# technical notes

## NAIL JOINTS IN TIMBER STRUCTURES

*Reviewed by N. Paskaran*

### 1. Introduction

Timber is one of the local materials which can be used both for structural and non-structural purposes. It is unfortunate that in Sri Lanka the timber technology has not been given prominence, and it was only in 1975 that some data on the mechanical properties of local timber has been published-. This has resulted in the inefficient use of timber. Further, it has been customary to use few of the popular species in building construction, and this has resulted in the scarcity of these primary species.

One of the structural applications of timber is in roof-work. In the past, the connection of members in trusses by carpentry joints, using jibs and cotters, has been cumbersome and valuable time was spent on fabrication. At present, bolted connections with gusset plates are being used. The use of wire nails in fabricating these joints will undoubtedly be a convenient method. Results from an extensive test program on "Nail joints in timber structures" conducted over twenty years at The Forest Research Institute, Dehra Dun, India is reviewed, and recommendations for such use are given in this note.

The nails used in corrosive environment, such as industrial buildings, coastal regions, and exposed to weather are susceptible to rusting. It is recommended to use galvanised wire nails in such locations, and ordinary wire nails in other locations.

The possible loads to which a nail in a structural joint may be subjected to are the following:

(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.

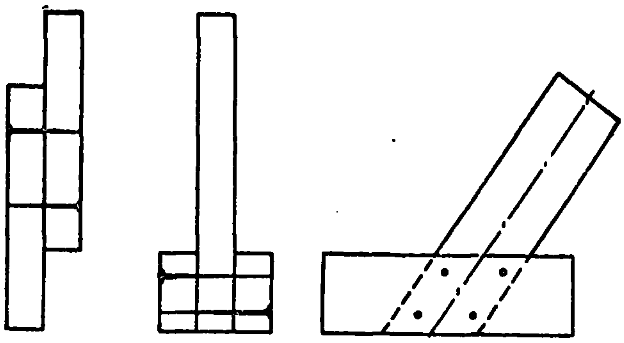
(b) lateral load when the nail is driven into transverse section (i.e. end grain) as in ridges in roof-work.

(c) withdrawal resistance when the nail is driven into longitudinal section (i.e. side grain) as in purlins and rafters in roof-work.

When the nail in a joint is subjected to a lateral 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 in a joint cannot be evaluated individually, the combined effect of these actions will be referred to as the "lateral strength of nail'.

### 2. Factors that Influence Strength

The important factors that affect the lateral strength of a nail in a joint are the following:



LAP JOINT BUTT JOINT

(a) species of timber.
(b) type of joints.
(c) ratio of thickness of members at joint.
(d) size, shape of point, number and spacing of nails.
(e) method of driving and depth of penetration of nails.
(f) factors that affect the strength of timber, such as inherent variability due to growth, duration of loading, moisture content etc.

### 3. Type of Joints

The type of nail-joints used in timber structures are:

(a) lap joint where the nail is essentially in single shear (Fig. 1.1).
(b) butt joint where the nail is essentially in double shear (Fig. 1.2).

The joints can be further categorised, depending on the angle at which the force in connecting members acts in relation to the orientation of their grains, as follows:

(a) Force acts parallel to grain as in lengthening joints.
(b) Force acts perpendicular to grain as in nodal joints in truss.
(c) Force acts between the extreme positions (i) and (ii), as in nodal joints in truss (Fig. 1.2).

The butt joints are more commonly encountered in timber structures.

### 4. Ratio of Thickness of Members at Joint

Detailed experiments to determine the influence of the ratio of thickness of jointed members on lateral strength of nail have not yet been undertaken. However, the following recommendations are given from limited tests carried out:

Minimum thickness of thinner members in

(a) lap joint be 2/3rds the thickness of the thicker member.

(b) butt joint be 3/4ths the thickness of the central main member.

## 5. Size, Shape of Point, Number and Spacing of Nails

### 5.1 *Size of Nail*

The diameter of nail considerably influences the lateral strength of nail at a joint.

The diameter of nail must be within the range of 1/11th to 1/6th of the least thickness of members being connected.

The length of nail must be such as to at least penetrate the total thickness of connecting members.

### 5.2 Shape of Nail Point

The following shapes of nail point were investigated.

(a) Blunt or flat-ended point.
(b) Tapered point.
(c) Diamond shaped point.
(d) Long sharp point.

The nail with either tapered or diamond shaped point had greater lateral strength than the other shapes of nail point.

In Sri Lanka, only nails with tapered points are manufactured.

### 5.3 Number of Nails

The line of nails at right angles to the direction of force in connecting member is referred to as the row of nails at a joint.

