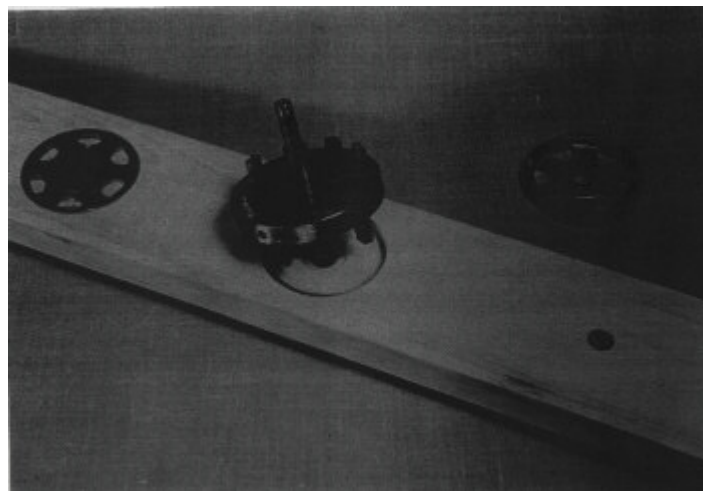
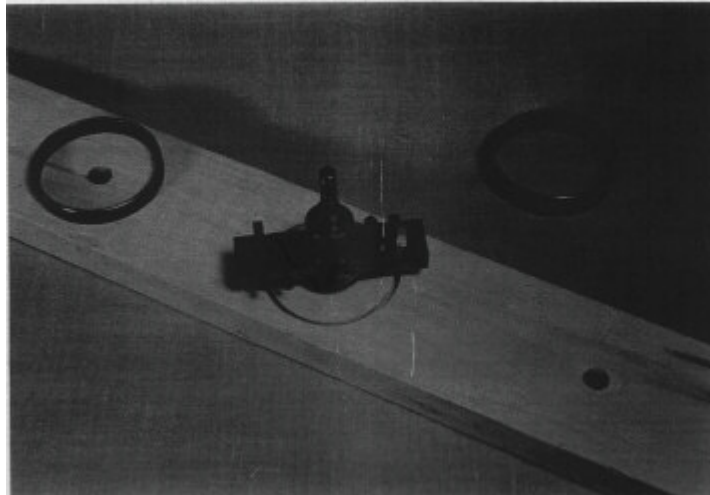


# CONNECTION METHODS for TIMBER ENGINEERING.

## TRADITIONAL CONNECTION METHODS.

The traditional connection methods consist mainly of:

DOWELS, BOLTS, LAG SCREWS, SPLIT RINGS, SHEAR PLATES,  
NAILS & SPIKES.

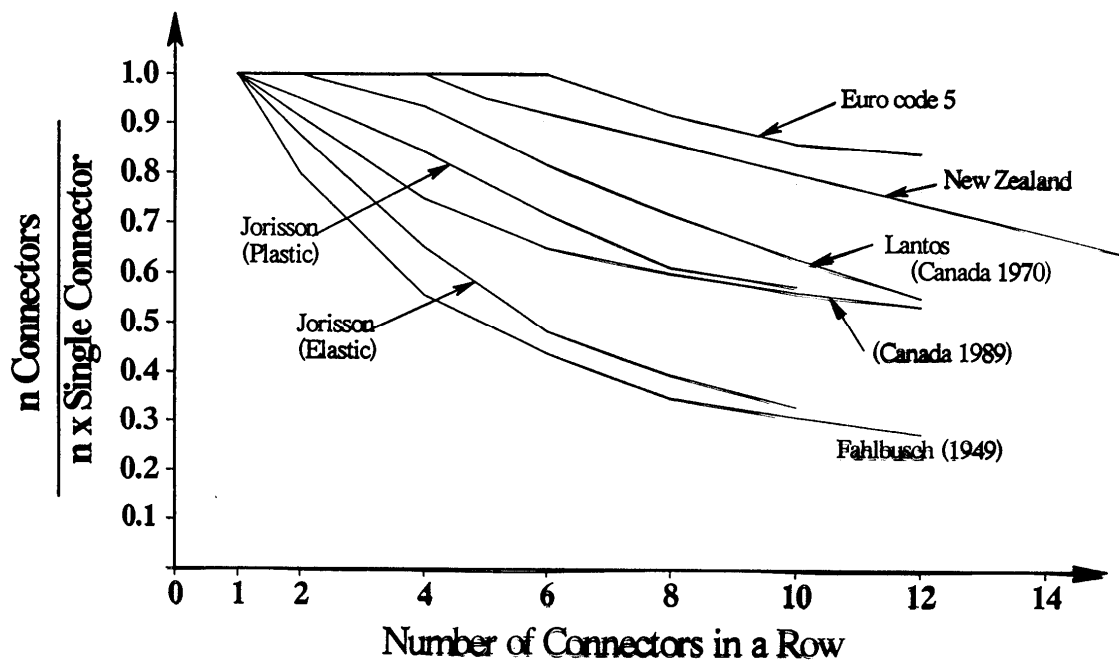


These connection types have all been used for a long time, but they are all suffering from developing large deformations during loading. In the past this has not been considered a deficiency.

However, with more stringent performance requirements the above jointing methods will no longer be satisfactory for structures larger than houses.

Unfortunately, not much testing information is available on the strength properties of the mentioned connections. In some cases it is not even known if the data quoted in the design code are based upon a strength criterion, or are governed by some deflection limit (slip).

In most cases only single connectors have been used and the effect of shear-lag has not been investigated sufficiently.  
(connectors in a row)



With the introduction of “Limit States Design” and of reliability considerations some years ago it was - due to lack of data - not possible to do more than an approximate soft conversion on the code section dealing with fasteners.

This was not even confirmed by relevant testing.

The trend towards better performance requirements also raises questions about the adequacy of the traditional jointing methods for larger structures.

The deficiency in the connectors can in many cases be traced to the use of oversized holes, too short end distances, or shrinkage and swelling caused by changing climatic conditions.

Few of the traditional connection methods can withstand reversal of the forces which is an important consideration for earthquake design as well as in determination of wind effects.

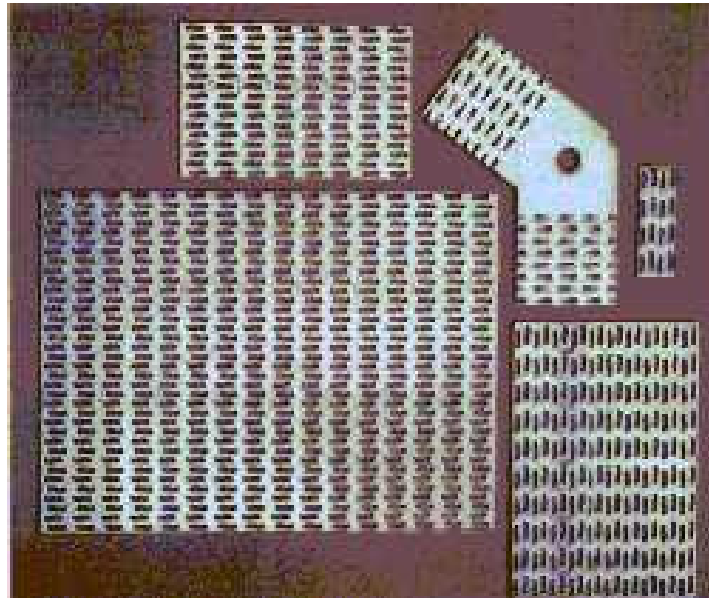
What I am trying to say politely is that our knowledge of the strength properties of the traditional timber connections are seriously absent.

## CONTEMPORARY CONNECTION METHODS.

In the late 1950's or early 1960's three new connection methods were introduced:

- A) Truss Plates
- B) Glulam Rivets
- C) Glued-in Steel Rods Parallel to the Grain.

A) The truss plate invention changed the manner in which roof trusses for houses were built.



Rather than construct rafter roofs on the job site, the new trusses are factory assembled and shipped to the job site for installation. The idea rapidly engulfed all of the worlds developed countries.

The annual sale of trusses in North America is in excess of \$ 2.8 billion.

The trusses are ideal for houses, but should be limited for use in buildings with clear spans of less than 10-12m.



B) The second innovation -the Glulam Rivet - is designed specifically for use in large buildings.

It consists of a predrilled structural steel plate in which glulam rivets having an oval shank are driven into the timber member.

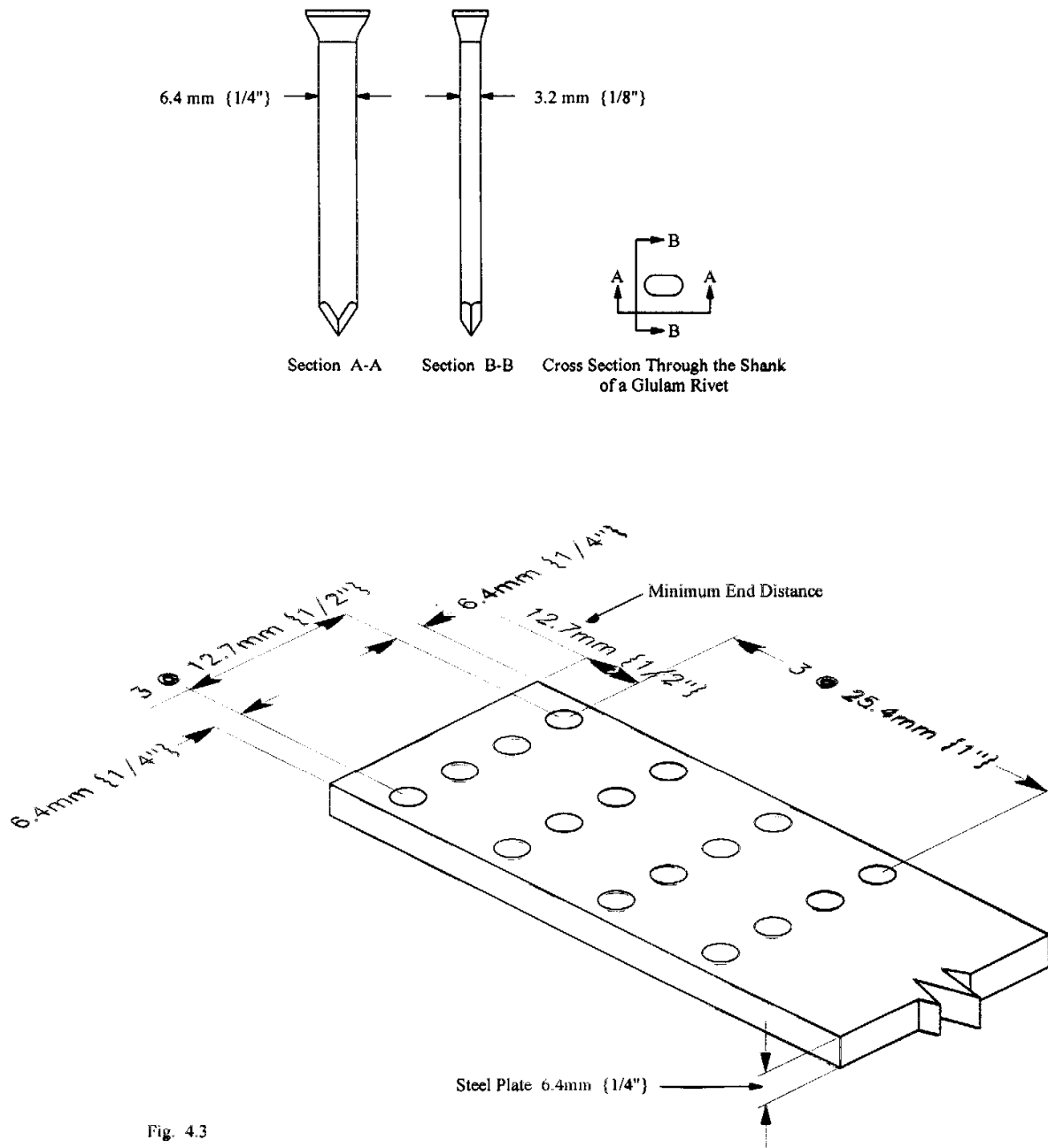
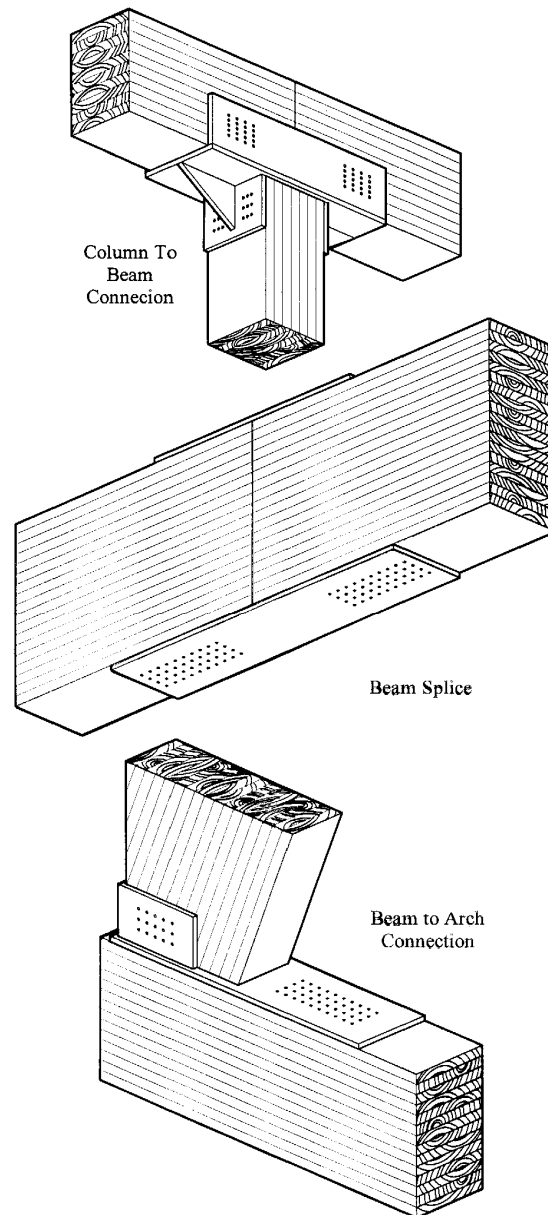


Fig. 4.3

The close spacing of the rivets and the conical shape of the head creates a very stiff joint, which is able to withstand reversal of the forces.

The glulam connection is capable of transferring bending moments and can therefore be used for statically indeterminate structures.



