TIMBER ROOF FOR MOUNTAINOUS REGIONS

Design and Installation Manual

सत्यमेव जयते
Government of India
Department of Science & Technology
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Development Alternatives

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INTRODUCTION

This manual has been prepared as part of a project on '*Delivery Model for Eco-friendly Multi Hazard Resistant Construction Technologies and Habitat Solutions in Mountain States',* which has been implemented in Uttarkashi (Uttarakhand) under the TIME LEARN (Technology Innovation in Mountain Ecosystem Livelihood Enhancement through Action Research and Networking) programme of the Department of Science and Technology. The project envisage to introduce new system of construction in the region which are resource and energy efficient, can be produced locally in a decentralized production setup, cost effective and easy to adapt. Considering all the above factors, ***Chir*** **Pine shingle roofing on timber under-structure** was proposed in the region. The technology was produced locally at an enterprise unit setup developed under the project. The local artisans and carpenters were trained in the technology specifications, production and its implementation through demonstration buildings at the project area. Timber based solutions include treatment system for timber, fabrication of trusses for roof under-structure and fabrication of *chir* pine shingles fabricated at a local carpenter's workshop. These solutions have been introduced with technical support from Forest Research Institute (FRI) in Dehradun.

This manual is meant to serve as a reference document for construction of a roof using timber truss and shingles in mountain areas, as characterized by Uttarkashi. It is meant to guide building artisans, especially carpenters in constructing sloping roofs which would be durable and show increased resistance to natural hazards like earthquakes and high velocity winds. It must be noted that timber as a material offers many possible designs for a given roof span. The design shown in this document is one of the truss designs developed by Forest Research Institute in Dehradun and implemented in a community building in Kamad village, Uttarkashi. This manual can be seen as a one step in addressing the larger design and training need for carpenters and to scientifically upgrade traditional carpentry practices in mountain regions. This manual is comprised of four sections – First, **Background** which covers the observations and shortcomings of traditional truss roofing practices in the region. Second, **Basic Principles of Timber Roof Technology** covers basic design, types of truss and jointing details of timber roof. Third, **Installation of Timber Roof Technology** covers the process followed for timber truss installation in in a community building in Kamad village, Uttarkashi. Fourth, **Timber Treatment** covers details of all timber treatment methods**.**

Background

The use of timber in construction in mountain regions, as characterized by Uttarkashi, takes many forms including structural framing, wall panelling, roof finish and also as tying elements in combination with stone masonry for increasing resistance to earthquakes. Roof construction in mountain regions has traditionally used locally available timber and stone. However, in the face of changing aspirations and access to newer materials, traditional skills have suffered. Also, the damages and casualties suffered in earthquakes like the Chamoli earthquake of 1999, preference has shifted to RCC slabs or to light-weight gable roofs with CGI sheets.

Like masonry, the practice of carpentry has also developed through the hierarchy of the master and apprentice. It is evident from current timber-based construction that the quality and level of skill in timber-based construction has been in decline. There are still master carpenters in villages but their role in maintaining the level of timber based construction has been compromised by focus shifting to RCC based construction and because there has been no concerted effort to upgrade carpentry practice in response to changing trends. The policy regulations which determine ease of ‘legal’ access to timber also seem to be responsible for continuation of the practice of sourcing timber from nearby forest regions and using it in unprocessed form instead of properly sized sections.

The use of timber in roofing is limited to Rafter and Purlin type of construction. The design of roof support depends ultimately on the size and weight of the roofing material, skill of carpenter and the type of timber which can be easily accessed. The final layer of roofing material has traditionally been *Pathal* or stone – either in the form of large, irregular and heavy slabs or thinner and lighter stone slates which are mostly irregular in shape. The practice of using stone slates which are cut to uniform size is not common in Uttarkashi – whereas it is fairly common in Himachal Pradesh.

One common typology observed in the region is **Purlin roof -**

In this roof, timber purlins span the length of the roof by directly resting on supports provided by the two gable walls. These purlins are often topped with a layer of timber planking which provides the base for a layer of stone roofing. The timber used is mostly in the form of unprocessed round beams of 8”-10” diameter which are placed at a spacing of 1’6” to 2’. The purlins are normally used for continuous span of 8’ to 10’ as per size of the room. Using the internal walls as intermediate supports, this roof can extend to the length of the entire house.

The round timber purlins are simply placed on the gable wall directly and project about 1 foot outside the wall. Rough timber planking is nailed on top of purlins to provide a base for *Pathal.*




Traditionally, a practice of checking the purlins for any bending or displacement was followed every few years. This was such that the purlins could be replaced if need be. With changes in lifestyle, this is not done anymore and damaged roofs are usually abandoned.

This practice of roof construction is vulnerable to damage and collapse during an earthquake, because of instability of the gable wall, poor connection between roof under-structure and masonry and no connection between the individual purlins.

The following are observations and shortcomings of the roof in the region which need attention-

1. The load of the roof is directly resting on the gable walls- these two walls are not stable enough to resist movement during earthquake. This will displace the rafters and may cause collapse of roof. There should be a seismic band in timber or RCC at the eave level of the roof and at the top of the gable wall to stabilize the triangular portion of wall. The two bands should be connected to each other.
2. The purlins in this type of roof construction have very little resistance against movement in case of an earthquake. There is a need to secure them with each other so that all purlins together behave a single unit instead of so many individual members. One way of doing this would be to support the purlins, preferably by a single piece rafter running between the ridge purlin and the two long walls opposite each other.

3. In many houses, existing sloping roofs are modified by extending RCC roof slabs which are structurally attached to the house. These extensions are dangerous for earthquakes. In case of ground shaking, they will transfer the impact of their heavy mass movement to the house structure and to the roofing under-structure, thereby increasing the chances of collapse of the sloping roof.

4. In some houses, due to limited economic means, the walls are constructed only till the lintel level, over which gable part of the roof is enclosed with lightweight materials like timber planks or even CGI sheets. This method is in fact very effective in increasing earthquake resistance of sloped roof houses in the mountain regions because it eliminates the vulnerable gable part of the wall. It also reduces the dead weight of the structure.

