CASE STUDIES OF GLULAM MANUFACTURED IN NEW ZEALAND SINCE 1957
- PRACTICAL DURABILITY -

Ken A. McIntosh, Managing Director, McIntosh Timber Laminates Limited,
P.O. Box 14-604, Auckland, New Zealand

INTRODUCTION

Glue laminated structural timber beams (Glulam) have been designed and manufactured in New Zealand for
40 years. As the pioneering Company for Glulam in New Zealand we have investigated the present state of some of the Glulam components we have manufactured to ascertain their durability and structural integrity. Timber, adhesives, coatings, connections related to associated climatic conditions and on-site appearance are aspects of this investigation. The resource of Radiata Pine and Douglas Fir grown in New Zealand since the 1930's has provided suitable timbers while research and development by the Forest Research Institute of New Zealand has provided the necessary design data. The development of the Timber Engineering of Architectural concepts coupled with the practicalities of correct manufacture, quality control and on-site erection procedures feature as important factors in the long term durability of Glulam. Specification of the timber should include strength, moisture content and treatment.

DURABILITY

The durability of glulam structures involves the four main components of Timber, adhesives, connections and surface coatings all successfully incorporated by the Specifier Architect, Engineer, Manufacturer and Builder.

COMPONENT MATERIALS

a. The basis of the Glulam Industry in New Zealand is the ready availability of the plantation softwoods, Radiata Pine and Douglas Fir. With the larger volume being produced in Radiata Pine most of the case studies in this paper cover the use of this timber.

b. Associated with this is the other main component in a Glulam beam i.e. the adhesives. In the early years we mainly used imported urea formaldehyde and resorcinol glues with an occasional project in melamine fortified urea glue and casein glue. Availability of resin adhesives from New Zealand manufacture soon followed. The New Zealand Glulam Industry now generally uses only two adhesives i.e. melamine fortified urea and resorcinol.

c. Connections of glulam beams to each other and to supporting or adjacent structures have varied considerably over the years being predominantly in

   i. Steel - bolted, nailed or epoxy dowelled.
   ii Plywood - nailed or glued.

The effective use of connections is an important ingredient in the integrity of glulam structures. Testing over many years by the New Zealand Forest Research Institute, and the University of Auckland and Canterbury has provided specific data for the refinement and development of connections. Occasionally manufacturers carry out testing in house or in conjunction with Testing Authorities to develop their own ideas.

d. Surface coatings vary widely in accordance with the end use of Glulam the primary aim being to preserve the dryness of the timber.

CASE STUDIES

1. *The first structure* we produced in 1957 was an elliptical arch for our new furniture factory of 10,000 square feet arch span 50 ft.

FIG 1:

Being unfamiliar at that time with the structural uses of radiata and because of the lengths available we purchased 30 foot lengths ex 4" x 1" of North American Oregon. There was no need for any end jointing. However because of limited floor space a platform was formed up in the sawtooth roof of the factory and each beam pressed in a vertical position using sash cramps or “g” cramps. The glue used was melamine urea applied with the resin on one face of each lamination and the hardener on the other. The beams were only lightly planer dressed and were never coated with sealer. Heavy single pin steel connections were used at the apex and shoe positions.

In 1988 a high stud glulam portal structure supporting an overhead gantry was built over the 1957 structure and the curved arches removed and sent off to two other new sites - one an aircraft hangar, the other a Community Hall.

Inspection of these arches after dismantling the building showed only one defect i.e. irregular separation between some laminations. With our lack of knowledge in 1957 in manufacturing laminated timber beams we had followed procedures which we are certain produced this lack of adhesion i.e.

a. We applied the glue in separate application not realising the soakage of the hardener into the timber before final clamping was applied.
b. The pressing area was in an enclosed spacing in the sawtooth roof framing in the summer when temperatures were high and some curing took place before clamping was completed.
c. Clamping was irregular and insufficient pressure was applied in some instances.