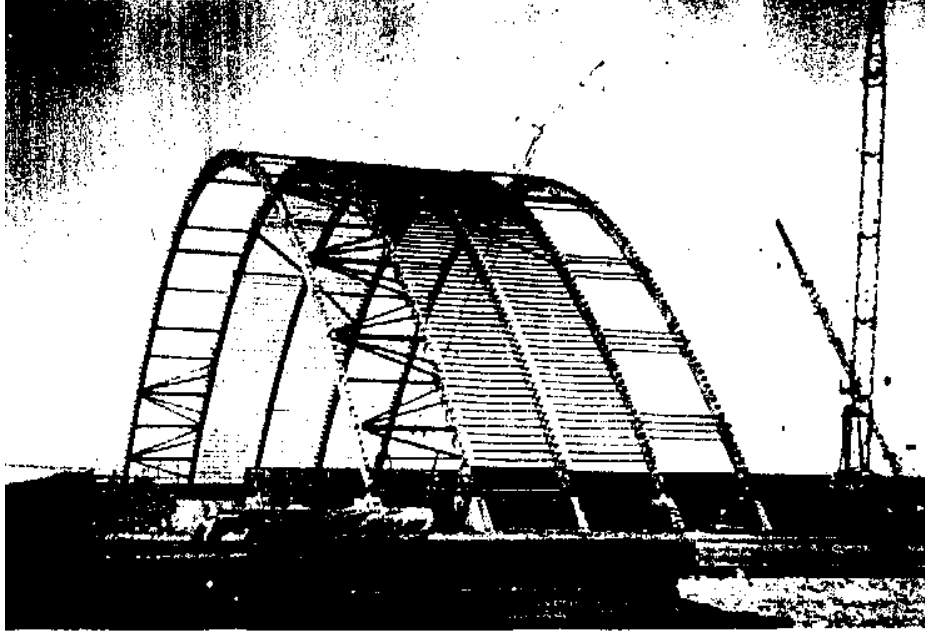
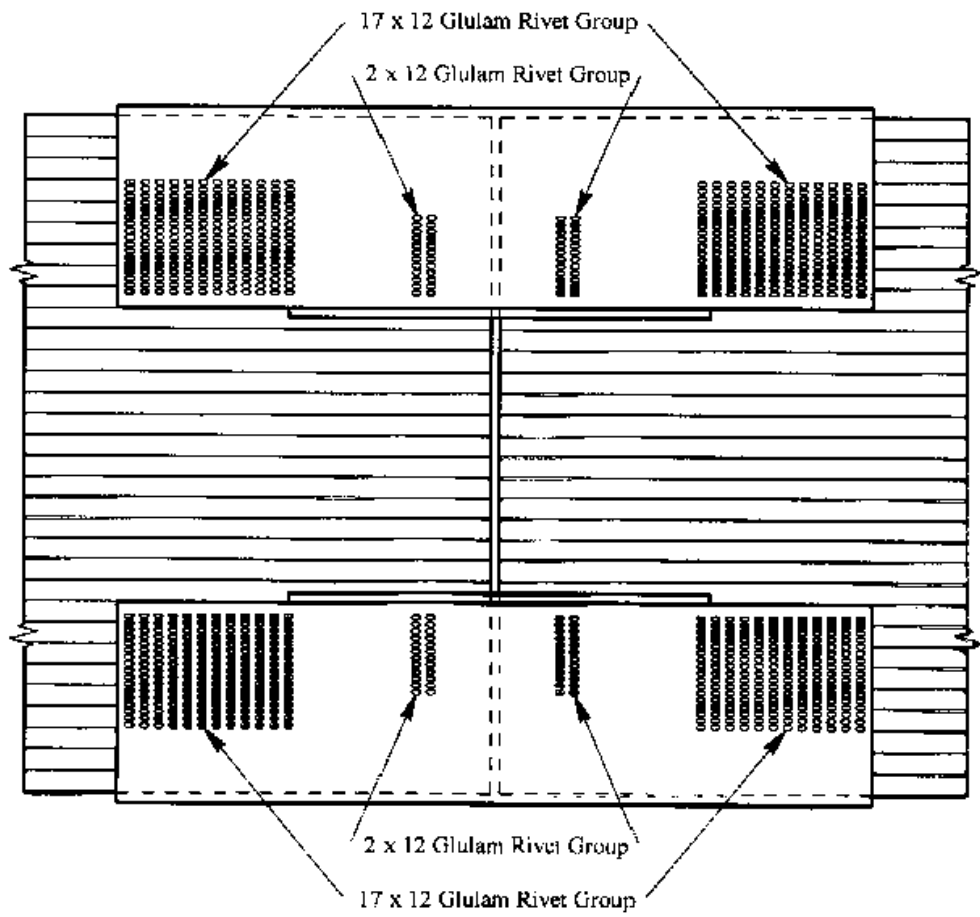
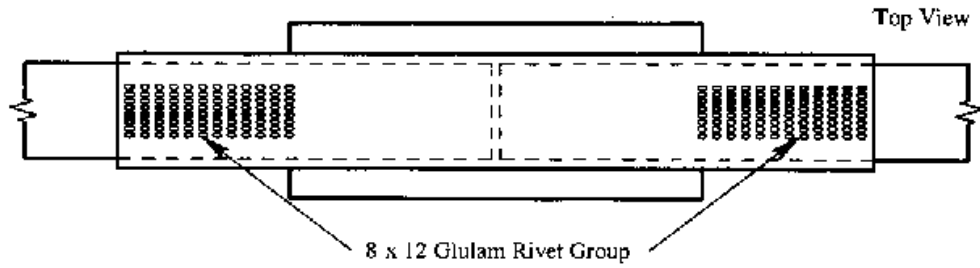


PLATE 14.3 A large potash storage building (70 m clear span) assembled using glulam rivets and prestressed lengthwise to improve lateral stability of the arches.



### Splice for 215' Clearspan Glulam Arch



C) In the late 1970's the development of a new connection method was reported in Scandinavia.

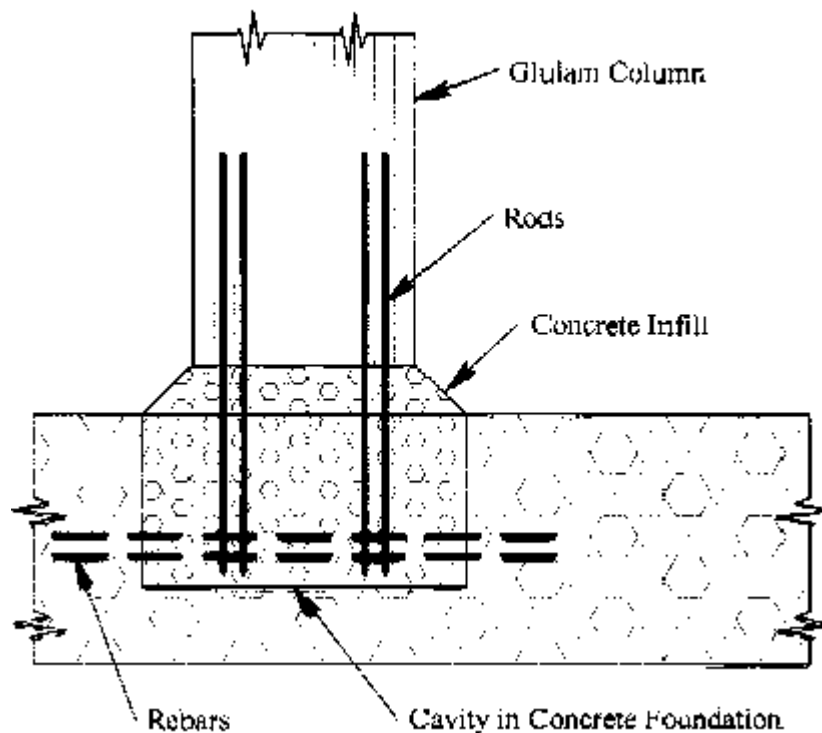
It consist of inserting steel rods into holes drilled parallel to the grain of the glulam member.  
(i.e. end grain).

Using Epoxy glue or Resorcinol glues it was possible to reliably transmit a load from the rod into the glulam member.

This was the first reporting of a successful application of gluing steel rods to timber.

It was used only for cases where the steel could be placed parallel to the grain.

Column to Foundation Joint (European)



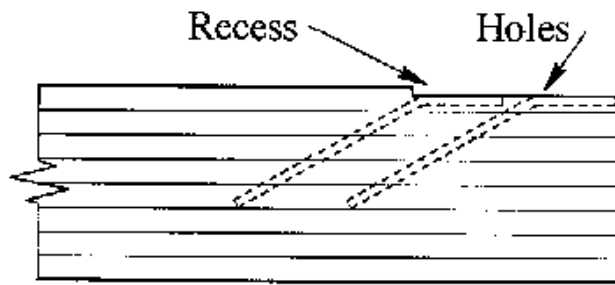
In Russia Mr. S. B. Turkowskij worked with the idea of enhancing the strength properties of glulam using reinforcing bars.

He started by placing the re-bars perpendicular to the grain in places where the glulam was subjected to bearing forces.

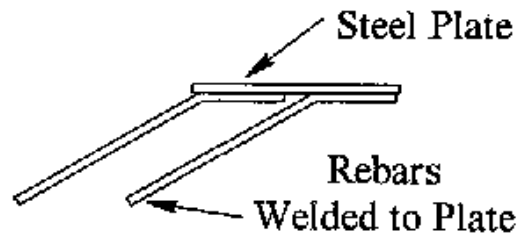
Later he also used re-bars placed at a  $30^{\circ}$  angle to the grain to reinforce the glulam members for high shear stresses.



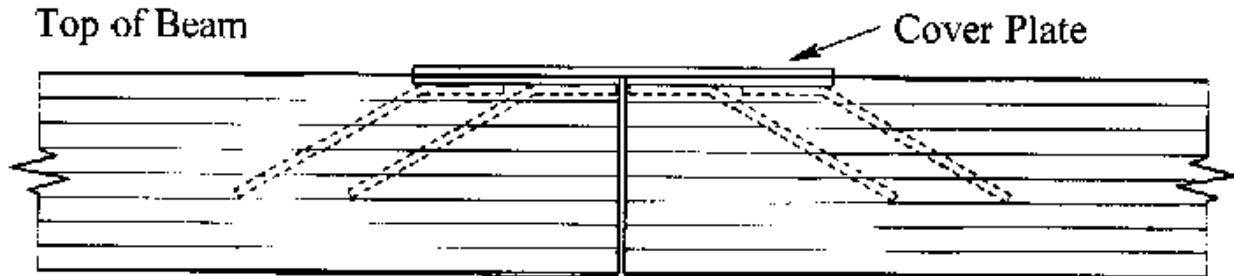
## Modifications to Russian Splice Joint



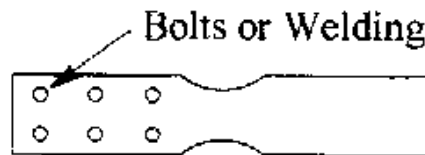
Framing in Glulam



Steel Assembly



Bottom of Beam

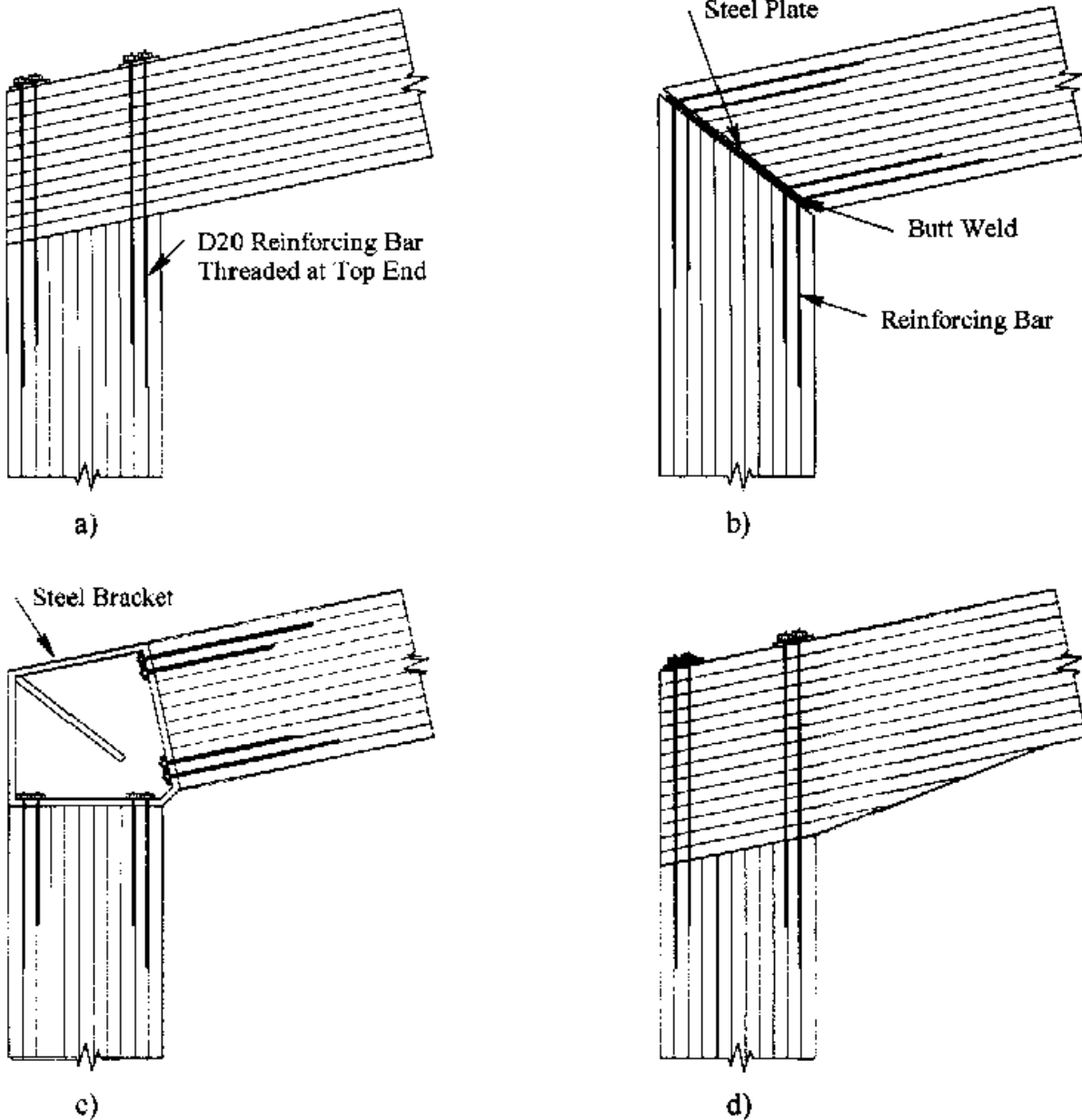


Shaped to Assure  
Yielding in Steel  
for Earthquakes



In New Zealand some recent work with steel rods was reported for knee joints.