At a joint where there are a large number of nails, the total load at a joint can be taken as the sum of the individual capacities of nails, provided they are grouped according to standard spacing. It was observed that the strength of a joint decreases with increase in number of nails in a row. However, the slip too decreases under such tests indicating a stiffer joint.

The following are the recommendations regarding the number of nails:

A minimum of two nails at a nodal joint in a truss and four nails at any lengthening joint are essential for obtaining a better and stiffer structural joint. When a large number of nails are to be provided at a joint, they should be arranged so that there are maximum number of rows rather than more nails in a row.

### 5.4 Spacing of Nails

The spacing of nails at a joint has been arrived at based on, ease of design and fabrication, prevention of splitting of connecting members, and ensuring maximum strength. The following spacings are recommended:

(a) distance of nail from the end of member along the grain, referred to as 'end distance' be a minimum of 10d.

(b) distance between two adjacent nails in a row, referred to as 'intermediate distance' be a minimum of 5d.

(c) distance of nail from the edge of the member perpendicular to grain, referred to as 'edge distance' be a minimum of 5d.

(d) distance between two adjacent rows of nails across the grain referred to as 'row spacing' be a minimum of 5d. where 'd' is the shank diameter of nail.
The distance between adjacent nails in a row of nails be a maximum of 15d.
Nails at a joint shall be grouped and spaced so that the line of force in structural member passes through the centroid of the group of nails. When such an arrangement is not practicable, the force in member be increased appropriately (say 25%), to allow for any eccentricity.

## 6. Method of Driving and Depth of Penetration of Nails

### 6.1 *Method of Driving Nails*

From practical considerations, the adjacent nails at a joint be driven from either faces.

Pre-boring is very essential, otherwise the driving of nails will cause primary splitting of fibres, thus reducing the efficiency of joint.

The recommended pre-bore diameters for various types of wood are given in Table 1.

TABLE I

RECOMMENDED PRE-BORE DIAMETERS FOR VARIOUS TYPES OF WOOD

| Shankdiameter of nail (mm) | 2.50 | 3.55 | 4.00 | 5.00 | |
|---|---|---|---|---|---|
| Gauge ... ... ... | 12 | 9 | 8 | 6 | |
| Pre-bore suitable for very hard wood | 2.24 | 3.15 | 3.55 | 4.50 | 1 gauge more than gauge of nail |
| Pre-bore suitable for hard wood | 2.00 | 2.80 | 3.15 | 4.00 | 2 gauge more than gauge of nail |
| Pre-bore suitable for soft wood | 1.80 | 2.50 | 2.80 | 3.55 | 3 gauge more than gauge of nail |

### 6.2 *Penetration of Nails*

It is possible that the nail in butt joints are in single shear, due to insufficient penetration of nail across the total thickness of connecting members.

Butt joints — Full penetration of connecting members by the nails must be ensured.

Lap joints — The nails should always be driven from the side of thinner member into the thicker member. The total depth of penetration must be at least 2.5 times the thickness of the thinner member.

The clenched nail joints are marginally stronger than uncut or flush nails, and hence the nails be clenched across the grain.

## 7. Moisture Content

The following tests were carried out to determine the effect of moisture content on the lateral strength of nail:

(a) dry nailed/dry tested.
(b) wet nailed/wet tested.
(c) dry nailed/wet tested.
(d) wet nailed/dry tested.

The use of seasoned timber at equilibrium moisture content of 12% is recommended.

## 8. Duration of Loading

This is allowed for by classifying the structures according to their service life, and by suitable calculation of lateral strength for the type of structure under consideration. The following classification of structures are recommended:

Temporary structures - life of about ten years.
Semi-permanent structures - life of about thirty years.
Permanent structures - life of about sixty years.

## 9. Calculation of Lateral Strength

The assumptions made in the calculation of lateral strength of nail are checked for safety consistent with economy through destructive and long-term proof tests on prototype trusses. Tests on lateral strength of nail for few of the local species have been carried out and the results are to be published by Paskaran[4].

It is envisaged that the use of nail joints in structural works such as housings, industrial buildings, site offices etc., will yield considerable cost savings.

## References

1. Masani, N. J., et al, *'First report on the strength of nailed joints for timber structures—Part I'*, The Forest Research Institute, Dehra Dun and The National Building Organisation, India, 1958.
2. Masani, N. J., et al, *'Research report on nail joints in timber structures—Part II'*, The Forest Research Institute, Dehra Dun, and The National Building Organisation, India, 1963.
3. Masani, N. J., et al, *'Research report on nail joints in timber structures—Part III'*, The Forest Research Institute, Dehra Dun, and The National Building Organisation, India, 1969.
4. Paskaran, N., *'Lateral strength of nails in butt joints'*, to be published.
5. Upali Fernando and W. A. R. Perera, *Structural use of local timber in buildings*, Engineer, Vol. 3, No. 4, Dec. 1975.