However the roof structure proved adequate for thirty years but as a precaution we inserted ½" bolts at every 6 feet through the depth of each beam before despatching them to the new building sites.

2. *A replica* of the first building was produced in 1961 and the arches show no sign of deterioration or insect infestation being presently used as a furniture showroom/factory. Part of the arch subject to suns rays through windows appears sound. The glue is melamine urea.

3. *School buildings*:- during the years 1959 to 1978 these provided the volume of work in the Glulam Industry. Designed for the High Schools and Colleges for the Ministry of Works and by the Education Boards for Intermediate and Primary Schools these included laminated timber beams as the main structural members. A full range of designs were used.

FIG 2: Post & Beam - for 2 storey classrooms. and libraries.

FIG 3: Portal Arches

FIG 4: Angled Knee Portals 12m to 16m for halls & 7m to 9m for classrooms

FIG 5: Angled Knee Portal - Glued Knee Joint

FIG 6: Curved pitched beams with epoxy steel dowelled connections

Except for the angled knee portals the adhesives predominantly used were urea and melamine urea formaldehyde. The radiata pine beams generally were surface soak treated with an insecticide followed by a coat of water repellant sealer.

Inspection of these buildings is visual because none have been demolished. However such inspection shows no deterioration or insect infestation in examples of the several hundreds of beams supplied for these schools.

EXTERIOR GLULAM

4.

a. ***Radiata Pine:-*** Where Glulam has been subject to the regular weathering of sun and rain there are some instances of surface defect in radiata pine. Lack of adequate surface coatings to prevent the incursion of water into the kiln dried radiata pine is the cause of these defects. The surfaces of beams or posts which most commonly show these defects are those subject to the direct rays of the sun. With the deterioration of the surface coating rain water swells the dry timber which then shrinks when dried by the subsequent sun's heat this action producing splitting adjacent to glue lines or knots. In New Zealand radiata pine pressure treated with CCA to $6kg/m^3$ then kiln dried before laminating is generally used for exterior situations, however while the preservative retains the long term durability of the timber the avoidance of the surface checking relies on the non permeability of the surface coating. Splitting adjacent to glue lines can be mistakenly called delamination but close examination shows a thin layer of wood fibre fixed to the glue. The structural integrity of the beam is rarely in question because the surfaces of the beam or post not subject to the direct rays of the sun or wetting by rain do not suffer from this surface checking. It is recommended to cap the top surface and ends of beams fully exposed to the weather. Regular maintenance of the surface coating restrains or corrects this surface checking

FIG 7: Southern Hemisphere view

b. ***N.Z. Douglas Fir:-*** In New Zealand when Douglas Fir has been used in exterior situations under roof eaves where only the ends of the beams are subject to rain and sun this timber has proved entirely suitable. Lack of full penetration of pressure treatments of preservatives into Douglas Fir has restricted the use of this timber in more exposed situations.

BRIDGES

5.

a. ***Road Bridges*** - Glulam has been used very little in highway bridges in New Zealand but has been used in a number of road bridges in forest plantations. A main highway bridge (Kopuroa Canal) consisting of four main beams 16 metres long x 1.5 metres deep x 280mm wide has been in use since 1965. These beams were creosote pressure treated after manufacture. A deflection of approximately 12mm is observed when heavy truck and trailer units weighing over 30 tonnes travel on the highway. This constant movement has caused loosening of the timber cross decking requiring regular maintenance of the tar sealed road surface. The glulam beams have remained in satisfactory condition.

b*. Foot Bridges* - A number of foot bridges have been built in New Zealand varying from less than 10 metre span to a 46 metre support arch with 60 metre walkway. The specification for the glulam beams in these bridges is generally radiata pine CCA pressure treated to H3 retention ($6kg/m^3$) or H4 ($12kg/m^3$) where ground soil contact is a feature. Resorcinol glue is always used. The pressure treatment and glue provide the durability while surface checking is restricted by maintaining the surface coating. In some instances this maintenance has lapsed with checking recurring on surfaces subject to sun and rain.