### Joints with Rods Parallel to Grain

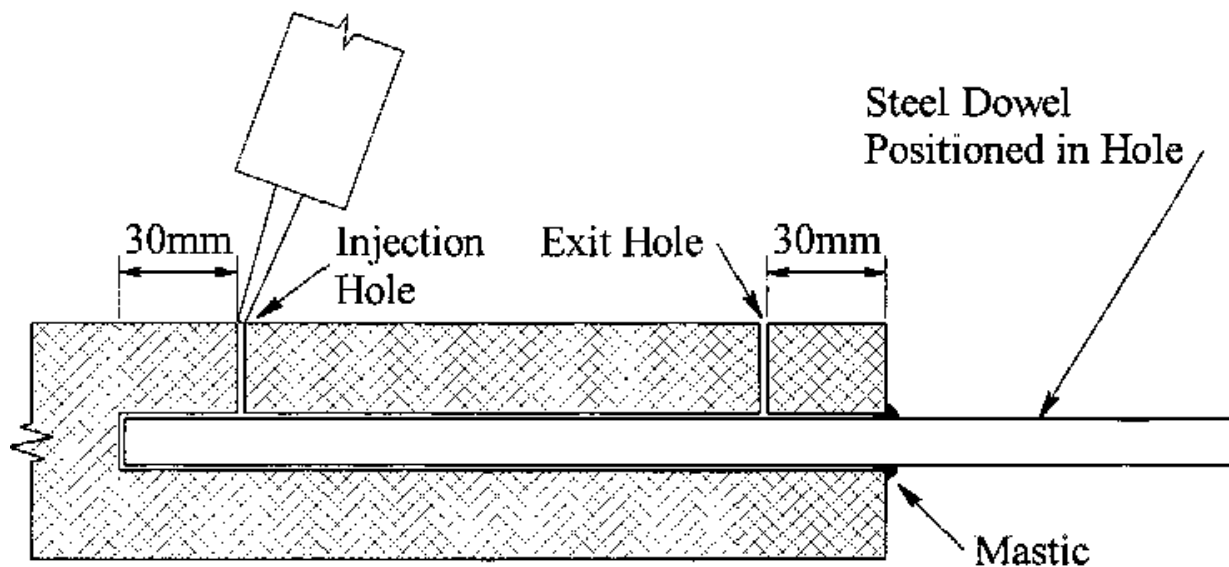


Here the rods were again placed parallel to the grain in the column and rafter members, but steel weldmends were used to guide the forces past the knee.

However, there are some disadvantages when the rods are placed parallel to the grain of the glulam.

One disadvantage is that the rod is often placed in a horizontal plane so the gluing, therefore, has to be injected under some pressure to avoid the forming of air pockets. This would impair the bond between the steel and the wood unless special techniques are used.

### Device to Avoid Air Pockets in horizontal Holes



Another disadvantage is that the rods will be placed close to the top and bottom of the glulam member thereby creating skin type joints where only the top and the bottom of the glulam carry the load from the rods.

## GLUED-IN RODS IN CANADA.

At U.B.C. an investigation to expand the use of glued-in rods was commenced in the late 1980's.

The goal was to develop one or more reliable connection methods that would meet today's performance requirements; they are:

HIGH STRENGTH  
HIGH STIFFNESS  
AVOID BRITTLE FAILURE  
TOLERATE REVERSE LOADING  
LOADS TRANSFERRED VIA SPECIFIED PATH  
SIMPLICITY OF DESIGN  
EASE OF MANUFACTURING  
CONSTRUCTION FRIENDLY  
ATTRACTIVE APPEARANCE  
NO FIELD WELDING  
NO FIELD GLUING  
PROVIDE FOR CORROSIVE ENVIRONMENT (IF  
NEEDED)  
FIRE PROTECTION  
COST

### NEW INFORMATION REQUIRED.

Behaviour of the glulam and the glued-in rods (strength and stiffness, for different sizes and lengths).

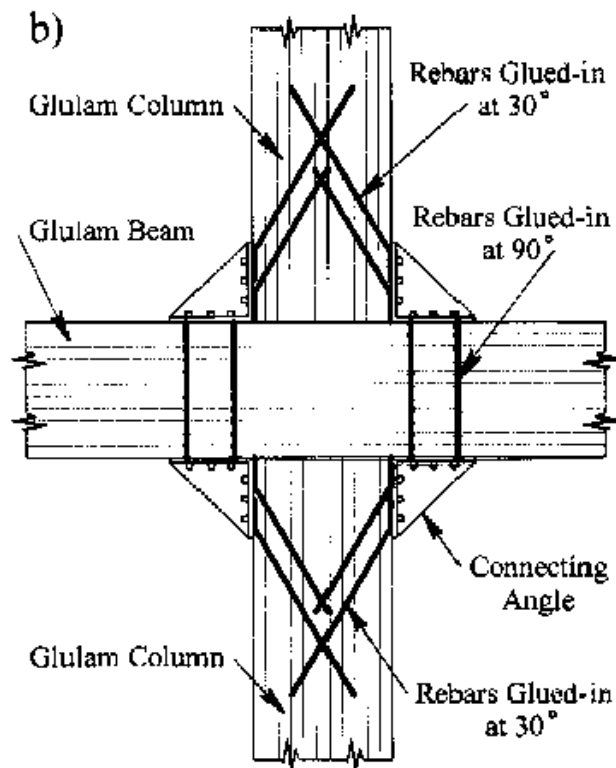
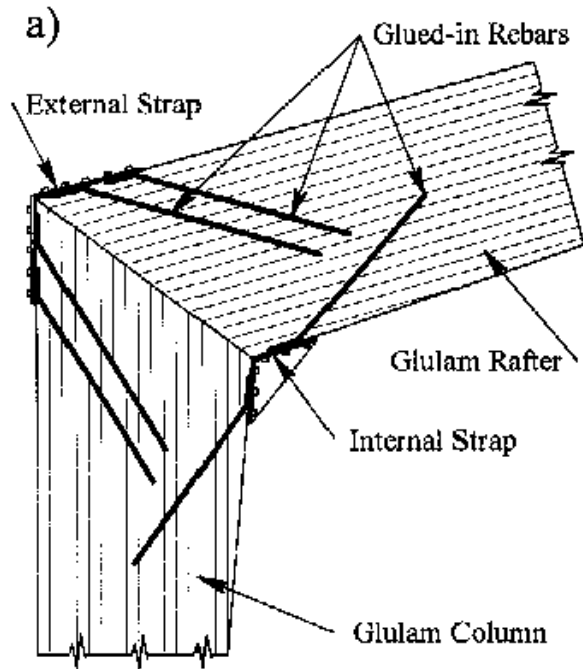
Behaviour of glued-in rods at an angle and perpendicular to grain.

Behaviour when subjected to climatic changes.

### INTENDED END-USE.

The primary applications were “beam to column connections” and “knee joint connections”

Proposed Solutions for a) Knee Joint, b) Beam to Column Connection



It turned out that several other types of connections also could be derived from the testing conducted.

The basic idea was to use steel anchor plates glued to the corners of the glulam members and then use straps between the adjoining anchor plates to transfer the forces from one member to the next.

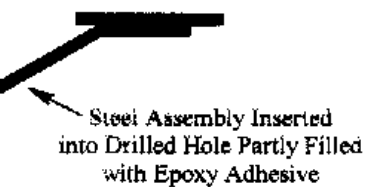
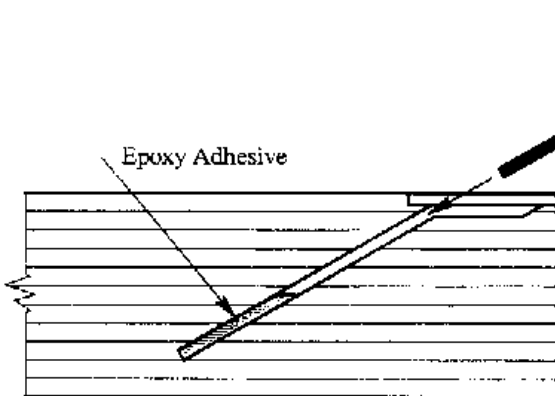
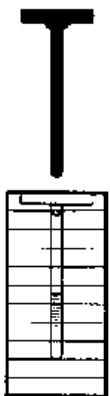
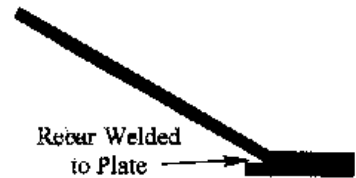
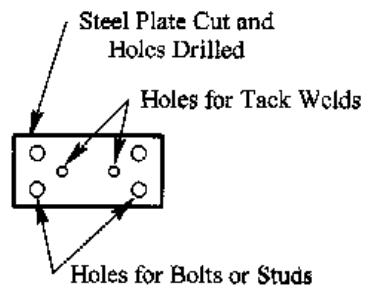
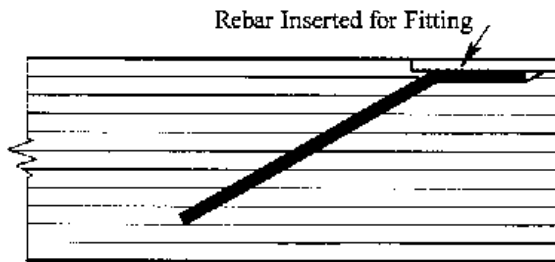
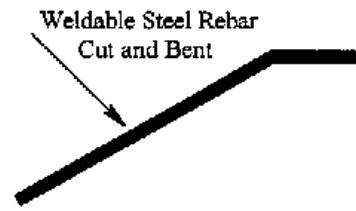
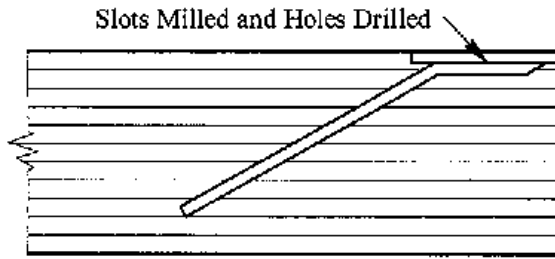
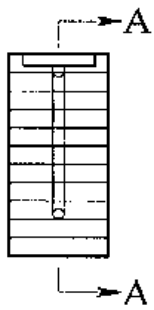
The anchor plates would have pre-welded rods on their underside which would be inserted into drilled holes in the glulam forming a  $30^{\circ}$  angle. Epoxy glues were used.

### Steps of Fabrication

END VIEW

SECTION A-A

STEEL

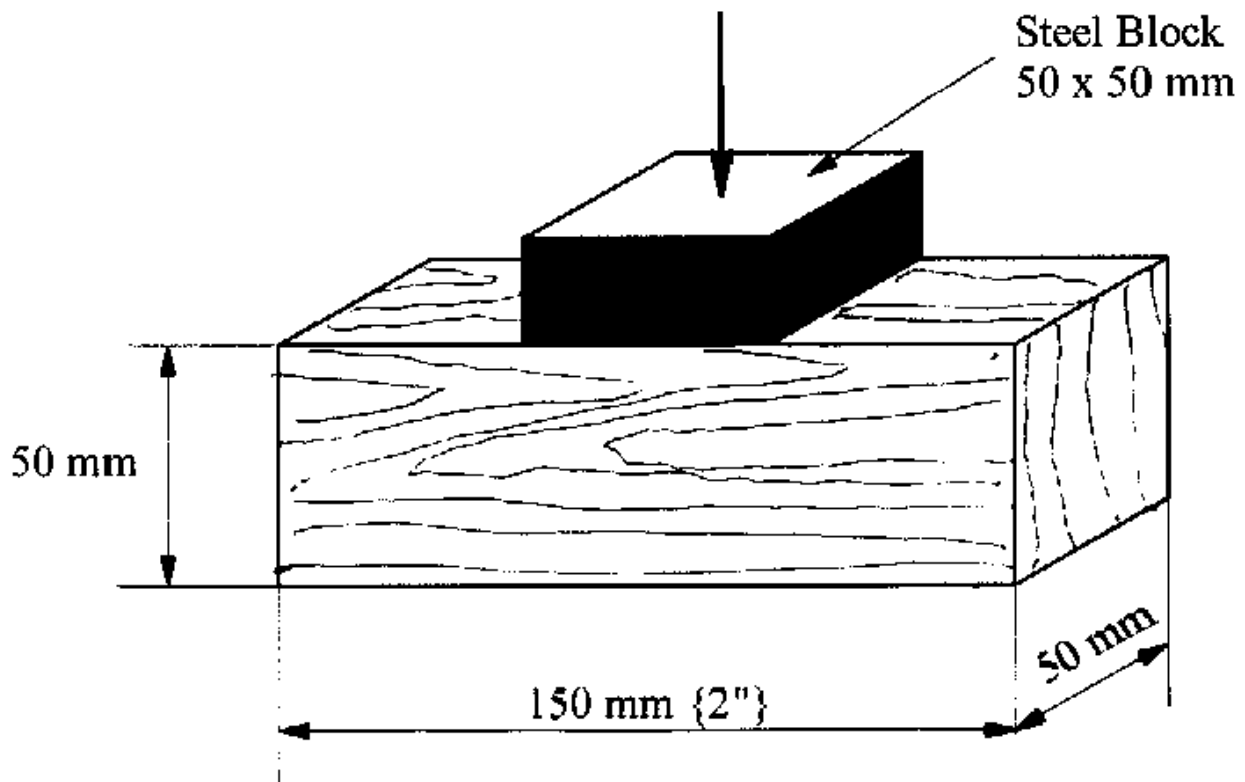


The advantages of using glued-in rods at an angle are that the rod will engage more of the glulam cross section to carry the load and at the same time will act as shear reinforcing for the glulam member.

A disadvantage is that large compression perpendicular to grain forces are generated where the rod is bent.