5. Seen here is the timber understructure of a primary school building in Kamad village. The understructure is with sawn Pine wood. Although the truss (King post type) principle has been adopted, the inadequate sizing of members and joinery compromise truss behavior. However, the adoption of a hipped roof design adds to the overall strength of roof understructure.

6. There are few instances of a truss construction in traditional houses – however this is largely in the form of a front veranda construted as a wooden frame resting on stone masonry of the lower storey. This kind of structural timber practice is rare today, even though traditional motifs on timber are incorporated in some cases. Seen here is a queen post truss in a house in Raithal village, Uttarkashi. The roofing is with slate stone. The house and the timber veranda are more than 30 years old.

Basic Principles of Timber Truss Technology

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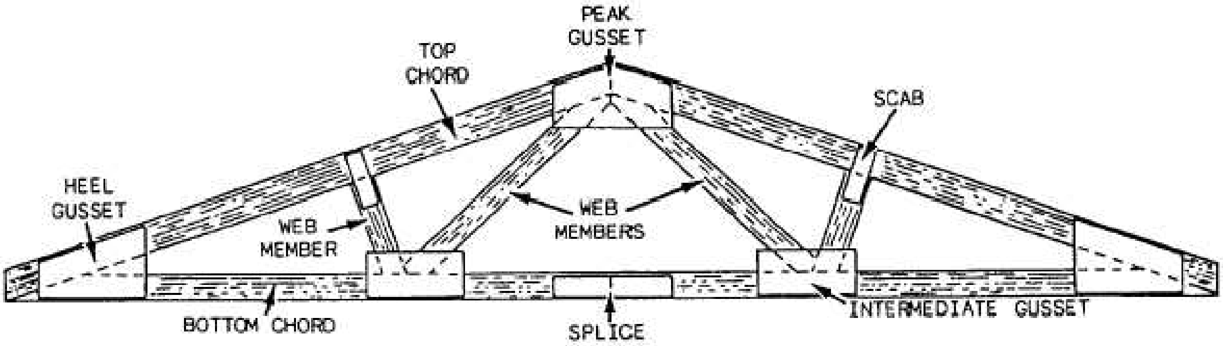
Design of Truss

A truss is a structure with straight pieces forming trinagles to support a load. The design of truss ensures that members of a truss are placed under tension or compression, but never under bending stress.

Roof trusses have the benefit of economic use of material (timber/ steel/ bamboo). Composed of individual lightweight pieces, a truss also has advantage in transport and assembly as compared to conventionbal roof structures. But trusses are more labour intensive and also often require connection devices to join members of a truss or to anchor the truss securely to wall masonry. However, if a number of identical trusses are to be manufactured, then there can be significant cost advantage. The height of a truss is usually larger than height of the purlin and rafter type roof. This is usually not a disadvantage because a sloping roof does not adequate slope to facilitate roof drainage and water-tightness.

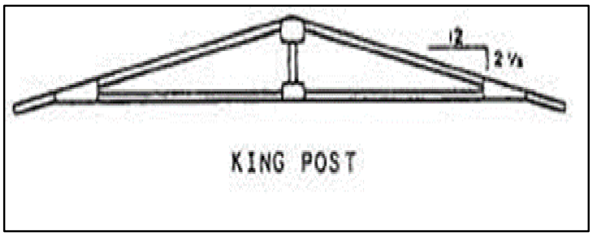


Types of Truss

Roof trusses come in a variety of shapes. The ones most commonly used in light framing are the king post, the W-type (or fink), and the scissors. The allowable spans of various trusses ultimately depend both the sizing of truss members and the design of truss. Sloping roofs in mountain regions like Uttarkashi are generally between 10'-20'. The size of truss members is generally not more than 5". Considering this, the following three types of trusses can be adopted for ordinary construction.

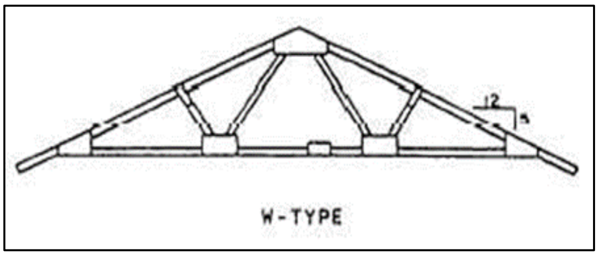
King Post

The simplest type of truss used in frame construction is the king-post truss. It consists of top and bottom chords and a vertical post at the center. **Can be used up-to a span of 12' to 14'.**



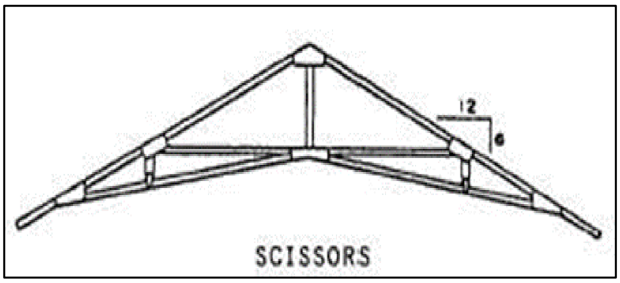
W-Type (Fink)

The most widely used truss in light-frame construction is the W-type (fink) truss. It consists of top and bottom chords tied together with web members. The W-type truss provides a uniform load-carrying capacity.
Can be used up to a span of 18'-20'