However good maintenance on the 46 metre Arch Bridge at Panmure, Auckland has rectified surface checking resulting from the initial sub standard sealer.

6. ***Swimming Pools:-*** The roofing of many public swimming pools has featured glulam structural beams. These heated pools generate a damp moist atmosphere in which glulam has proved more desirable than steel. Careful detailing of hot dip galvanised connections in these buildings is essential to avoid collection of moisture. In most instances these beams are pressure treated radiata to H3 retention with the surfaces coated in the factory with three coats of a two pot epithane. It is advisable to keep the base of the glulam arches or portals well clear of the pool water as I am aware of an instance where the supporting glulam posts were placed on concrete pads within the area of the pool and only about 150mm above the water where the posts were subject to constant splashing.

As in public pools where glulam also provides an architectural feature, some private pools or conservatories which include spa pools have a glulam structure as an attractive alternative to aluminium.

7. *Wool Scouring*:- The processing of sheeps wool in New Zealand includes the cleaning of the wool by high temperature water. These large washing machines are housed in a building known as a Scour Tunnel which is 77 metres long. The atmosphere in the building is constantly at least 30 deg C and 100% humidity, and very corrosive. In a number of these wool processing sites with buildings covering up to 7000m^2 overall Architect Ted Patten selected our angled knee portals (Refer Fig 4 & 5) where in the Scour Tunnel he specified CCA pressure treated radiata. The portal span is 11.3 metres with wall height of 6 metre. Samples taken from the timber portals 10 years after installation show no deterioration to the timber or portals - interesting development being a brown case hardening to the surface of the timber. Ted reports that a steel structure in an identical building has rusted out and needs replacing.

8. *Corrosive Materials*:- Glulam has been specified in a number of buildings housing materials such as lime, soda ash, phosphate and other fertilisers which rapidly attack steel structures. These buildings are mostly A frame structures with spans up to 30 metres although a variation of this was a building for a Tannery Lime Yard where a plywood gusset structure was preferred as the replacement of a steel building. Pressure treated CCA radiata pine and resorcinol glue is the general specification in these buildings however one building done in 1969 to house Salt Cake used surface treated radiata pine and casein glue. Recent observations of this building report apparent soundness of the timber it being possible that this fertiliser is in fact a preservative to timber but a destroyer of steel.

9. *Timber Sawmill and Chipboard Factory:-* In 1963 we supplied 14 Angled Knee Portals (Ref Fig 5) 18.30 metre span with 4.60m wall height. This design of portal was soon to become known as the McIntosh portal because of the unique method of construction. Because it had not been load tested the Design Engineer carried out a load test by suspending a 12 tonne log from the apex of one of the portals. The result was convincing and therefore acceptable. This building was demolished in 1995 to make way for urban development the portals being purchased for erection by a timber sales yard. Visual inspection shows soundness of the structural glue joints but as the portals are stacked outside and not fully covered there is some surface checking.

10. *Glulam Protects Steel:-* In 1969 an unusual remedy was found by an Architect to lengthen the life of a steel structure by covering the steel with glulam panels. The steel portal structure was of the open web design and is sited near wharf and subject to salt air and wool scouring environment which has caused extensive rusting. Calculations to stiffen the failing steel structure resulted in glulam panels being designed to not only add strength but also to protect and cover the steel from the atmosphere. The portal span is 18 metres and wall height 5 metres. The panels were 42mm thick and were ingeniously bolted in place with stainless steel fixings

to provide an envelope structure with a prolonged life of over 25 years.

11. *Ply Gusset Portals:-* Extensive testing by the University of Auckland Timber Research Engineer about 15 years ago produced reliable data for the design application of nailed plywood gussets. This has resulted in an economical portal mainly used in competition with steel for industrial buildings. The ply gusset has mostly superseded the nailed steel plate gusset because of easier nailing of the plywood and also the ready availability of radiata construction plywood with its relevant supporting design data. However on portal spans greater than 30 metres the gussets are specified in sheet plate reinforced radiata ply, or hardwood ply, or steel gusset plates.

