.

The system behaviour of a cellular deck in "normal" prestress range is essentially linear elastic up to the design ULS T44 and abnormal vehicle load events. Interim design procedures for "built-up" decks, have been recently published in Australia [7]. These procedures are based on linear elastic behaviour with restrictions on minimum prestress levels and incorporate reliability provisions consistent with the new Timber Structures Code (AS1720.1 – 1997).

6 FIELD APPLICATIONS – LONGER SPAN BRIDGES

In most applications where spans greater than 9m occur the most cost effective solution will be a built-up section deck. However, where the deck is prone to flood inundation the use of a closed cell where water may be trapped in the cell void for an extended time after flooding has subsided.

Whilst this problem could be solved using a 'T' beam section, fundamental work on characterising the performance of this structural form is still being finalised and its use in Australia is still some time off. The tensile capacity of timber webs in T deck systems is normally significantly less than the compression flange, which results in material inefficiencies. Methods for overcoming this problem are the subject of another R&D project currently being at UTS [8].

For these reasons deep plate LVL decks have had and will continue to have some limited application in Australia. Glulam could also be used in these applications, although experience to date indicates that it is not as cost competitive as LVL.

6.1 Longer Span LVL Plate decks

The first deck constructed as a solid LVL plate was installed at McGrath's Flat Lagoon on a major arterial road to the north-west of Sydney during March 1994. This bridge has a span of 9.6 metres and is a solid LVL deck. The LVL has an overall depth of 400mm and is manufactured from Radiata Pine veneers and creosote treated after fabrication.

A similar deck has also been recently completed at Hortons Creek, on a secondary road about 5 km north of the McGrath's Flat site. Both decks are performing very well and are subject to ongoing monitoring.

Whilst a number of continuous plate decks have been designed using sawn timber, to date only one continuous deck has been constructed using LVL. The bridge over Cedar Party Creek at Wingham, NSW was originally constructed in 1896, consisting of eight (8) 10.8m spans and 4.6m between the kerbs. This was widened in 1989 to 6.3m between the kerbs to accommodate two traffic lanes, but Council was forced to revert this back to a single lane structure in 1993 due to deterioration of the superstructure.

A number of possible solutions were examined, including replacement with a new concrete structure, carrying out conventional repairs and rehabilitation using an SLT deck. The length of the spans would normally have dictated the use of a cellular deck, but because the site is flood prone, a 400mm deep continuous LVL plate was selected as the most viable option.

The stress laminated system was selected for the following reasons:

- significant cost savings over replacement. Including rehabilitation of the substructure, all oncosts, consultants fees and a by-pass road, the cost of the replacement was $0.9m, compared with estimates of $2m to $4m for a concrete alternative.

- significant time savings were achieved over the closure times required for both conventional repair methods and replacement. The final closure period was 6 weeks.
- the SLT deck is re-cyclable and can be disassembled and re-used when (or if) the bridge is replaced- noting that the design life of the new SLT deck is 50 to 100 years.

The previous bridge consisted of a hardwood girder bridge with corbels on a timber pile substructure. The bridge is heavily trafficked and takes a fairly high traffic load as a result of forestry activities to the west of Wingham and a number of local sawmills in the area as well as commercial and industrial activities in the surrounding hinterland.

The new Cedar Party Creek Bridge is continuous over eight spans with an overall length of 85 metres and has been widened to overall width of 8.0 metres. The rehabilitation involved removal of the existing corbels and capwales and replacement or repair of any substandard hardwood piles. Prefabricated 600mm deep LVL headstocks were then installed and anchored to the existing timber pile substructure.

The new deck was prefabricated about 10 km away in 7 sections, which were then transported to site, spliced together and progressively launched into place as a continuous 400mm deep LVL plate from the northern abutment.

This has provided a successful rehabilitation solution to an existing bridge, which was becoming unserviceable. The reconstruction also enabled the Council to widen the bridge by nearly 2m, thus increasing the safety for users of the bridge.

6.2 Cellular Decks

The specific application of cellular SLT decks in NSW arose from two unrelated rehabilitation problems that could not be solved using existing SLT plate deck technology. The first was an existing hardwood bridge at Pound Crossing in the Hunter Valley which had a central span of 12.2m. The second involved two existing concrete bridges in Greater Taree City Council, which had significant deterioration and spalling in their decks, each spanning about 11.5m.