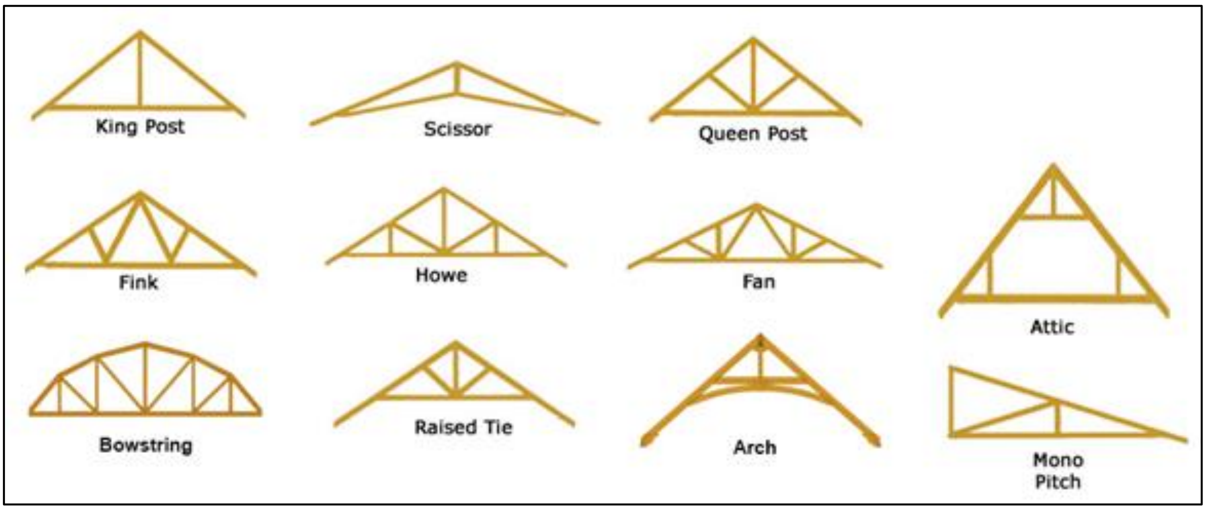


Scissors

The scissor truss is used for building with sloping ceilings. Many residential, church, and commercial buildings require this type of truss. Generally, the slope of the bottom chord of a scissor truss equals one-half the slope of the top chord. Generally, flatter the slope, greater are the stresses. Flatter slopes, therefore, require larger members and stronger connections in roof trusses.
Can be used for spans of 20'-22'.



A truss can be made in a variety of designs. It is an excellent building element for efficient use of timber and for beautiful architectural expression!



Truss Jointing Details

Construction of timber trusses is governed by a large extent to the type of connectors available for use. In many cases, the sizing of truss members is dependent on the type of connector, since each connector needs a certain contact area with the truss members. The material and quality of connection between truss members directly influences the durability and economic efficiency of the truss. The following are common options for connectors.

Nailed joinery

Nails are the most commonly available options for joining truss members. They come in various sizes and can be applied in construction easily. The diameter and length of nails are the two important considerations.

As a rule, it is important to remember that for a good quality of jointing – greater number of nails of smaller diameter is more effective than using fewer nails of large diameter. The nails should be plain headed and diamond pointed. Galvanized nails should be used in case of chemically treated timber.

Diameter of nail: the diameter of the nail should be between 1/11 and 1/6 of the least thickness of the members being jointed.

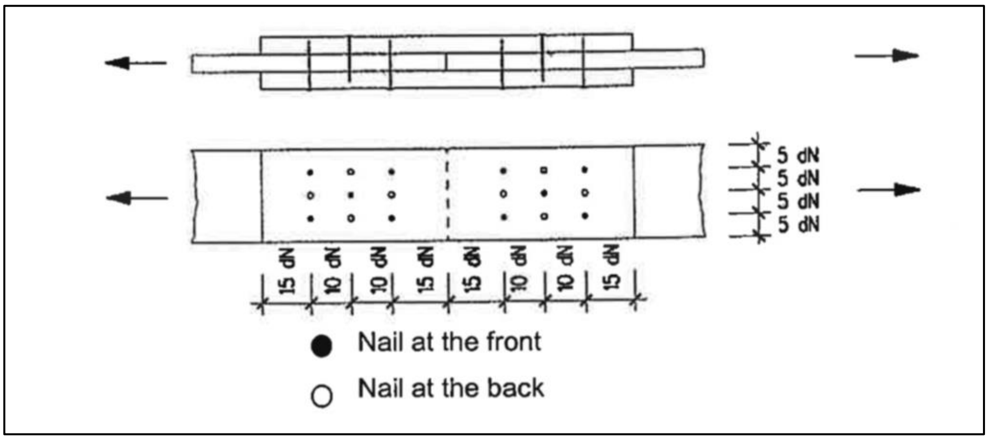
Length of nails:

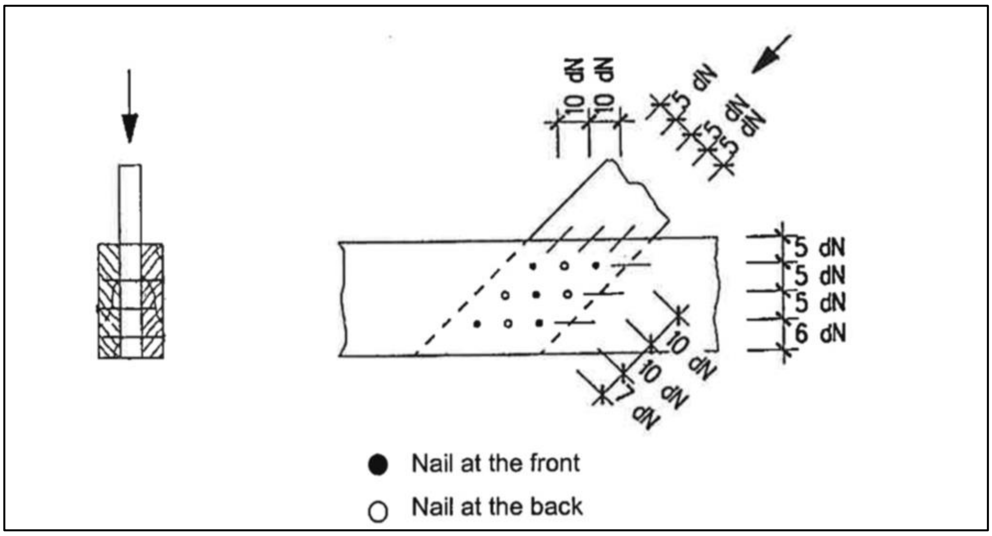
- The length of the nail should not be less than twice the thickness of the timber being secured OR it should be equal to the total thickness of the joining members at the joint.
- The nail must enter the second timber at least 12 times the diameter of the nail.
- The nail must enter the third timber at least 12 times the diameter of the nail.