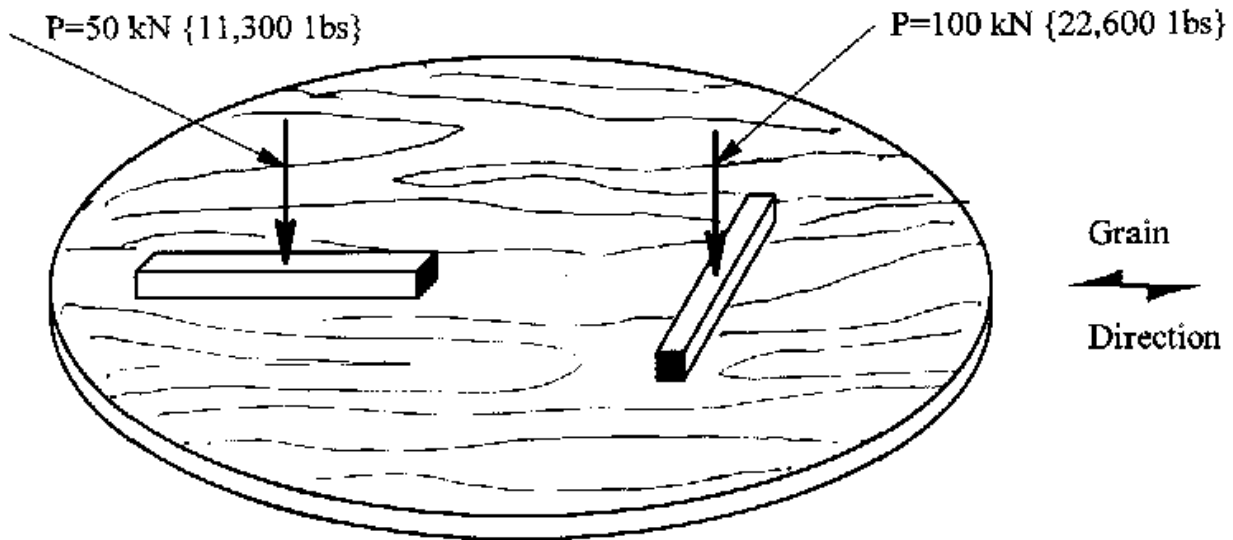
### COMPRESSION PERPENDICULAR TO THE GRAIN.

According to ASTM - D 143 the perpendicular to grain strength could be established by a simple test as shown. The stress is equal to  $P/A$ ; (force divided by area).



While that method is simple, it is - unfortunately - a deception.

A small experiment will illustrate the problem.

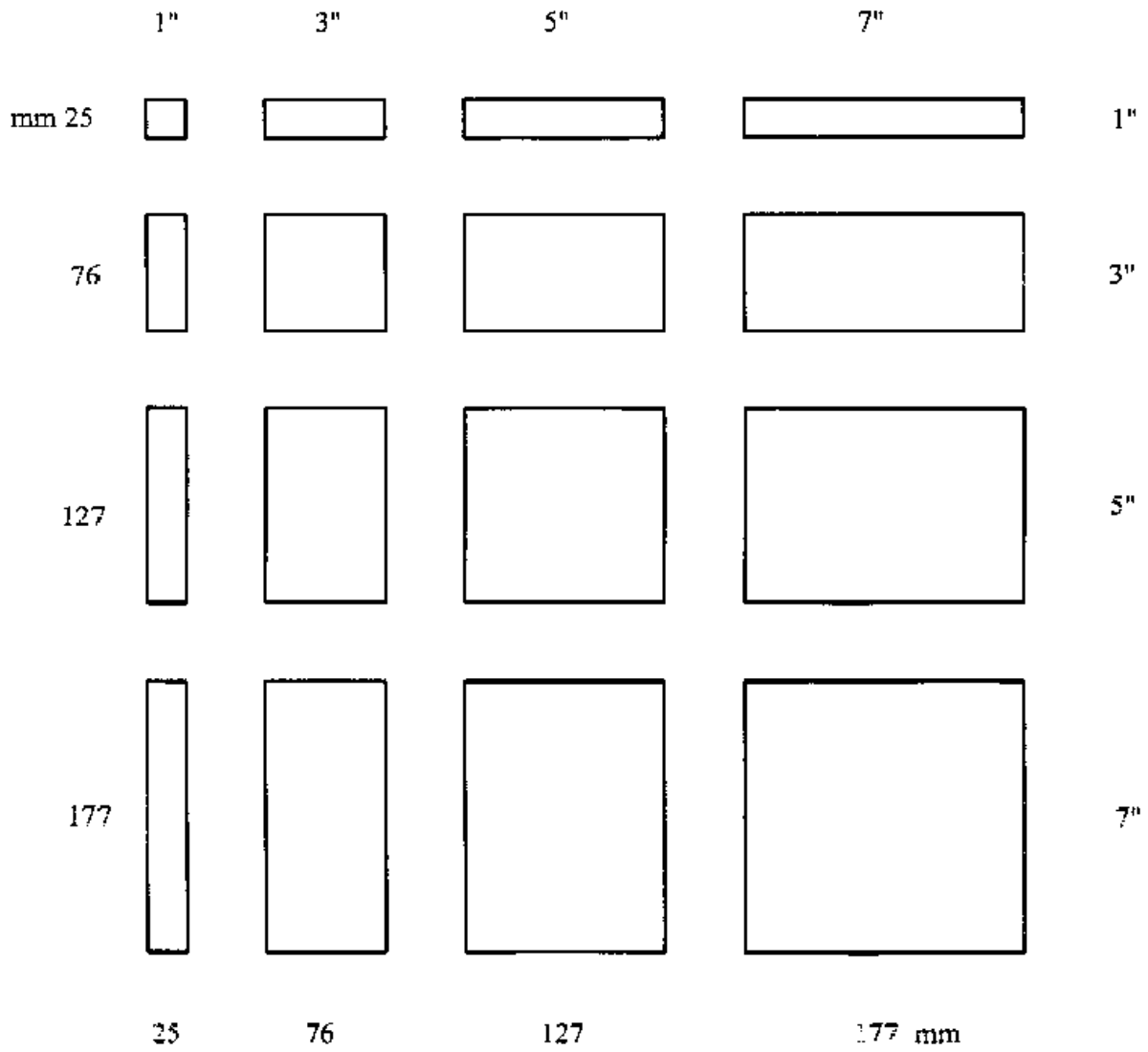


Closer examination of the compressing perp. behaviour reveals that four different component are active in providing the bearing capacity of glulam.

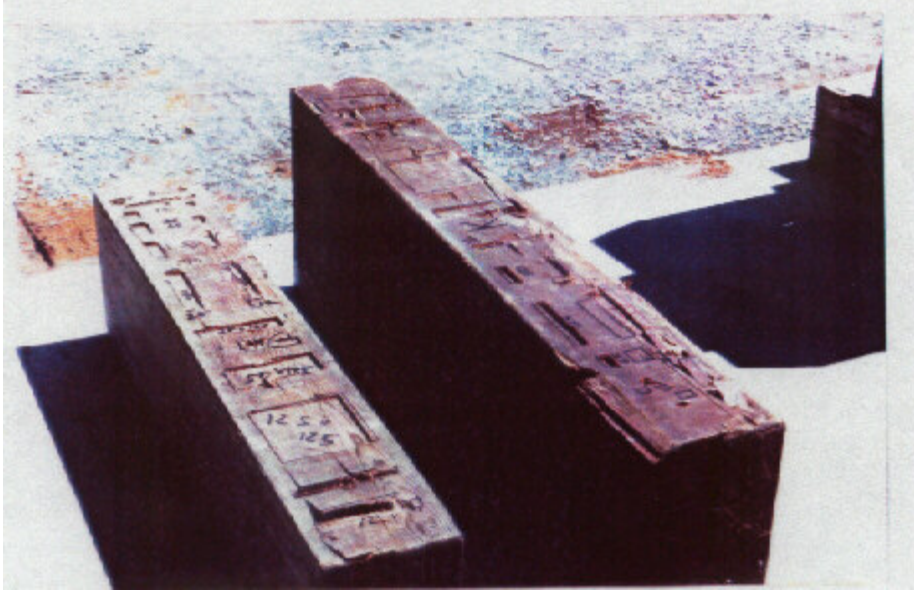
The active components are:

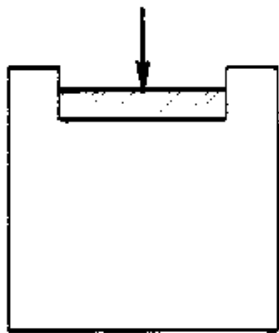
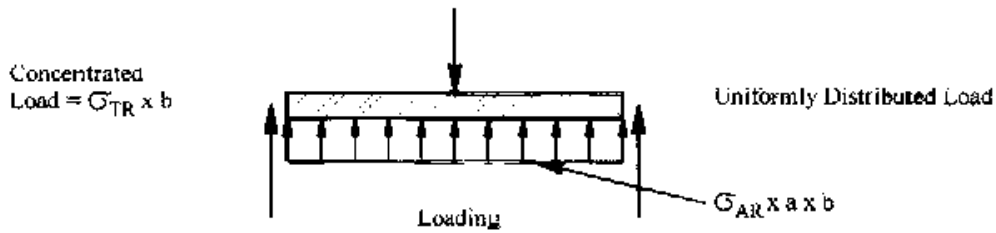
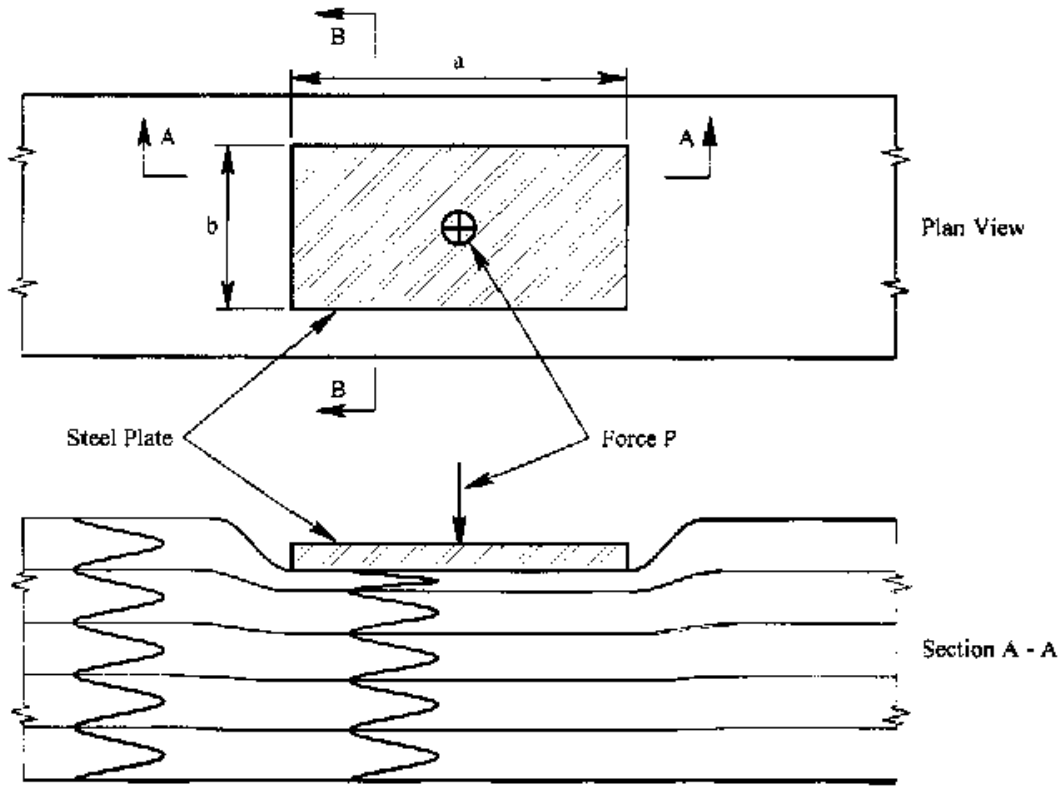
- 1) The area of the plate.
- 2) The length of the plate edges parallel to the grain.
- 3) The length of the plate edges perpendicular to grain
- 4) The magnitude of the indentation imposed.

A deeper insight can be had by testing bearing plates of different sizes.