All three bridges were required to carry heavy loads from forestry operations and one of the concrete bridges (at Lansdowne) served as the flood free route for the main highway for vehicles travelling north of Sydney.

No significant work had been undertaken on cellular timber bridge decks and no proven analytical models were available for design of these structures. Research work had already commenced at the University of Technology, Sydney (as noted above) and this work enabled ultimate load testing of 2 full scale single lane bridge decks spanning 12.2m, which established the viability of the prototype bridges.

Lansdowne Bridge:

The first of these bridges to be constructed is a single lane, four span cellular bridge deck constructed of Radiata Pine laminates with Radiata Pine LVL webs. The overall depth is 600mm with a nominal web spacing of 485mm centre to centre.

This particular cellular bridge is located on the Lansdowne River, north of Taree on the mid north coast of NSW. This deck has been constructed to upgrade an existing concrete bridge, which was first built in 1930 but had deteriorated to the extent that the deck cannot carry full highway loads.

The cellular bridge consists of four simply supported spans just under 12 metres in length, with an overall length of approximately 48 metres and a deck width of 4.9 metres. Each span being discontinuous over the supports and being so located as to transfer load directly into the concrete columns immediately below the supports. Inverted reinforced concrete 'T' beams were poured insitu on the existing deck and over the centre of the columns to act as a headstock for the new cellular decks which carry the traffic at a level about 1m over the old concrete deck.

Ashlea Bridge:
A similar bridge to the Lansdowne River bridge has been recently rehabilitated, located over Dingo Creek at Ashlea to the west of Taree (both these bridges have been constructed for Greater Taree City Council). The existing reinforced concrete bridge at Ashlea is of almost identical design and age as the one at Lansdowne except that it has seven spans rather than four, with an overall length of 85 metres and a height above the water of 20m. Deterioration of the concrete

deck in the Ashlea bridge was more advanced and the bridge had been scheduled for replacement at an estimated cost of $2.2m.

The cellular deck overlay used to upgrade the Ashlea bridge is almost identical to the one at Lansdowne, except that with hindsight on the first bridge some minor design refinements have been included and the decks bear on composite timber beams rather than poured insitu concrete. The cellular decks were prefabricated in a council depot about 25 km from the bridge and transported to site. The total road closure time was 3.5 weeks and final cost of the total deck rehabilitation is expected to be about $450,000 or about 20% of the cost of the replacement structure.

It should be noted that the Ashlea bridge will (most probably) still need to be replaced at some future time, but the cellular overlay decks have effectively increased the life of the bridge by a further 20 - 25 years. After this time it is anticipated that deterioration of the reinforced concrete substructure will necessitate full reconstruction. However, another significant advantage of the cellular SLT decks is that they can be transported and reused at another site when this replacement occurs.

Both the Lansdowne and Ashlea decks are performing at a level exceeding expectations and have resulted in Council adopting SLT technology as a major component of its Asset Maintenance Strategy for its 206 bridges. The application of SLT in construction of the Ashlea bridge was recognised in 1996, by an Institute of Municipal Engineers commendation award for Engineering Excellence.

Pound Crossing Bridge:
The Pound Crossing bridge is a 60m long timber structure, located on the road between Gresford and Singleton and has been in service since 1930. The original bridge was a 6 span timber girder bridge with corbels over the timber pile / headstock substructure. The span range is 7.6m (25 feet), 10.7m (35 feet) and 12.2m (40 feet), with a carriageway width of 4.9 metres between kerbs.

The Pound Crossing bridge encompasses a larger span range than could be met by the use of SLT plate decks and the timing of the rehabilitation coincided with the development by the University of Technology, Sydney and the Roads and Traffic Authority of NSW of the cellular deck. It is believed that the Pound Crossing bridge is the first hardwood cellular SLT bridge in the world.

The original brief to the Consultant (the author) involved simply redecking the existing substructure and widening the deck to 7m. Further representations to the State Road Authority, after investigations by Council and the Consultant, extended the brief to include a totally new timber substructure (with reinforced concrete abutments and pile caps), a full 8m (clear) deck width and raising the road level by 600mm.

This makes Pound Crossing bridge unique not only in terms of its cellular deck, but also in its innovative substructure using new timber piles and mechanically laminated LVL headstocks. This technique, pioneered on the Pound Crossing bridge because of its inherent strength and flexibility for construction, has now been specified for a number of rehabilitation designs which utilise SLT technology.