Nail spacing and edge distance:

Nailed connections often fail because of inadequate distance from the edge or the centre-to-centre distance of the nails. The grains of the timber act prevent them from tearing the edge. In order to achieve full loading capacity of the nailed connection, the following spacings should be maintained-

	Parallel to the wood grain	**Perpendicular to the wood grain**
Centre to Centre distance	10 times nail diameter	5 times nail diameter
Distance to loaded edge	15 times nail diameter	5 times nail diameter
Distance to non-loaded edge	7 times nail diameter	5 times nail diameter





Construction of Timber Truss and Shingle Roof

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Truss Design

A Fink type truss was used for a pine shingle roof of the community building constructed at Kamad village.

Internal dimension of the room: 16'6" x 8'8" (5m x 2.7m)

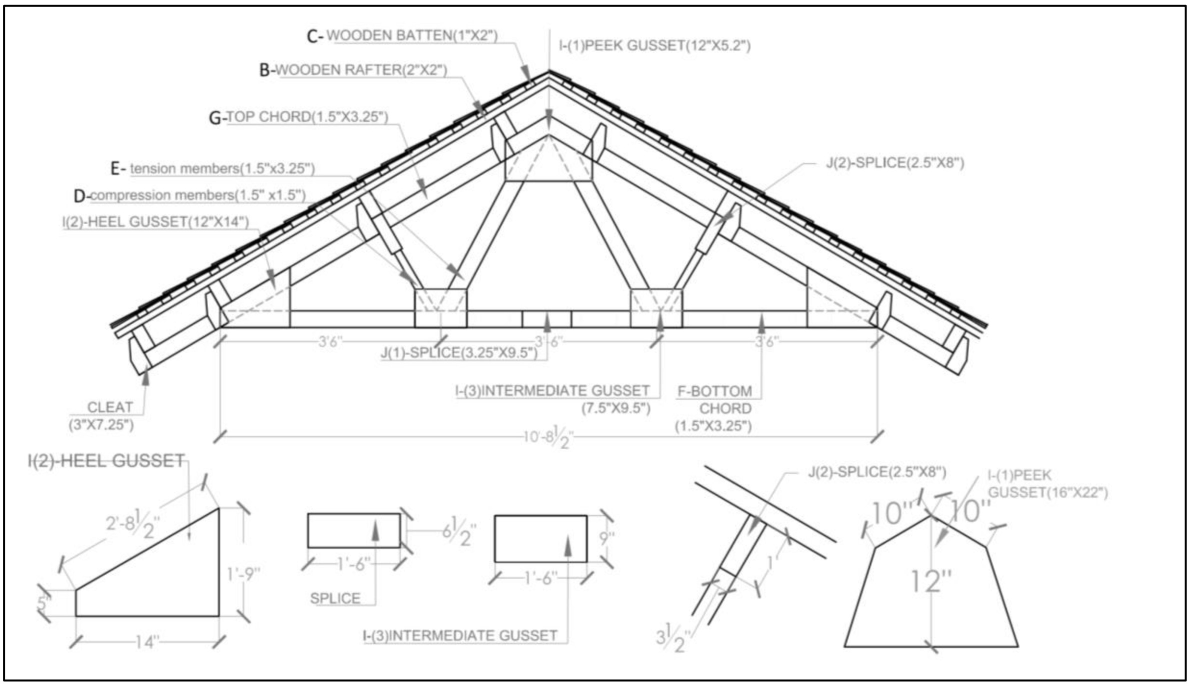
Thickness of walls : 8" (200mm)

Span of truss : 10'9"(3.3 metres)

Slope of truss : 30 degrees

Number of trusses : 3 – two at gable ends and one at mid length of room

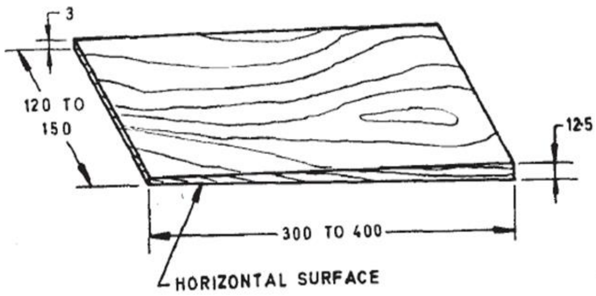
Joinery : Nails with Pre-bore, Nail diameter 3mm, length min 4"-5" (100-125mm)