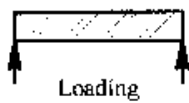


Sizes of Bearing Plates





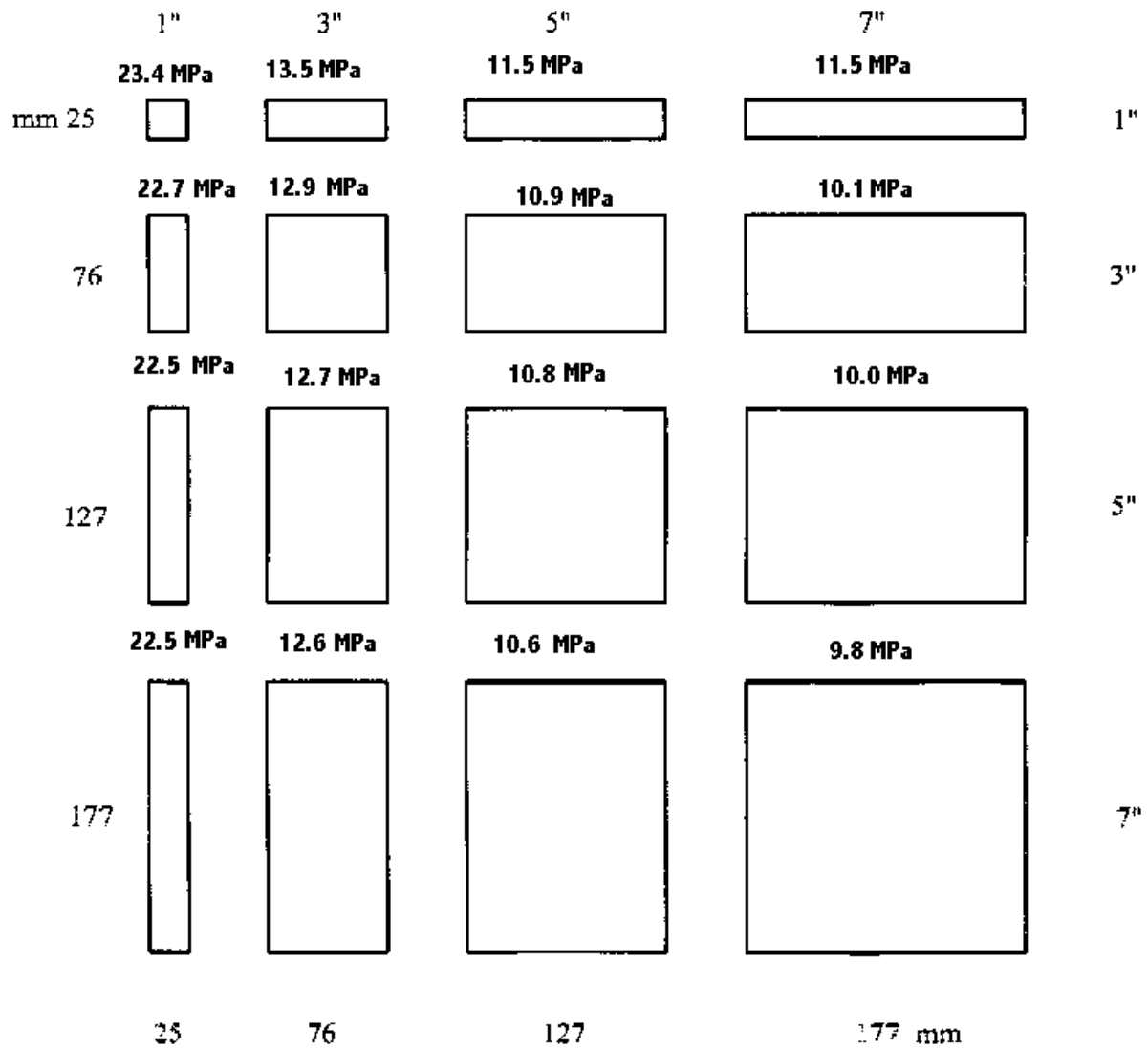
Section B - B



$\sigma_{LO} \times a$

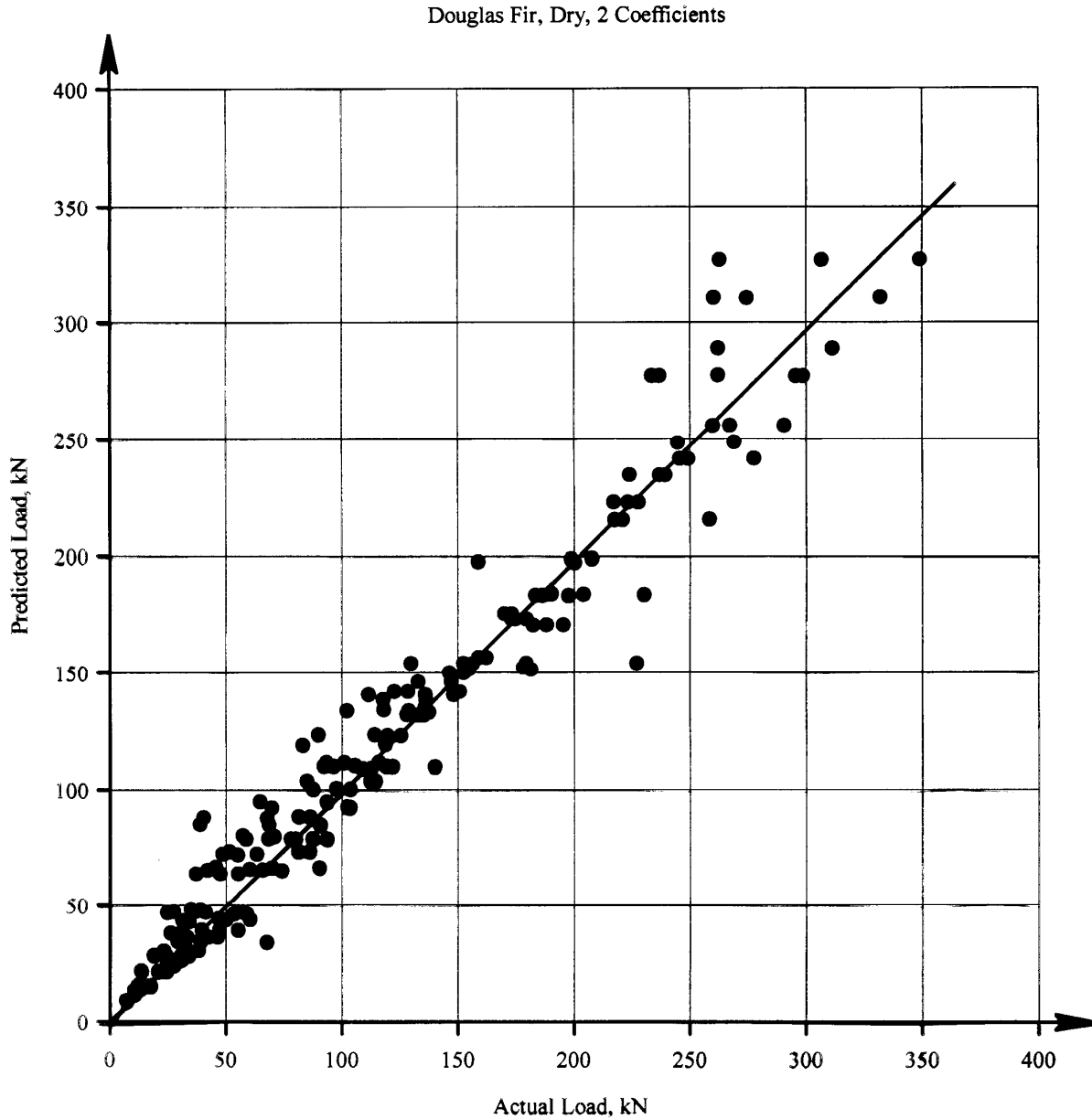
$\sigma_{Area} = 4.5 \text{ N/mm}^2 \{660 \text{ psi}\}$ $\sigma_{Travers} = 90 \text{ N/mm} \{510 \text{ \#/in.}\}$ $\sigma_{Longitudinal} = 20 \text{ N/mm} \{170 \text{ \#/in.}\}$
---

From these tests it was then possible to obtain the contribution of the four types of behaviour observed.



Sizes of Bearing Plates

A formula was developed from the data and the predictions were compared with the test results.

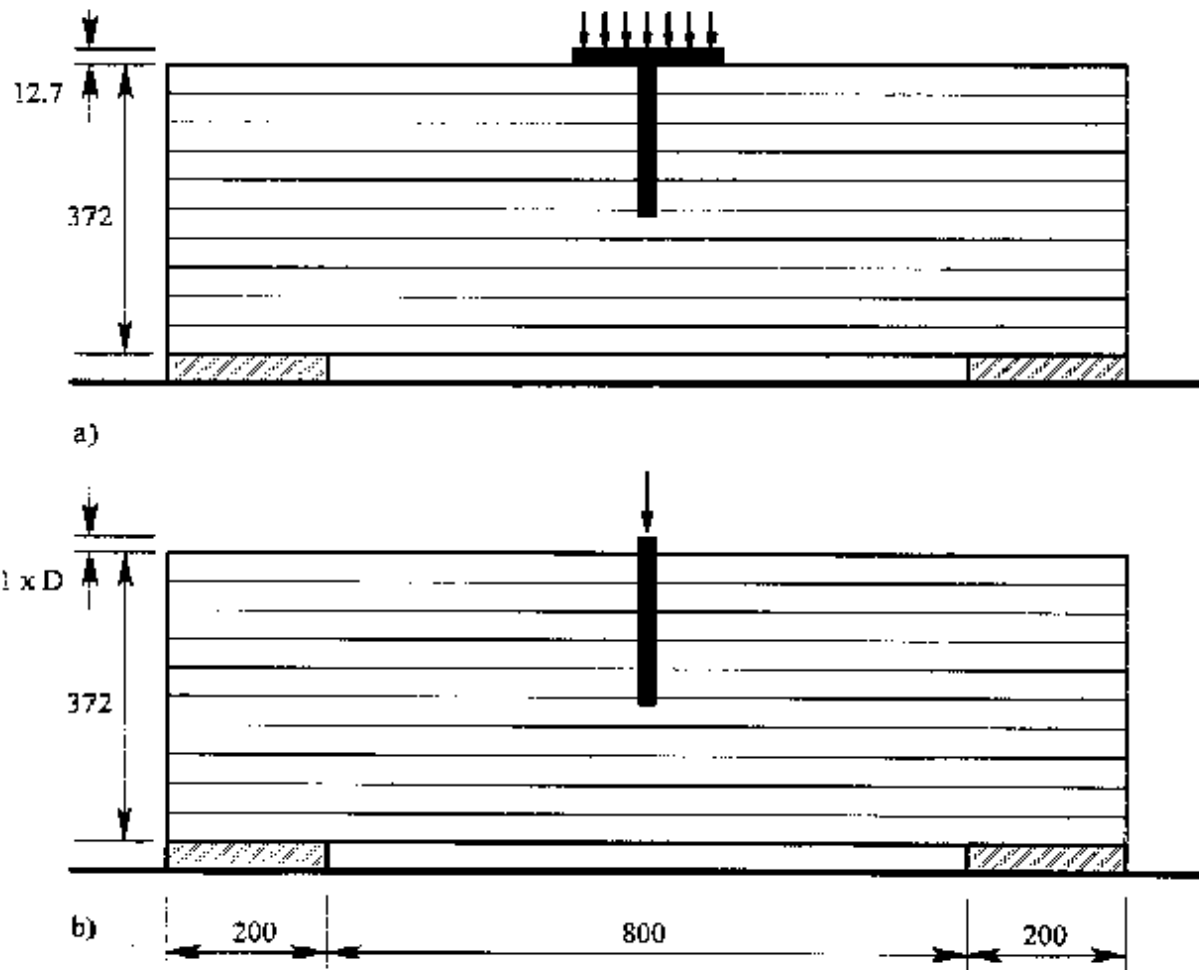


The proposed method of prediction was then compared with the ASTM method.

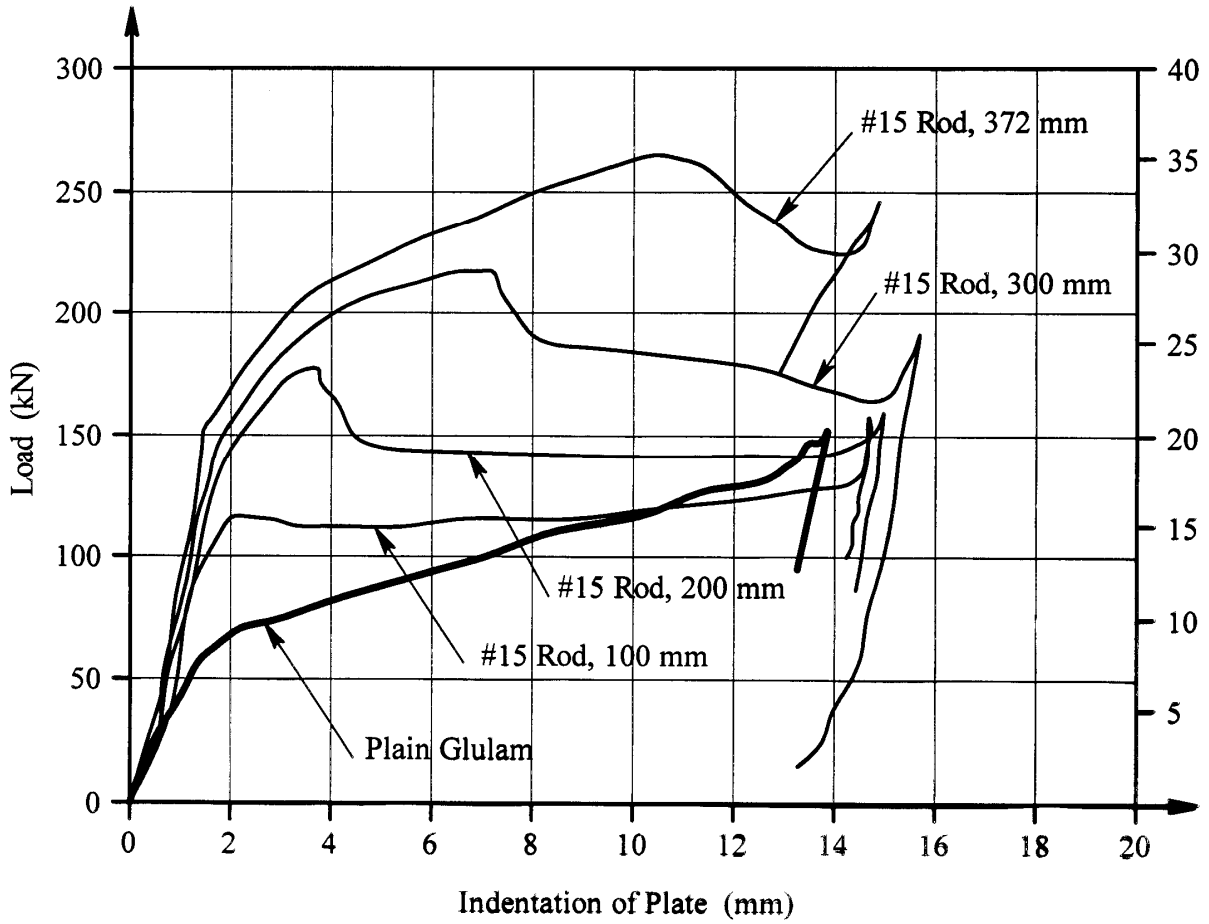
The above comparison showed that for small bearing plates the ASTM method is grossly conservative, while for large bearing plates it is un-conservative.

## INCREASING THE BEARING CAPACITY.

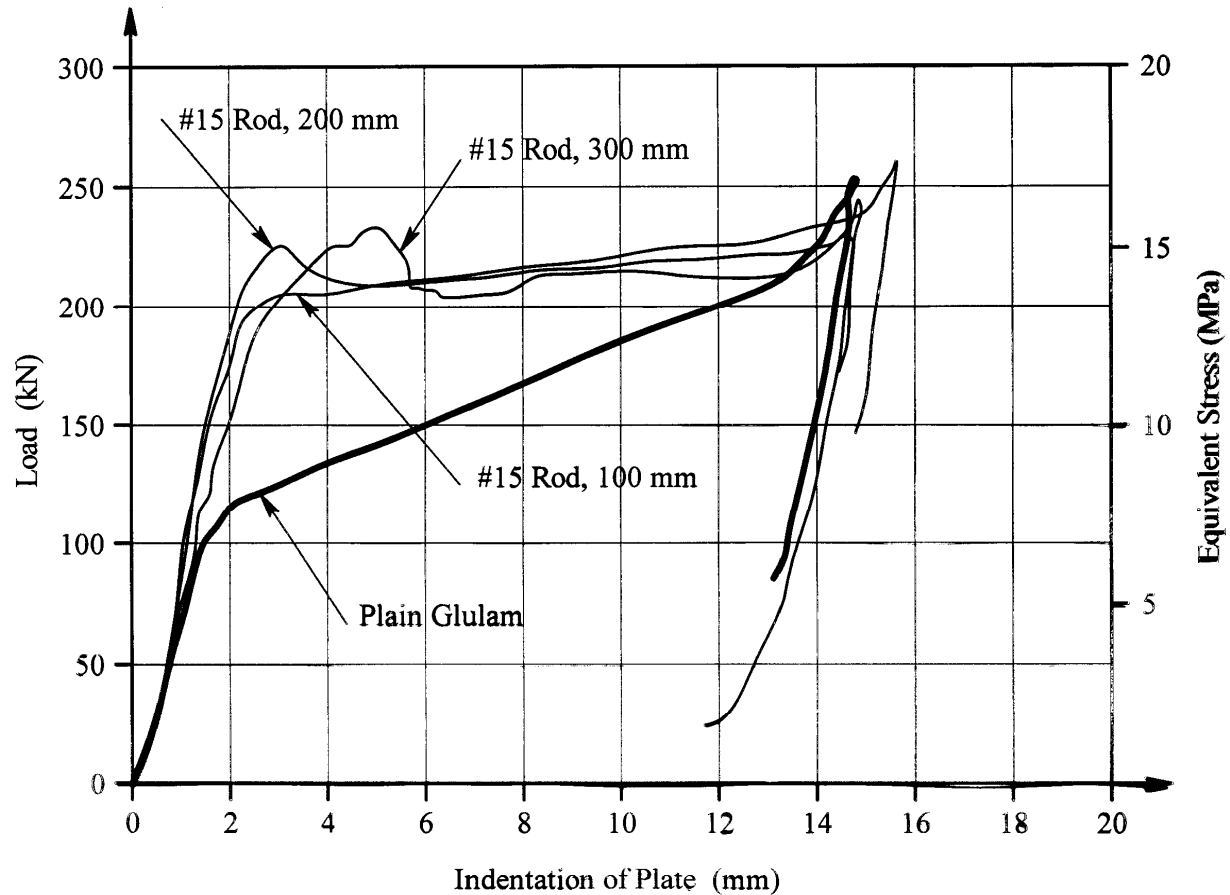
A substantial gain in the bearing capacity of compression perp. can be achieved by combining the usual bearing plate with one or more rods glued into the glulam member perpendicular to the grain.