FIG 8:

The durability of these portals once again relies on the specification relating to the use of the buildings e.g. The Tannery Lime Yard building in section 8 above was CCA pressure treated. In every case the nails should be galvanised. To sometimes provide extra stiffening to the edge of the ply gusset a strip of galvanised sheet steel is epoxy glued to the inner surface of the ply. Further protection of the nails for anti corrosive or architectural reasons can be achieved by fixing a cover sheet of thinner ply or particle board.

12. *Aviary Arches:-* In 1984 the kiln dried CCA pressure treated radiata was put to an extreme test in two 25 metre span arches holding up stretched netting to form a bird aviary. Undoubtedly the problem here is the surface checking caused by sun and rain i.e. the dry wet cycle referred to in section 4 above. These arches were used in a Heritage Park for eight years then removed and re-sited at a Zoo Park. The arches were re cut to fit the new site this work being done in our factory. The surface checking was evident (with no residual surface coating) but not considered to create any structural deficiency, in fact the checking was found to be only 2mm deep when the surfaces were machine sanded before re-coating with a urethane-acrylic system.

13. *Fire:-* The resistance of glulam in fire is well documented and there have been several instances in New Zealand where the charred glulam structural members have been retained in place after sand blasting removal of the char. A good illustration of this was the Reception Centre where beams spanning 29 metres curved upwards to a centre apex. The severe fire produced a char thickness of 10mm after about 16 minutes. Calculation by the design Engineer showed adequate residual strength so the char was removed and the beams retained in place. The adjacent kitchen roof supported by steel web lattice trusses was replaced.
There was no deterioration in the New Zealand Douglas Fir timber or the resorcinol glue in these beams - their durability under fire being proven.

14. *Structural Panels:-* A large area of University Library was covered in 1968 by a series of panels spanning 14 metres. The panels were made of a 65mm thick glulam core (glued with casein glue) with 6mm thick hardboard glued to both sides with resorcinol glue. The panels were formed into inverted U shaped units with side 1.20 metres high and a top panel 800mm wide with connected edges glued and nailed. The units were transported to site and lifted into final position when spaced gutter panels were site fixed to provide water run off. Roof cover was then completed. Care was needed to keep rain water from the casein glue in the laminated core panels. These unique structural panels continue in good service.

15. *Angled Knee Portal with Gantry rail support corbel.*

FIG 9:

In 1963 we built an extension to our Glulam factory using the Angled Knee Portal - span 18.30 metres wall 6.00 metres. Timber radiata pine.

The principal feature of this portal is the factory glued knee joint of overlapping glulam panels however to support the overhead gantry beam a glulam corbel is built into the column. All joints are glued with resorcinol and have no mechanical fixings. The longitudinal glulam gantry beam is bracket connected on top of the corbel. The gantry weighs 3.6 tonnes and lifts 2 tonnes. In actual usage there are two gantries often lifting about 4.5 metres apart in the same building. Constant daily gantry action over 33 years has been a severe test for these portals especially the glued corbel joint. There is no evidence of deterioration in material or strength of the glued joints. Because this building was to be demolished to make way for a new regional road we took a sample core from the cross lapped knee joint of one of the portals which provided enough for 4

shear block tests these achieving 12 Mpa average. Because of this excellent performance we are using similar portal and gantry design in our new factory built last year. One line of the portals supports a 3 tonne and a 2 tonne gantry. While the other line supports a 5 tonne gantry.