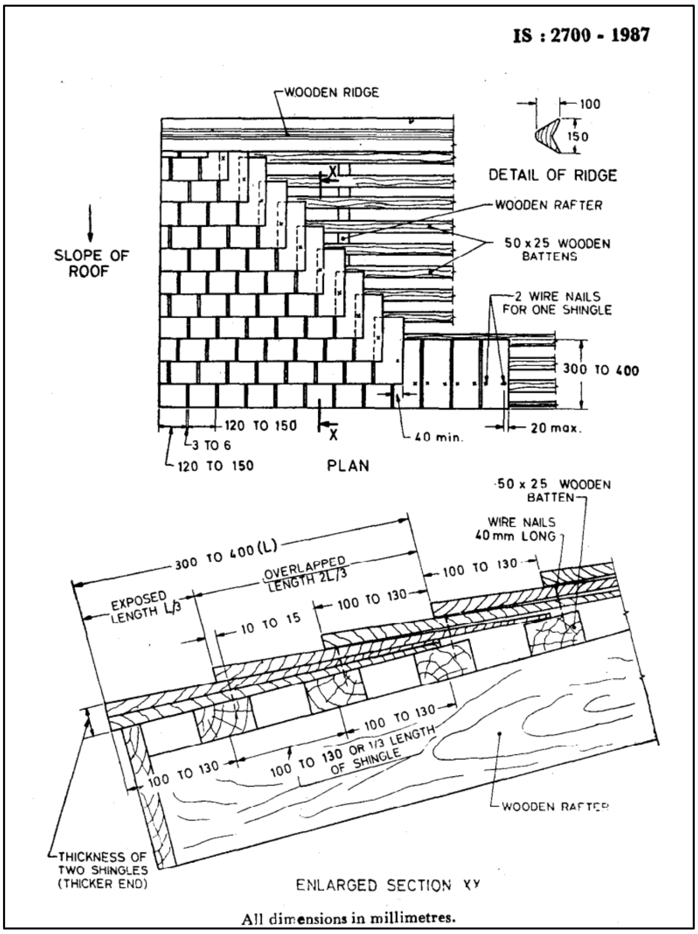
The truss is made with treated chir pine timber *(see later about treatment of timber).* The truss is made with sawn timber sections of sizes given below in the table. The truss members are connected using nailed joints and with 1.5” thick gusset plates on both surfaces of the members being joined at various joint locations. Lengthening of timber pieces is done using monochord type butt joint. The design of the truss has been provided by the Forest Research Institute, Dehradun and is structurally validated for spans upto 4 metres, carrying a dead load of upto 70 kg/m^2 of the roof area and wind velocity upto 28m/s which is experienced in the event of strong/ severe gales. Both ends of the truss are fixed to masonry walls through bolted connections (12mm dia bolt)

Pine Shingles

Wooden shingles are short, thin, rectangular pieces of timber, usually tapering in thickness along the grain, used in the same way as tiles for covering roofs of buildings. Thickness of shingles ordinarily reduces from tail (butt) to head. Depending upon the spacing of the battens, wooden shingle sizes may be chosen from 300 to 400 mm for length and 120 to 150 mm for width. The cross section of the timber shingle is tapered with thickness varying from 12mm to 3-4mm at the two ends.



All dimensions in millimetres.



Typical details of roofing with wooden shingles

As per IS Code: 2700-1987 Code of Practice for Roofing with Wooden Shingles

Quantity of timber for truss at Kamad community building of three truss

Label (as per diagram)	Item	Nos.	Size			Volume (cubic feet)
			Breadth (inches)	Depth (inches)	Length (inches)	
A	PURLINS	16	2.5	5	255	29.07
B	RAFTERS	12	2	2	110	3.01
C	BATTENS	72	1	2	255	20.93
D	WEB (tension members)	4	1.5	1.5	53	0.27
E	WEB (compression members)	4	1.5	2.5	26	0.22
F	BOTTOM CHORD	2	1.5	3.25	139	0.77
G	TOP CHORD	4	1.5	3.25	106	1.18
H	CLEAT	16	3	4	7	0.77
I-1	PEAK GUSSET	4	17	1.5	10	0.58
I-2	HEEL GUSSET	8	14	1.5	11.5	1.10
I-3	INTERMEDIATE	8	9.5	1.5	7.5	0.49
J-1	SPLICE	4	3.25	1.5	9.5	0.11
J-2	SPLICE	8	2.5	0.6	8	0.05
	TOTAL					60
	TOTAL AFTER ADDING 15% WASTAGE					69
S	SHINGLES	2600	0.5	6	15	11
	TOTAL AFTER ADDING 15% WASTAGE					13
	TOTAL CHIR PINE TIMBER TO BE PROCURED					**82**

Costing

S. No	Item	Quantity	Rate	Amount (INR)
A	**Materials procurement, fabrication and treatment of timber components and shingles**			
A.1	Components of three truss	82 cuft	INR 600/cuft	49,200
A.2	Fabrication charges of truss components	82 cuft	INR 150/cuft	12,300
A.3	Fabrication of shingles (INR 600/ cuft for wood + INR 7/piece making charges)	2600 Nos.	INR 22.6/shingle	58,760
A.4	Nails	11 Kg	INR 100/Kg	1,100
B	**Manpower cost**			
B.1	1 Carpenter	15 days	INR 700/day	10,500
B.2	2 Helper		INR 500/day	15,000
	TOTAL COST			**1,46,860**