The headstocks were constructed of mechanically laminated, creosote treated Hyspan LVL, which was made from Radiata pine laminates. This system permits considerable flexibility in both design and construction and permitted the deck to be widened to the full 8m.

Great attention to detail was taken by both the Consultant and the Contractor to ensure that all the end grain timbers were treated and flashed and that moisture traps were not created in the new bridge. The bridge represents a totally engineered modern timber structure, utilising the best details that are currently available to ensure long life and low maintenance costs for the new bridge. This bridge was also recognised by industry as the winner of the 1995 Institute of Municipal Engineers top award for Design Innovation and Engineering Excellence.

6.3 Future Applications

With the exception of the Pound Crossing bridge, all the cellular bridges built to date in Australia have been constructed as simply supported spans, up to 12.2m (40ft) maximum. All decks have been 600mm deep, identical to the deck section tested at UTS.

No “T” beam decks have been built to date. However, the proposed Hopkins River Bridge in Victoria, will significantly extend these current limits of built-up technology in Australia [9].

The existing bridge was built in 1895 and consists of 24 spans, with an overall length of 154.5m. Apart from a 15m navigation truss span near the middle of the bridge (which no longer carries load and is now aesthetic), there are 23 simply supported girder spans each of about 6m. The age and location of the bridge give it historical significance and as such, it is necessary for any rehabilitation solution to maintain the character and appearance of the existing bridge.

Extensive design investigations concluded, that to achieve:

- a required unrestricted load capacity in accordance with the requirements of the "Australian Bridge Design Code"
- meet Council's expectations for the bridge to cater for today's traffic
- and to extend the life of the bridge to approximately 50 years,

the bridge timber decking and existing timber piles require replacement**.**

After careful consideration of both the initial and anticipated life cycle costs for a number of design alternatives, the preferred option for a marine environment is an appropriately treated and detailed Stress Laminated Timber Bridge structure. The foundation conditions at this site would encourage longer spans than exist on the present bridge to reduce the possibility of marine encrustation growth reducing the effective bridge waterway and providing a light superstructure.

Details of the design are still being finalised at the time of writing. The proposed design solution is a built up deck which has a short cellular form over the pier supports and a “T” beam form in the main span regions between the pier caps, except for the 15m truss span which will retain the cellular form. The web depths will be constant at about 600mm, with specially developed mechanically fastened splice connections at the points of inflexion, to ensure web continuity and adequate shear transfer. The webs will be made from multiple LVL beams with an anticipated thickness of 135mm to 180mm and c/c spacing of 500mm to 600mm, with load distribution and interlaminate slip modelling derived directly from the results of recent testing at UTS.

The proposed construction sequence is to fabricate the deck in two half-width sections and progressively launch each into position in two stages. The authors propose to use cold rolled galvanised strand wrapped in heat shrunk PVC to stress each deck section, before joining the decks using a secondary stressing system. Appropriate anchorage details, which are both durable and aesthetically acceptable, have already been developed by Walter [9] on other Vicroads projects and adaptations of these will be used for the stressing system in the Hopkins River Bridge.

7 CONCLUSIONS

The recently completed R&D project at UTS provides a substantive technical undergirding for the design and implementation of longer spanning stress laminated timber bridge decks which utilise cellular and / or “T” beam sections. Once analysis and reporting is completed by the mid 1999, a new design code will be developed to permit wide spread use of this technology.

The Hopkins River bridge at Warrnambool, will be the first Australian application of this new technology using both “T” and “cell” beams and will have consequences for design procedures currently proposed for North America and Europe. This project will demonstrate both the structural efficiency and cost effectiveness of built-up stress laminated timber decks. The anticipated favourable life cycle costs in a corrosive marine environment further illustrate the versatility of this type of bridge deck system.

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9 ACKNOWLEDGEMENTS

The author wishes to thank and acknowledge the contribution of the following persons in supporting the research and development work outlined in this paper:

- Prof Steve Bakoss – UTS
- Ian Hutchings, Mario Benitez and Milo Taragel – Structures Laboratory, UTS
- Mr Mike Ritter – Project Leader FPL, Madison Wisc
- Mr Graeme Walter – Vicroads