technical notes

LATERAL STRENGTH OF NAILS IN BUTT JOINTS

by N. Paskaran

1. Introduction

The earliest structural joints in timber have been the carpentry joints. These are cumbersome and considerable time is spent on fabricating them. Subsequently bolted connections with gusset plates were used. The use of common wire nails in fabricating these joints will undoubtedly be a convenient method. However it is essential to ensure that such joints are efficient and safe.

The possible loads to which a nail in a structural joint may be subjected to are given below:

(a) lateral load when the nail is driven into longitudinal section (i.e. side grain) as in both nodal and lengthening joints in roof truss.
(b) lateral load when the nail is driven into transverse section (i.e. end grain) as in ridges in roofwork.
(c) withdrawal resistance when the nail is driven into longitudinal section as in purlins and rafters in roofwork.

When the nail is subjected to the first two types of load, it is essentially in shear. In addition it undergoes bending and also bearing resistance is encountered. In unclenched joints certain amount of slip occurs and withdrawal resistance comes into play. Since these various actions on the nail at a joint cannot be evaluated individually, the combined effect of these actions will be referred to as the 'lateral strength of nail'.

2. Types of joints

The type of nail joints used in timber structures are the lap and butt joints, where the nail is essentially in single and double shear respectively. The butt joints are more commonly encountered in timber structures, and hence the investigation is confined to such joints. These joints are encountered when either two members are fixed to either side of a gusset plate, or single members are fixed to two gusset plates or connected by fish plates (Fig. 1). Depending on the angle at which connecting members meet at a node, the butt joints can be further categorised as follows:

(a) Force acts parallel to grain as in lengthening joints (Fig. 2.1).
(b) Force acts perpendicular to grain as in nodal joints in truss (Fig. 2.2).
(c) Force acts between the extreme positions (a) and (b) as in nodal joints in truss (Fig. 2.3).

It is possible that the nails in butt joints are in single shear, due to insufficient penetration of nails across the total thickness of members. Thus full penetration was ensured in the tests, and should be achieved in practice too.

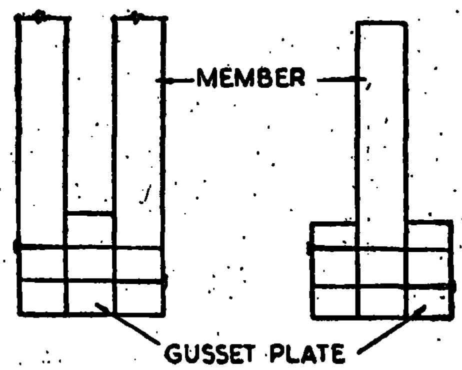

FIG. 1

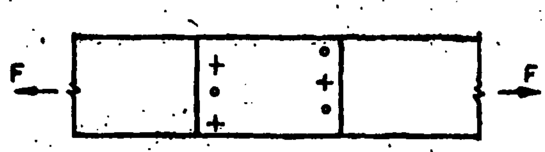

FIG. 2.1

LOAD PARALLEL TO GRAIN NAILS IN CONSECUTIVE ROWS STAGGERED.

3. Factors that influence strength

The important factors that affect the lateral strength of nails in butt joints are as follows:

(a) Species of timber.
(b) Ratio of thickness of members at joint.
(c) Variation in moisture content.
(d) Size, shape of point, number and spacing of nails.

The effect of the ratio of thickness of jointed members on lateral strength of nail has not yet been investigated. It was decided for the present test work on butt joints that the ratio of thickness of jointed members be unity. Since sections having thickness of 25mm. can be used in timber trusses upto a span of 15m. the test joints were fabricated from timber sections either 25mm. or 18mm. in thickness.

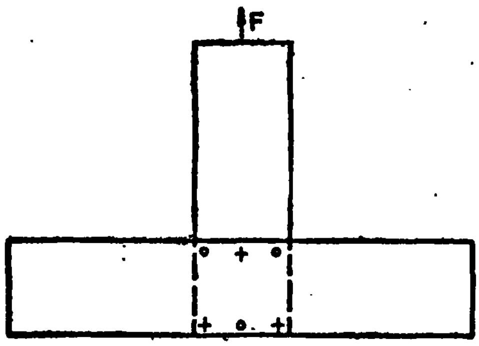

FIG 2·2

LOAD PERPENDICULAR TO GRAIN NAILS IN CONSECUTIVE ROWS UNDERNEATH ONE ANOTHER.

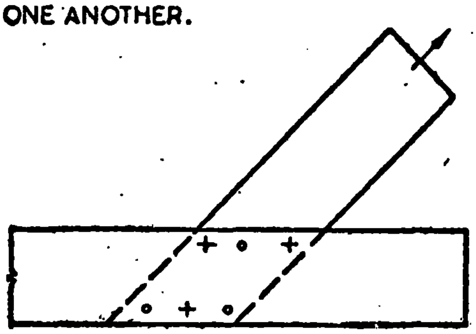

FIG 2.3

LOAD INCLINED TO GRAIN

On seasoning the timber, water from the space between the cell walls evaporate. No shrinkage takes place until all such water has evaporated. This is called the fibre saturation point, which is between moisture content of 25% to 30% in Sri Lanka. Thereafter water from the cell walls begin to evaporate and shrinkage occurs. This process takes place until equilibrium point, which is between moisture content of 12% to 18% in Sri Lanka. As shrinkage of timber occurs below the fibre saturation point, the grip by the fibres on the nail increases, thus reducing the slip and probably increasing the lateral strength of the nail in the joint.