Testing was conducted and showed that it was possible almost to double the carrying capacity.



### Load / Indentation Curve Plate 102 x 150mm



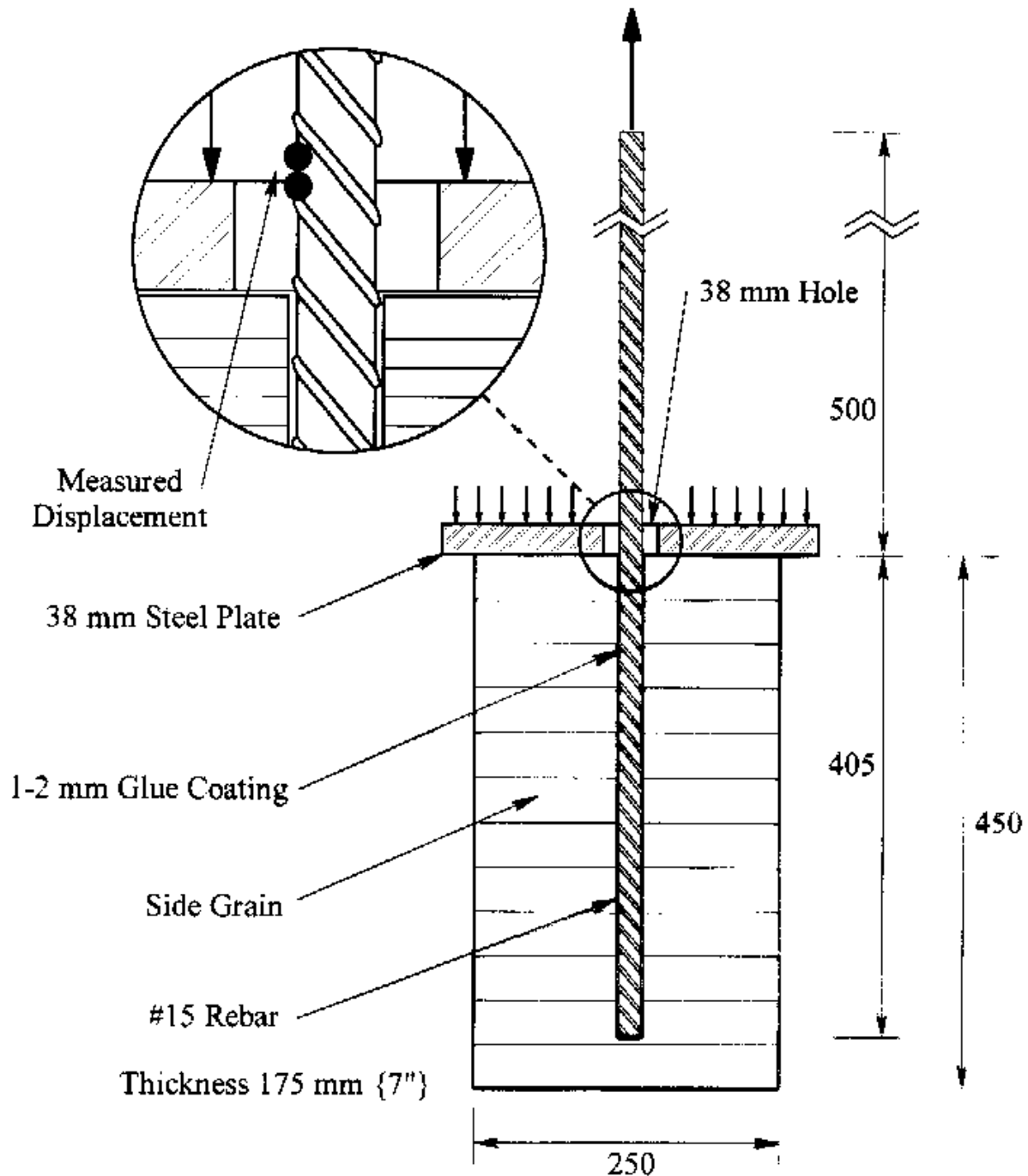
The minimum end distance was established and a design method was prepared by which the effect of the rod could be combined with the effect of the bearing plate.

### EFFECTS OF CLIMATIC CHANGES FOR GLUED-IN RODS.

Because steel and wood have very different expansion coefficients the behaviour of the two materials glued together was investigated.

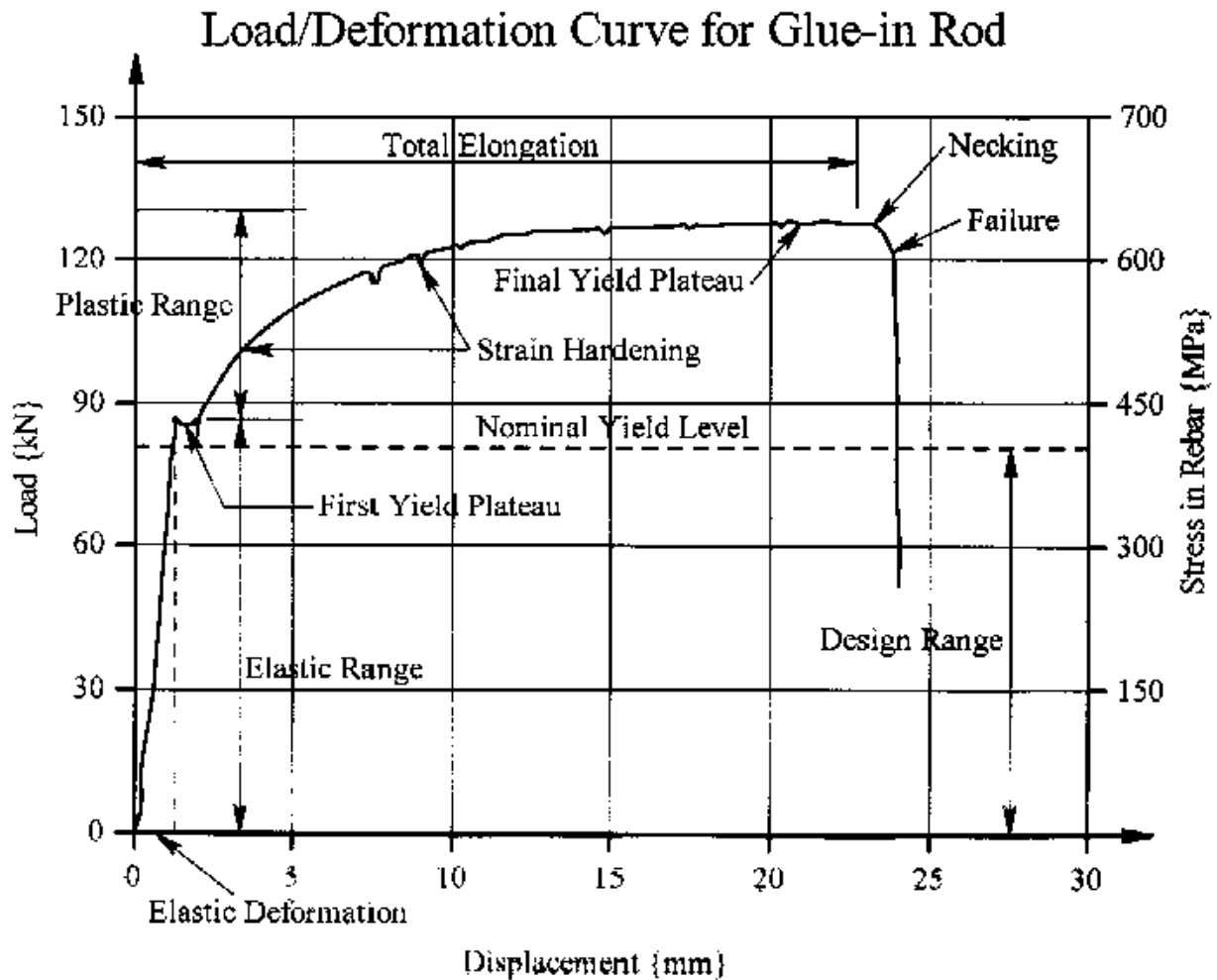
The specimen chosen consists of a 178 x 250 x 450 mm glulam block having a 16mm dia x 905 mm long rod glued into the center of the block.

### Tension Test Specimen



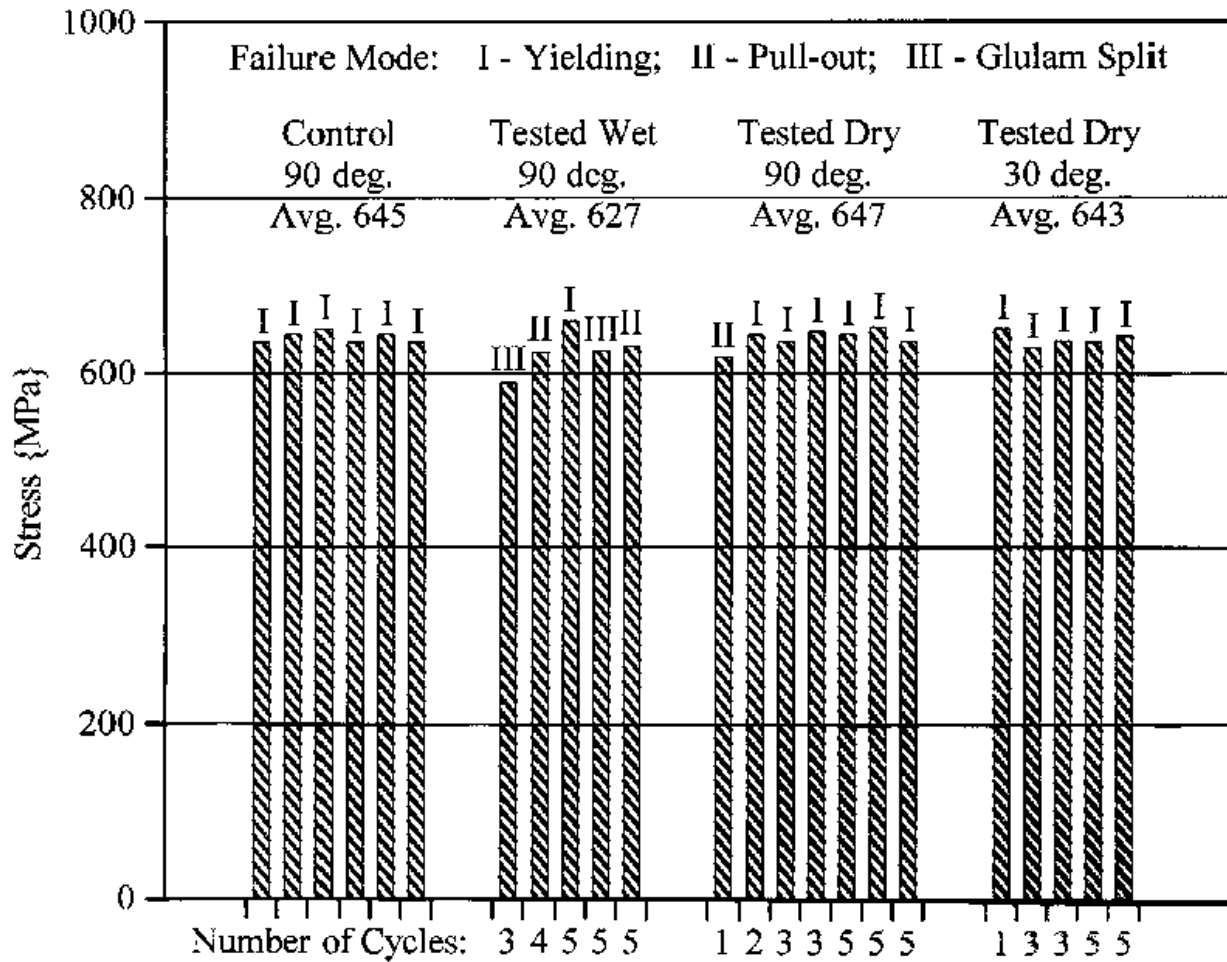
Three types of tests were conducted:

Control test (n=6),  
 Moisture Content (M.C.) test (n=17)  
 Temperature test (n=7)