16. 3 Storey Office Building:- Built in 1965 for N.Z. Forest Products this had floor and roof beams glued with casein glue and surface treated radiata pine while the exterior columns were in CCA pressure treated radiata with resorcinol glue. Recent inspection shows no defects in the interior beams however the exterior columns developed surface checking where exposed to strong sunlight when they were painted a dark blue several years ago a condition which had not developed when the columns were previously painted white. The blue paint has since been removed and replaced with a pale green paint. The inspecting officer reports there is no reason to doubt the structural soundness of the columns.

17. *Street Light Standards:-* In 1965 the same Timber Town of Tokoroa where the N.Z. Forest Products building is there are several streets in which "S" shaped laminated timber light standards were installed. These were fabricated out of 3 laminations with the centre lamination having a groove through which the underground electric cable was threaded up to the light fitting at the top. CCA pressure treated radiata to 10kg/m^3 and resorcinol glue was the specification, while the surface was painted with specially formulated white paint. The Electric Power Authority reports no delamination however over recent years at about 4 per year some standards have been replaced due to rot occurring on the base where it has constantly been buried in wet soil.

18. *Farm Sheds for Poultry:-* To eliminate ledges for collection of dust and vermin a considerable number of angled knee portals were used in the 1960's and 70's for egg and chicken producing buildings. Minimum preservatives were applied to the timber in the sealer coat. The portals generally 12m span with 2.2m wall height were set up on a concrete nib wall to allow for floor cleaning and to keep the timber portals from water damage, although on one farm the interior specified portals had the lower part of the portal exposed to the weather resulting in some rot deterioration to the timber surface. It was recommended that the cement fibre board used on the walls be extended down to cover the weathered exposed portion of the portal.

19. Creep: Excessive deflection or creep has not been reported as being a problem in interior situations. Neither is it a problem in the more severe exterior situations where maintenance has been carried out.

The only instances brought to our notice are:-

a. A glulam beam supporting the exterior wall of the first floor of an office building is showing deflection below horizontal. The beam has end fixings and 2 support posts within the span. The beam shows sag or deflection in the centre span. An experienced structural Engineer who regularly observes this beam as a passerby concludes that lack of maintenance to the coating on the exterior face of the beam has allowed the wetting and drying cycles of weathering to cause relaxation of the timber fibre resulting in creep. Recent maintenance appears to have stopped the creep.

b. He also reports another instance of a lintel beam which not only was allowed to soak up rain water during the construction period but after being fixed in place was for an extended period excessively loaded in the centre span with a stack of roofing material which caused the beam to deflect below the built in camber. Additional struts were introduced to restore the cambered shape of the beam.

SUMMARY

In this paper the examples of specific glulam structures have featured those where special conditions of heat, moisture or chemicals are predominant over and above those found in normal interior situations.

Where correct manufacturing procedures are followed we have found in our experience that beams in normal interior situations do not deteriorate. The only example from our production brought to our knowledge where delamination has occurred was one in the early years when pockets of moisture in excess of the recommended limit for the timber affected the adhesion in the beam. After the timber dried out epoxy resin was successfully injected into the glue line where the openings showed.

It is therefore obvious that the priority should be to keep the timber dry at the recommended levels specified for particular timbers and glues.

Comments in this paper emphasise the desirability of good surface coatings in exterior conditions. Otherwise water repellent sealers effective for the exposure on the construction site are all that is necessary for normal interior glulam.

Strict quality control of all aspects of glulam manufacture is mandatory.

CONNECTIONS

Where steel connections are used it had become normal practice to specify hot dip galvanising of these components. In extreme conditions painting with specialist coatings on the galvanising has been specified or on rare occasions stainless steel connections have been preferred.

"REVIEW"

Looking recently at Glulam beams we have made over the past 40 years has been a heartening experience. The file records of the beams in these case studies and of the many thousands of beams produced contain the design specification which represents the necessary theory and engineering to produce the beams. Diligent manufacturing procedures and quality control turn this theory into a practical result. Our faith in the processes and materials in Glulam over these many years has been vindicated.

We conclude that Glulam properly specified and produced can be claimed to be durable and structurally sound.