Guidelines for spacing of nails to be used at a joint are given by Masani[1]. A minimum of two nails per row at nodal joints and four nails per row at lengthening joints are to be used. The nails manufactured in Sri Lanka have tapered points only. As such, the influence of nail point on strength was not investigated. However, it has been found that nails with tapered or diamond points are best suited for structural joints, Masani[1].

4 Types of tests

The following types of butt joints were tested:

(a) Load acting parallel to grain.
(b) Load acting perpendicular to grain.

Ordinary wire nails were used in tests. The nails in the two rows in test specimens were arranged as follows:

(a) Nails underneath one another in the two rows (Fig. 2.2).
(b) Nails staggered in the two rows (Fig. 2.1).

Sizes of nails tested were as follows:

(a) Gauge 8 (diameter - 4 mm.) and 90mm. in length.
(b) Gauge 10 (diameter - 3.15mm.) and 65mm. in length.

Three specimens were tested for each test. The joints were tested to destruction with gradually increasing load (Fig. 3). The displacement of the central member with respect to the side members were recorded for each increment of load using a dial gauge. This was referred to as the slip of the joint.

The test joints using gauge 8 wire nails were fabricated from 200mm. x 125mm. x 25mm. timber specimens, with three nails per row as per standard spacing. While the joints with gauge 10 wire nails were fabricated from 200mm. x 50mm. x 18mm. timber specimens, with two wire nails per row as per standard spacing. The nails were driven to full penetration after pre-boring. Suitable pre-bore diameters for each species were chosen from trial tests. Pre-boring is very essential, otherwise the driving of nails will cause primary splitting of timber fibres, thus reducing the efficiency of joint.

From practical considerations, the adjacent nails were driven alternatively from either face of a joint. As it is known that clenched nail joints are marginally stronger than uncut or flush nails, the nails were clenched across the grain. This manner of fixing the nails is both convenient and safe in structures. The length of nail was chosen so that it penetrates 10 to 15mm. beyond the total thickness of the jointed members after full penetration.

5 Theory for calculating lateral strength of nail

The calcalation of lateral strength of nail in butt joints is carried out as suggested by Masani[1]. They have checked their assumptions for safety consistent with economy through destructive and long term proof tests on prototype trusses. The following classification for the life of timber structures can be adopted:

Temporary structure	— life of about 10 years.
Semi-permanent structure	— life of about 30 years.
Permanent structure	— life of about 60 years.

The maximum slip after which the nail joint may be considered to be unserviceable is assumed as 10mm. and the load corresponding to this slip is defined as yield load.

Safe lateral strength of nail is the lesser of the following two values:

(i) For temporary and semi-permanent structures;
   (a) load calculated such that it has a load factor of safety of 3 on the ultimate load.
   (b) load corresponding to an allowable slip of 1.5mm.
(ii) For permanent structures:
   (a) load calculated such that it has a load factor of safety of 3 on the average yield load.
   (b) load corresponding to the restricted slip of the joint, which is taken as one quarter of allowable slip (i.e. 1/4th of 1.5mm.).