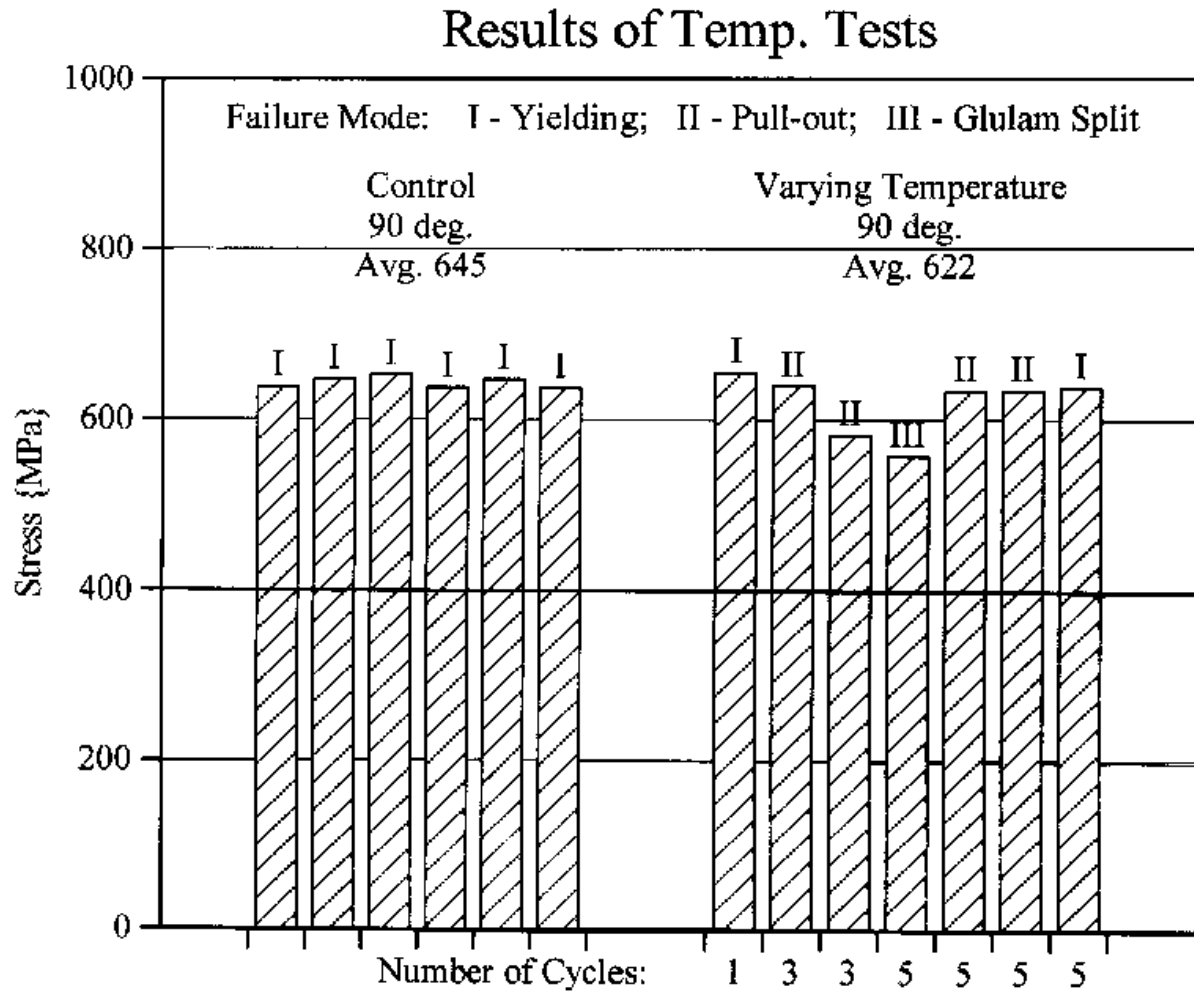


The M. C. specimens were cycled 5 times from 10% to 30% taking a total of 3 months to complete.

### Results of M.C. Tests



The temperature specimens were subjected to five cycles of variation of the temperature from  $-30^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$ .



The results showed that neither of the two “torture” methods had weakened the specimens.

## TESTING FULL SIZED SPECIMENS.

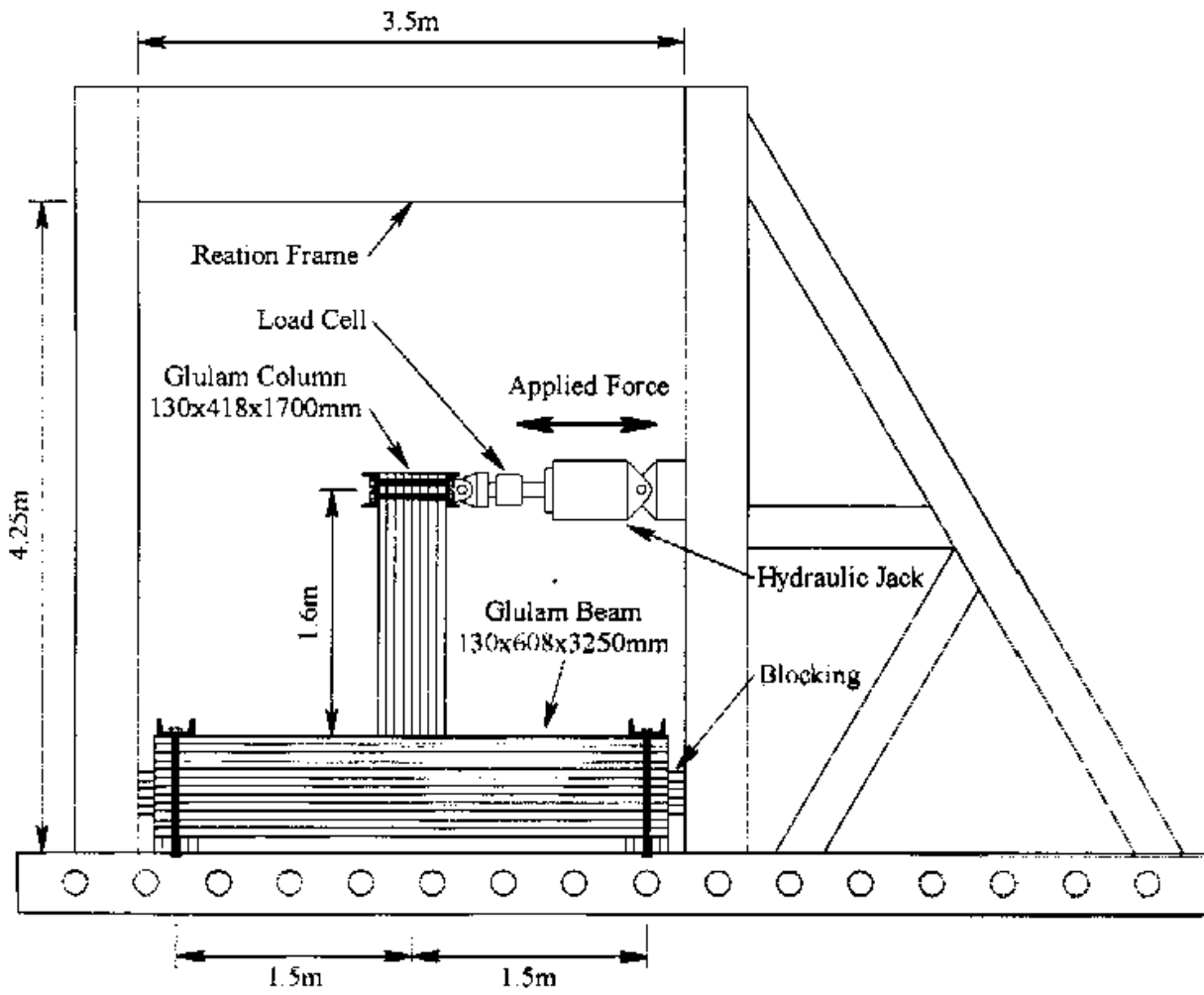
Using the new information we could now design practical joints equal to those of existing steel structures and test the performance of the glued-in rods.

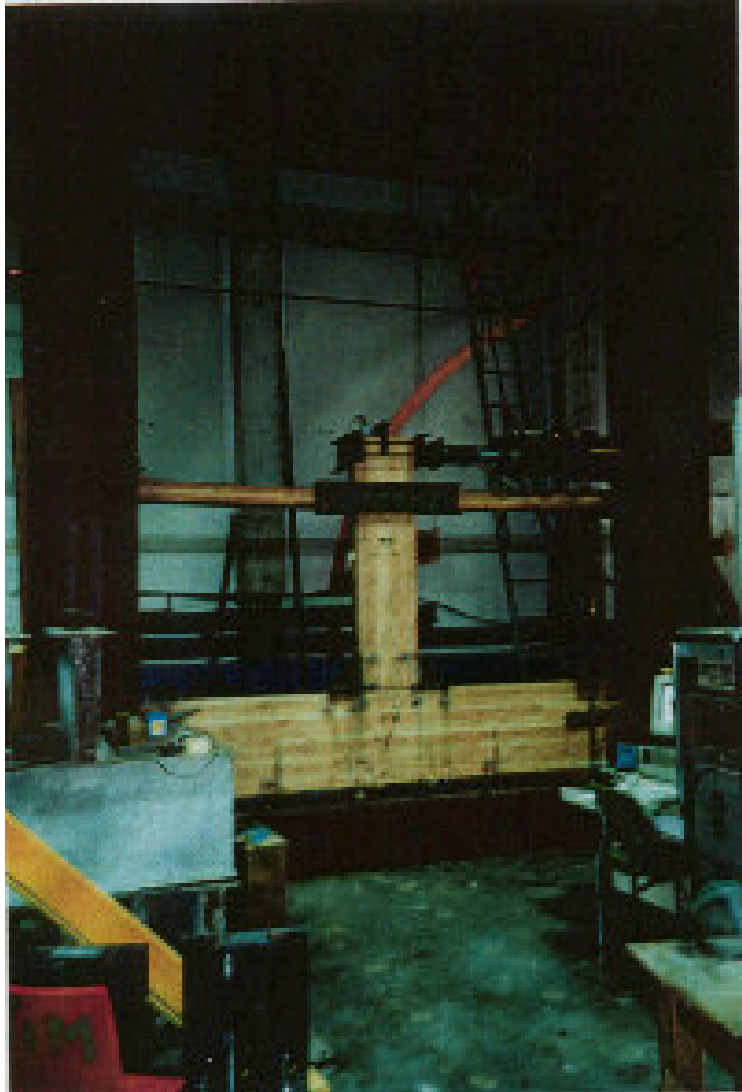
Racking tests were performed first and found to be satisfactory.



Then one-sided beam to column tests were done which also passed with flying colours.

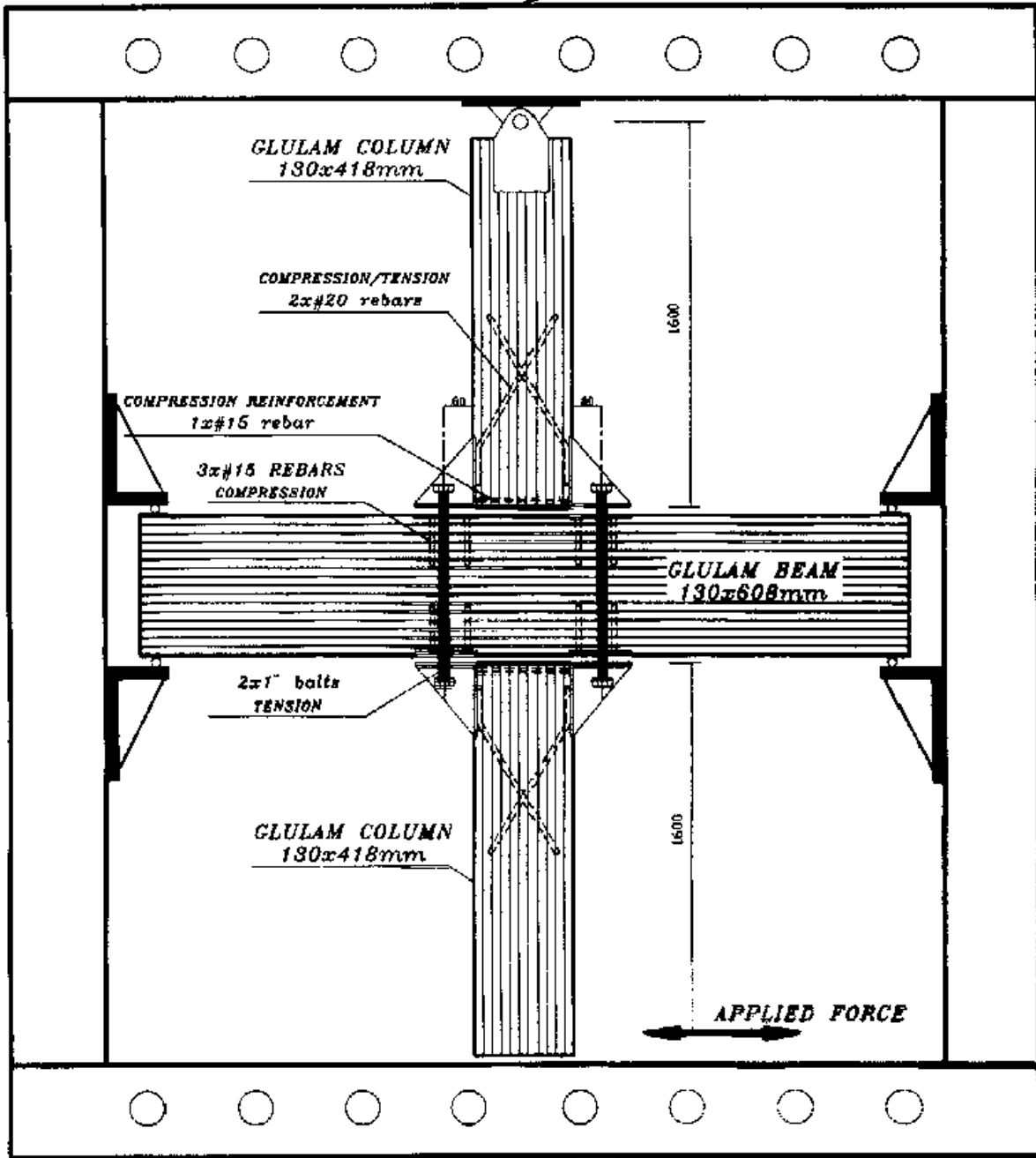
## Testing Frame





Tests with beams having columns top and bottom were also carried out and showed that they amply passed our criteria, except for interstory drift caused by wind loads.