Truss Installation Process

1. Fabrication of truss

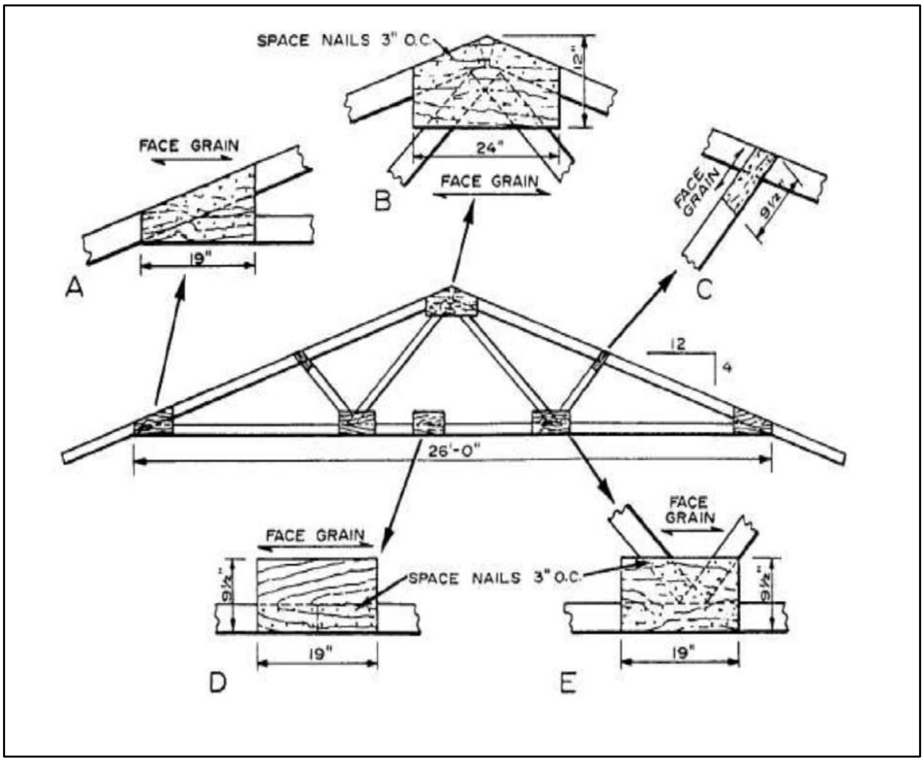

The various members of the truss were identified as per the truss drawing. The basic profile of the truss was fixed as per the vertical height between the bottom chord and the top most point of the truss where the two top chords meet. Markings were made on the floor to indicate this profile as a guide for subsequent work.


The length of the top chords was kept a little extra beyond the specified horizontal overhang of the roof. Little pieces of wood were used at the two ends of the truss to mark the inside edges of the gable walls. After the bottom chord and top chords were positioned, the tension (diagonal) members were positioned. All members were lightly nailed 2mm nails as a temporary (kutcha) joint to keep fix the basic profile of the truss and the positioning of diagonal members.

The truss at this stage was then positioned on the masonry walls to ensure that the span and profile match the dimensions of the room accurately. After this was ensured, this truss was used as a template to fabricate the remaining two trusses.

2. Gusset plates

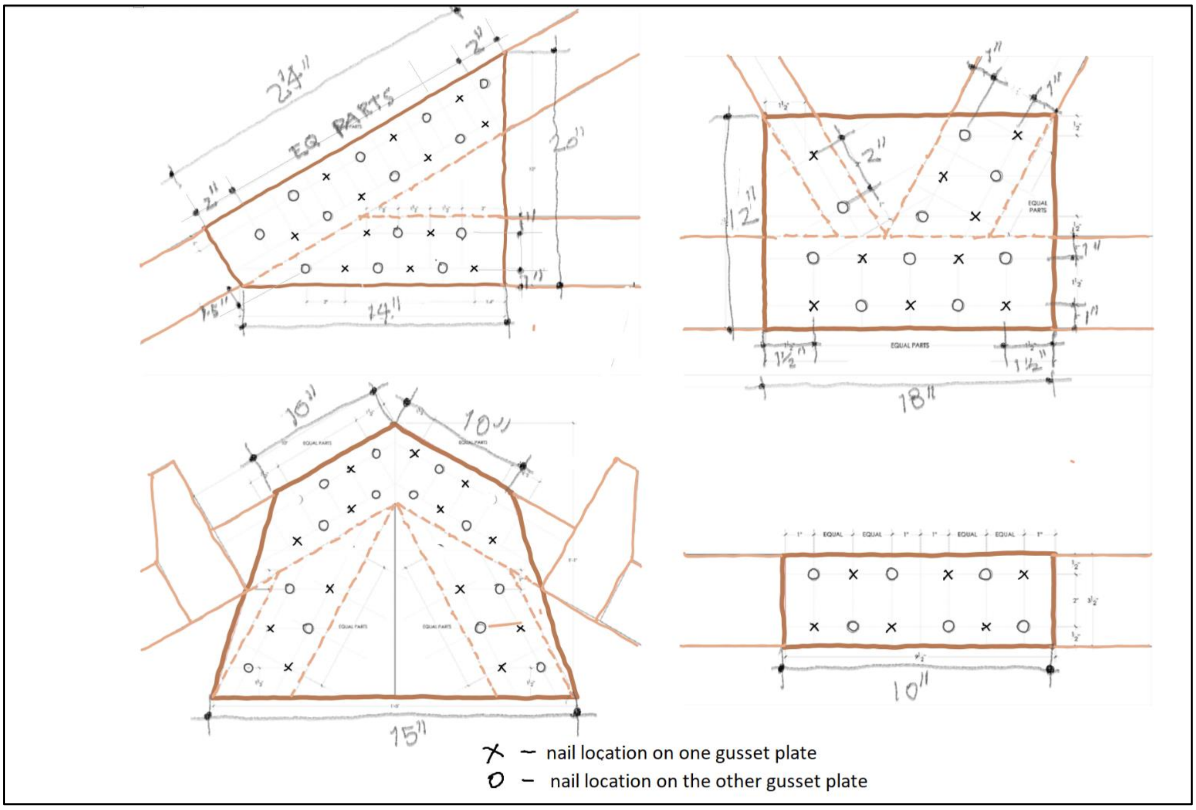
The next step is to cut the gusset plates as per their given profile in the truss drawing. This was done by placing pre-cut bigger size square pieces of the gusset plate at the various jointing locations and tracing the cutting angle onto the timber pieces. The cutting is done with a hand held mechanical wood saw for precision.



3. Nailed Connections

The next step is making the truss joints permanent with nails. This is an important step to ensure that the truss can ultimately carry its designed load without any compromise because stresses generated by improper nailing. This is one aspect of carpentry which deserves careful attention in the timber based construction. Senior carpenters have a practice-based understanding of the type of nails and pattern of nailing. Much of timber based construction is done on gut-feel based on experience. While this is valuable, it needs to be strengthened with stricter protocol of joinery. For instance, there is no awareness of the advantages of choosing the right nail as per the kind of timber and the type of nailed joints. The process of nailing is carried out without any markings prior to actual nailing. One reason for this is no practice of using gusset plates for stronger joinery in timber trusses. **In the case of gusset plate connections, marking the nail positions on the timber before driving in the nails is important to avoid both stress-free joints and insufficient nailing. The practice of pre-boring the timber members before driving in the nails also needs to be introduced.** This is to avoid unnecessary high impact of driving nails which increases the risk of causing cracks depending on the quality of timber and its degree of seasoning.