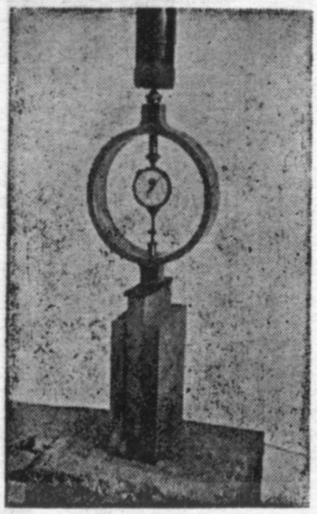

Fig 3: Measurement of slip

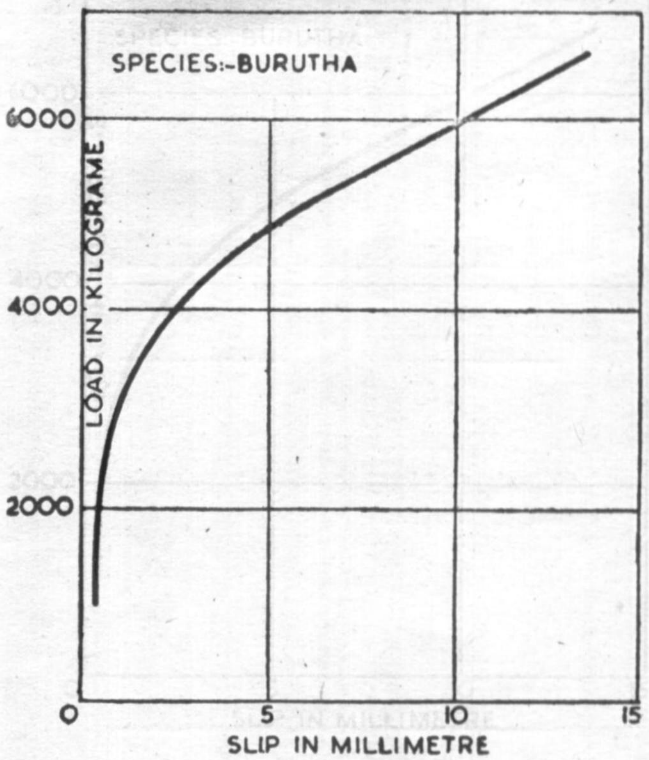

Fig 4: Test Results

6. Calculation of lateral strength of nail

A specimen calculation is given for the test results of load parallel to grain (Fig. 4).

(i) For temporary and semi-permanent structures:

Ultimate load	6,550 Kg.
Load with L.F. of 3 on ultimate load	2,183 Kg.
Load corresponding to allowable slip	3,500 Kg.
Safe load for nail joint ...	2,183 Kg.
Safe load per nail	364 Kg.

(ii) For permanent structures:

Yield load	6,150 Kg.
Load with L.F. of 3 on yield load	2,050 Kg.
Load corresponding to restricted slip	1,800 Kg.
Safe load for nail joint ...	1,800 Kg.
Safe load per nail	300 Kg.

7. Conclusions

The lateral strength of nail at a joint is increased if the nails are staggered in the rows rather than driven one beneath the other.

The values of lateral strength of nail obtained for some of the local species of timber are given in Table 1. The strengths for gauge 8 nails are higher than those of gauge 10 nails. As such it is recommended that gauge 8 nails be used for fabricating the joints in trusses.

(*Continued from page* 20)

earthwork involving 3000 cubes of earth was carried out in levelling the site, from June 1974 till November 1974. Structural work began in July 1974 and by the end of July 1976 Rs. 8.3 million worth of work had been completed. This includes the production area of the main factory building and all other ancillary structures other than the administration block.

The main factory building with a floor area of 120,000 sq. ft. is being constructed in two stages in order to facilitate installation of production machinery. The first stage comprising the production area with a floor area of 96,000 sq. ft. has been completed and the second stage work involving the rest of the factory is in progress. The second stage of construction involves the construction of 24,000 sq. ft. of annex area of the factory that houses the humidification plant rooms, the underground main exhaust air duct, the overhead supply air duct, the switch gear room and other connected services to the production room. The second stage of construction is nearing completion and the entire civil works are expected to be completed by the end of this year.

Analysis of the results of the extensive experimental program undertaken at The Forest Research Institute, Dehra Dun, suggests that for temporary and semi-permanent structures, the lateral strength of nail is approximately same irrespective of the angle at which the members meet at node. This is evident in our results too. Hence the lower of the values obtained for the two type of tests undertaken here can be used as the lateral strength of nail, irrespective of the angle at which the members meet at node.

However, for permanent structures the lateral strength of nail varies considerably with the angle at which members meet at node. It is recommended to carry out tests for these particular cases. However. as an interim measure, the lateral strength of nail when members meet at an angle other than zero or ninety be taken as 0.7 times the lower value obtained from the tests for permanent structures. This will inevitably lead to uneconomical design for the present.

References

1. Masani, N, J., Pruthi, K. S., Lal Sharma and Bhagirath Prasad, *Research report on 'Nail Joints in Timber Structures—Part III'*. Published by The Forest Research Institute, Dehra Dun and The National Building Organisation, New Delhi, 1969.
2. Paskaran, N., *'Nail Joints in Timber Structures'*. Technical Note—"Engineer" Journal of the Institution of Engineers, Sri Lanka, March 1976, Vol. 4, No. 1.
3. Tisseverasinghe, A. E. K., *'A Manual of Timber Utilization for Ceylon'*. Ceylon Forest Department publication, 1971.

TABLE I

LATERAL STRENGTH OF NAILS IN BUTT JOINTS

	Load parallel to grain (Kg.)		*Load perpendicular to grain (Kg.)*	
Species	*Temporary & Semi-permanent*	*Permanent*	*Temporary & Semi-permanent*	*Permanent*
(i) Gauge 8 Nail				
Burutha ...	350	325	300	100
Cypress ...	210	163	80	20
Hora ...	270	110	270	50
Urukanu ...	300	180	225	60
(ii) Gauge 10 Nail				
Burutha ...	240	160	230	60
Cypress ...	80	80	150	55
Halmilla ...	135	90	100	90
Hora ...	125	110	140	100
Kos ...	—	—	125	125
Mahogany ...	75	75	125	60
Milla ...	185	120	150	120

(Nails in consecutive rows are staggered: moisture content 18%)