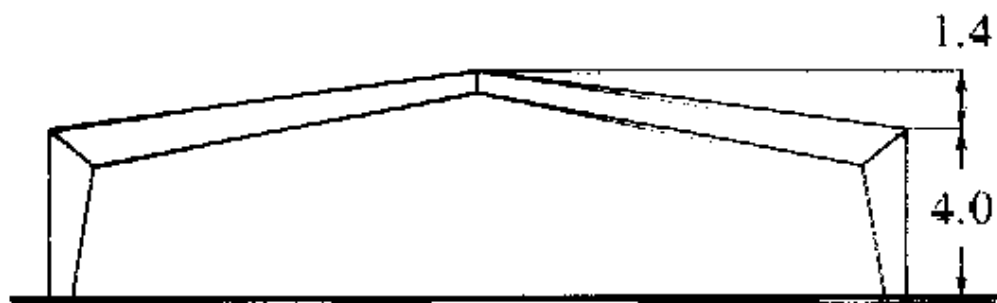
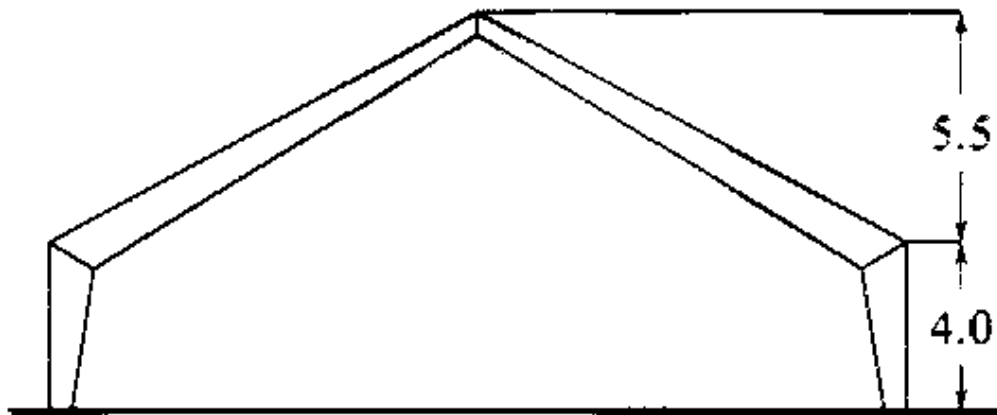
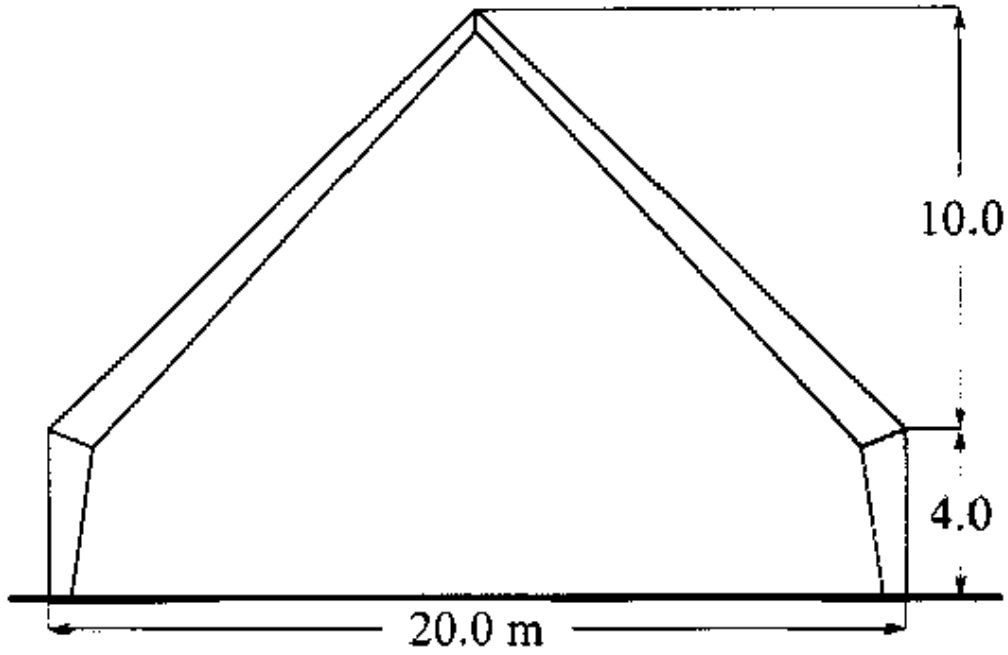
REACTION FRAME





This was followed by testing of knee joints with different slopes.

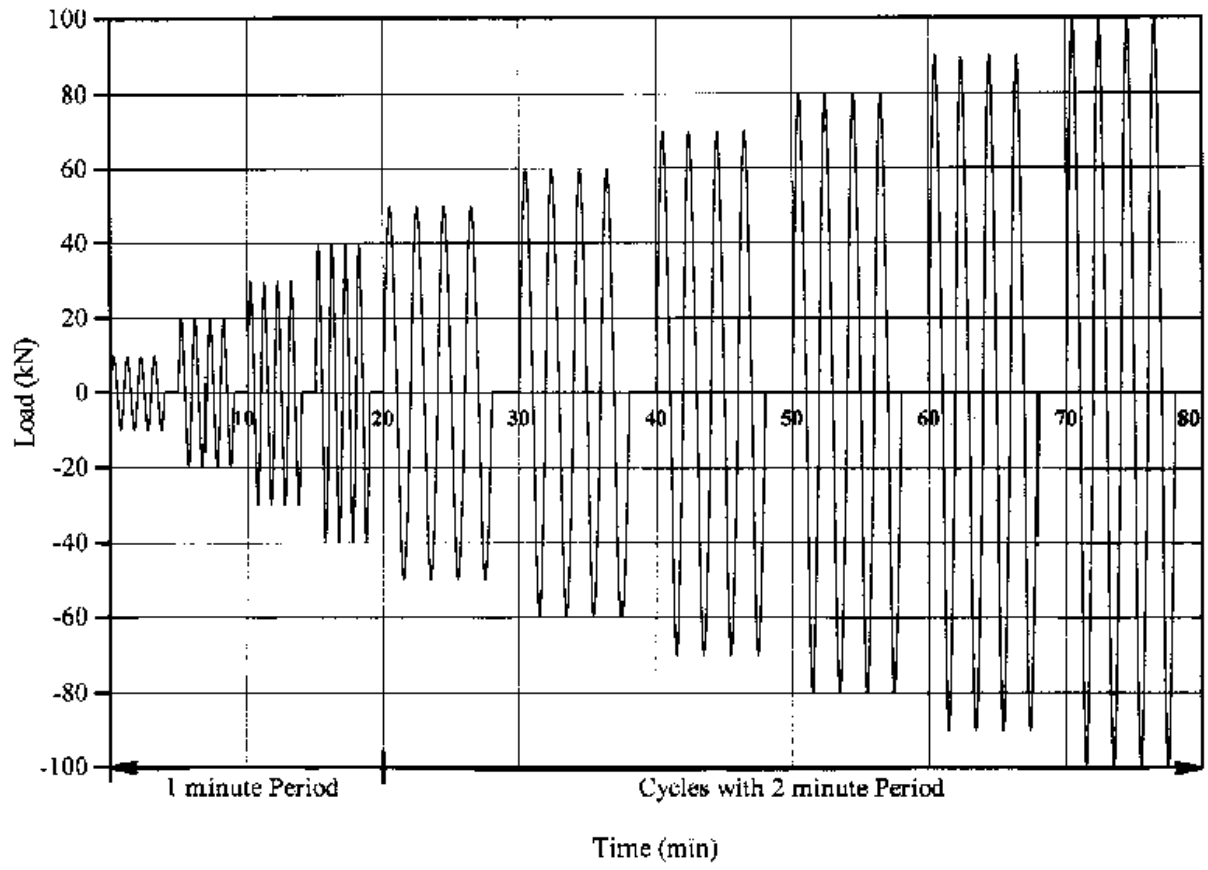
## Different Knee Joints



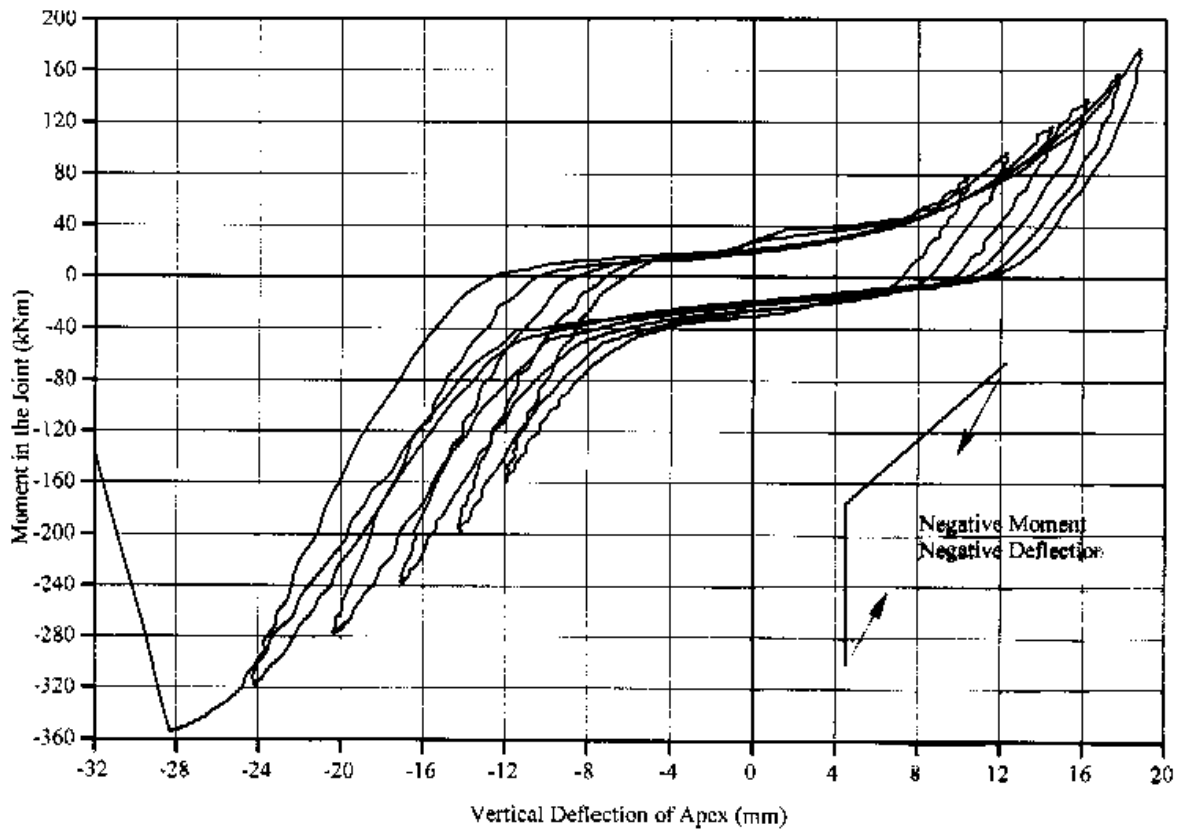


The final test was a long-term load experiment in which the design load was present for seven months while the climatic conditions changed four times.

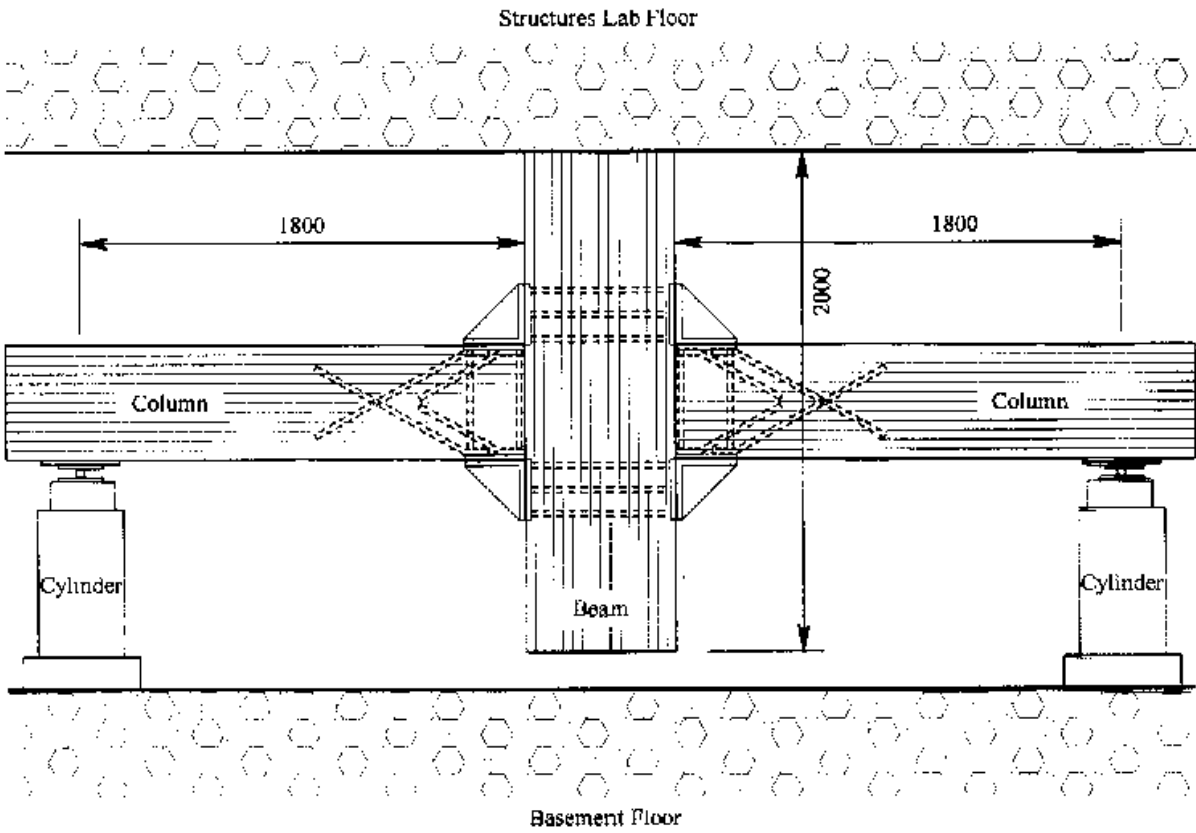
### Load Application Regime



### Moment vs Vertical Deflection: Knee Joint #9 Cycles 5-10



### Long Term Loading Set-up



## SUMMARY.

It was shown that the traditional connections methods for timber do not live up to today's needs for stricter performance requirements

Three types of contemporary connection methods were described, showing that it is indeed possible to implement better jointing methods.

Research work conducted at UBC dealing with the use of glued-in rods was explained.

The advantage of having the rod forming a  $30^{\circ}$  angle is that a greater portion of the cross section will contribute to the transfer of the forces; thus providing greater reliability.

The drawback is that additional bearing stresses are created.

However, a review of the behaviour of the bearing stresses show that our present concept of the compression perp. stresses is underrating their actual capabilities.

Two simple calculation methods are presented that will enable the design engineers to take advantage of the real compression perp. strength.

**THE USE OF STEEL RODS WILL ENABLE US TO DESIGN  
TIMBER CONNECTIONS WITH THE SAME STRENGTH  
AND RELIABILITY AS THAT OF STEEL.**