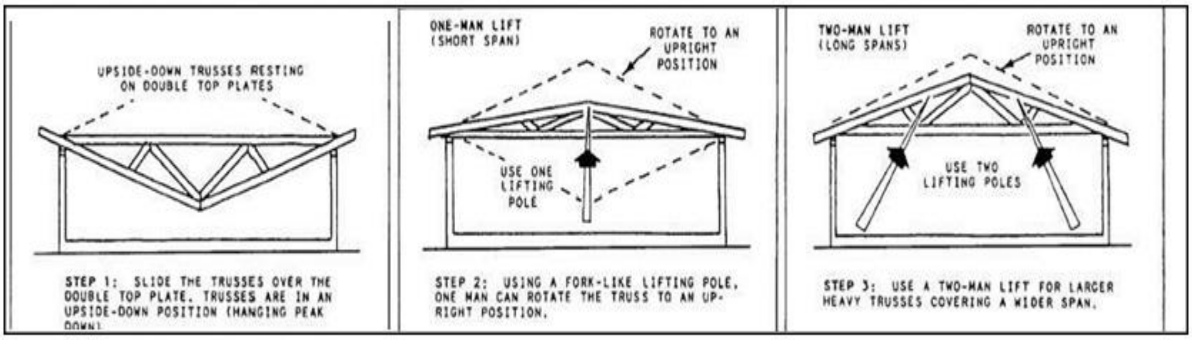
The nailing pattern was first drawn accurately on paper individually for each gusset plate which was then traced onto the gusset plate through a carbon paper. The drawings showed the combined nailing pattern for each of two gusset plates to be used at the joint. This pattern showed nail locations with two different symbols- one for each gusset plate. One half of the nailing points were transferred to one gusset plate and the other half to the gusset plate on the other side of the timber member to be secured. Pre-bores were made at each nailing location with an electrical drill with a 2mm drill bit. It's important to make a bore of smaller diameter than the diameter of the nail.



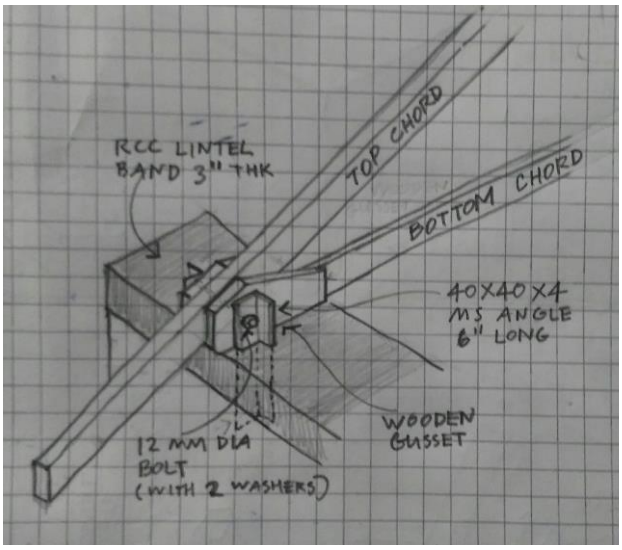
Nailing pattern on gusset plates

4. Installation of truss and other roofing under-structure

Once trusses have been fabricated, being lightweight they can be easily lifted and positioned manually on the superstructure. Truss positions should be marked beforehand on the wall plate/ RCC band on top of the masonry wall. The truss can then be placed by first inverting the truss and resting it on the wall plate/ RCC band and then slowly rotating the truss into an upright position.



5. Anchorage of truss to superstructure



It is critical to ensure that the truss is anchored securely to the supertstructure in order before installing the remaining undersatructure and roofing. This can be done with a bolted connection at both ends of the truss. A 12mm bolt with double washers can be used for this purpose. It is important to remember to insert the anchors (for holding the bolt) into the masonry at least till 6" depth before the top of the masonry is finished. In case of roof level RCC bands, a pair of MS angles can be inserted into the masonry and then subsequently cast into the roof band RCC. The spacing of angLe sections should be carefully maintained to allow for the thickness of bottom chord along with the two gusset plates. The bottom chord is then positioned between these angles and the bolts are then threaded through the gusset plates.

The remaining under-structure – purlins, rafters and battens – are then nailed into position as per specifications. The spacing of battens, which support the shingles, shall be equal to about one-third of length of the shingles, that is, from 100 to 130 mm. If necessary, batten length shall be extended only by means of butt joints, which shall occur only over the rafter. The joints of two adjacent rows of battens shall not come over the same rafter

6. Laying Roofing shingles

One of the main principles of laying shingles is to maintain adequate overlap between them and staggering of joints to ensure no rain water penetration through the roof. The close spacing of battens also ensure that they are properly anchored to the under structure. Shingles can be cut at site to stagger the joints.


7.Nails for fixing shingles

For use in fixing of wooden shingles made with *Chir* Pine timber, nails shall be of 2-2.4 mm diameter and length 40 mm depending upon the species. Higher diameter may only be used in case of more dense species. Subsidiary battens shall be fixed to main battens by 3mm diameter, 60 mm long nails which, in turn, be suitably fixed to purlin/rafter, etc, as the case may be.

Following are guidelines to lay wooden shingles-

- Each wooden shingle shall be fastened to the battens by two nails.
- The distance of the nails from the butt end of the shingle being nailed shall be equal to the shingle exposure plus 10 to 15 mm.
- The edge distance of the nails from the sides of the shingles shall be not more than 20 mm.
- The nail shall be driven flush, but not so hard that may crush or split the wood.
- Each course of wooden shingles shall be overlapped by another course such that only one-third of the length of the shingle in the lower course is left uncovered; the remaining two-third length shall be overlapped. Except for the bottom two courses, the wooden shingle shall be three courses deep throughout the roof area.
- In each horizontal course, the shingles shall be laid 3 to 6 mm apart to allow for swelling, when wet.


- Each horizontal course of wooden shingles shall break joints with two courses above and two courses below it.
- The gaps between wooden shingles in each course shall be off set at least 40 mm centre-to-centre from the corresponding gaps between the shingles in the course above. The two courses of shingles at the eaves shall also be break-jointed.
- The first shingle course laid in double should extend 50 to 60 mm beyond facia member, if adopted, to prevent the water from backing up underneath the shingles.

Timber Treatment

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Pressure treatment

Impregnation of wood under pressure is the most desirable and best method to get uniform and proper treatment under controlled conditions. This is usually done in a pressure cylinder equipped with vacuum-pressure system, storage tanks and mixing tanks for preservative solutions. For treatment with creosote the cylinder and storage tank are equipped with steam, heating coils. The basic principle for all pressure impregnation processes for treatment of wood is to inject preservative solution either hot or at ambient temperature into the wood structure under pressure with or without the use of initial vacuum. The pressure duration and magnitude vary with treatability class of timber. The advantage of the process is to have quick and continuous flow of treated material.

Full Cell Process

This process is used when high absorptions of the preservative are desired. In case of thin planks and plywood, spacers or grills should be used to separate the pieces. The door is tightly closed and a vacuum of at least 56 cm of mercury is created and maintained for half an hour. The object of this operation is to remove as much air as possible from the cells. At the end of vacuum period, the preservative is introduced into the cylinder, with vacuum working. When the cylinder has been filled with the preservative, the vacuum pump is stopped and the cylinder is subjected to an antiseptic pressure of 3.5 kg/cm2, after it the preservative is withdrawn from the cylinder and finally a vacuum of 38 to 56 cm of mercury for about 15 min. is once again applied.

Non- Pressure treatment

Pressure treatment requires sophisticated infrastructure which results in highest level of treatment efficiency. However, often this facility will not be accessible for construction in mountainous regions. There are two options for treatment of timber which can be carried out with basic requirements and minimal infrastructure at or close to the construction site – the Hot and Cold method and the Dip method.

Hot and Cold method

This process is suitable for easy-to-treat species in which the required absorption can easily be obtained. The timber to be treated is heated in a preservative solution to about 90 degrees for 2-34 hours. This heats the air inside the wood which escapes partially due to expansion. The preservative and timber is allowed to cool by itself. On cooling, the preservative flows into the wood as a result of partial vacuum created by contraction of air. For water soluble type preservatives, timber is heated separately in water and immersed while hot in the preservative solution for 24-48 hours. After the timber is removed from the chemical solution, it should be placed in a shade for drying with minimum 6” spacing between individual timber elements and with some pressure on them (sand bags can be used) to prevent them from warping during drying. The drying period should be minimum 2 weeks and preferably not less than 4 weeks – depending on climate.

Dip method

Stainless steel tank for dipping the wood in preservative. Size 8'x2'x2'

This is the simplest method for wood treatment and also relatively superficial as compared to other methods. However, it is still effective in enhancing the durability of secondary timber such as *chir* pine. The method consists of dipping or submerging the wood in the preservative solution for a short period. This is better than spraying or brush painting because the wood remains in contact with the preservative for a longer duration. This requires a vat for complete submergence of wood. The vat can be made using cut tin drums or can also be made below the ground using masonry- in this case, it is important to line the underground tank adequately with thick tarpaulin sheets to prevent any leakage of the preservative into the soil. Ensure a spacing of at least 2" between different timber pieces before submerging so that each piece is completely surrounded by the chemical preservative.

Freshly cut timber has a lot of moisture- typically above 70%- and cannot be treated in this method. The timber should be allowed to dry so that the moisture level reduces to below 20%. The duration of submergence depends on the cross section of timber – thin planks, purlins, beams which are normally 3"-4" in thickness can get a reasonable penetration of preservative after 24 hours of submergence. After the treatment is done, the wood should be allowed to dry ideally for a minimum of one month – this is the time during which the preservative gets fixed inside the wood.

Preservatives for treatment

There is a variety of preservatives available for wood treatment. The water soluble fixed type preservative is the most suitable for timber to be used in construction. These preservatives are mixtures of various soluble salts along with fixative salts- usually sodium or potassium dichromate- which in the presence of water, react and form insoluble complex salts and thus get permanently fixed. Following are typical preservative formulations-

1. CCB – Copper Chrome Boric composition. This comprises of a mix of **Boric Acid, Copper Sulphate and Sodium Dichromate in the ratio of 1.5 : 3 : 4. The concentration of the chemical solution is 4-6% for exterior application and 2% for interior application.**
2. Zinc-Chrome-Boric composition – this comprises a mix of **Boric Acid, Zinc Chloride, Sodium Dichromate and Water in a ratio of 1 : 3 : 4 : 100**
3. Forest Research Institute in Dehradun has developed a preservative called **ZIBOC** which is a mix of Borax, Zinc and Copper. Since it does not have Chromium, it is eco-friendly. It is suitable for Pine as well as bamboo.

4. Fixed Type

These preservative are mixtures of various salts, which in the presence of wood, react and form insoluble complex salts and thus get permanently fixed. Bamboo treated with these compositions can be used in outside locations also. Treated wood/bamboo should, however, be allowed to dry for 1 to 2 weeks to complete the fixation process. These preservatives are applied at ambient room temperatures as the chemicals are precipitated at elevated temperature. Various formulations under this type are:

Copper-Chrome-Arsenic composition (CCA) consisting of following percentage (by weight) (IS:10013 Part II) (Anon.,1980).

Normal Minimum

Copper sulphate ($CuSO_4\ 5H_2O$) 37.5 -35.0
Sodium dichromate ($Na_2Cr_2O_7\ 2H_2O$)

OR

Potassium dichromate ($K_2Cr_2O_7$) 50.0 -47.5
Arsenic pentoxide ($As_2O_5\ 2H_2O$) 12.5 -10.0

About Development Alternatives Group

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social equity and environmental management. It is credited with numerous technology and delivery system innovations that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs; enabling economic opportunities through skill development for green jobs and enterprise creation; and promoting low carbon pathways for development through natural resource management models and clean technology solutions.

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