

## **ROOF CONSTRUCTION SYSTEMS**

- Provision should also be made for adjustment in the level of the hinges if there is a possibility that deflection may interfere with the proper operation of truss - suspended doors or machinery.
- Only two basic systems of roof construction need be considered in truss design.
- One applies roof loads to the truss only at the panel points; the other applies UDL over the top.
- The former system produces only direct stress in the chord member; the latter introduces bending as well as direct stress.

## **ROOF- TRUSS SPACING**

There are no fixed rules for spacing trusses in buildings.

Spacing may be affected by

- roof framing
- wall construction
- size of material available
- loading conditions &
- the column spacing desired for material handling or traffic.

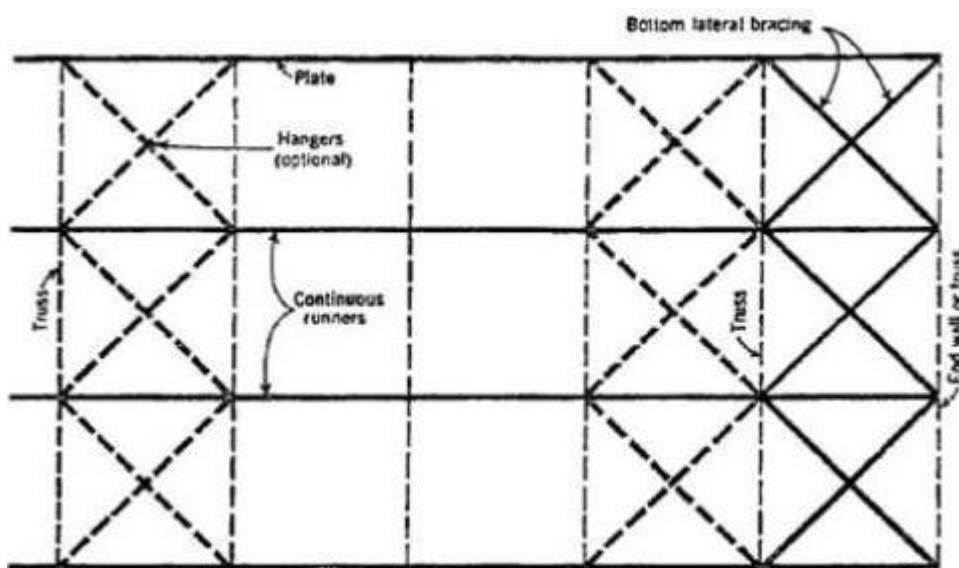
In general, greater the bay spacing, lesser be the economical. Spacing limits are set by the purlin or girt sizes available for framing between trusses.

## **ROOF- TRUSS BRACING AND ANCHORAGE**

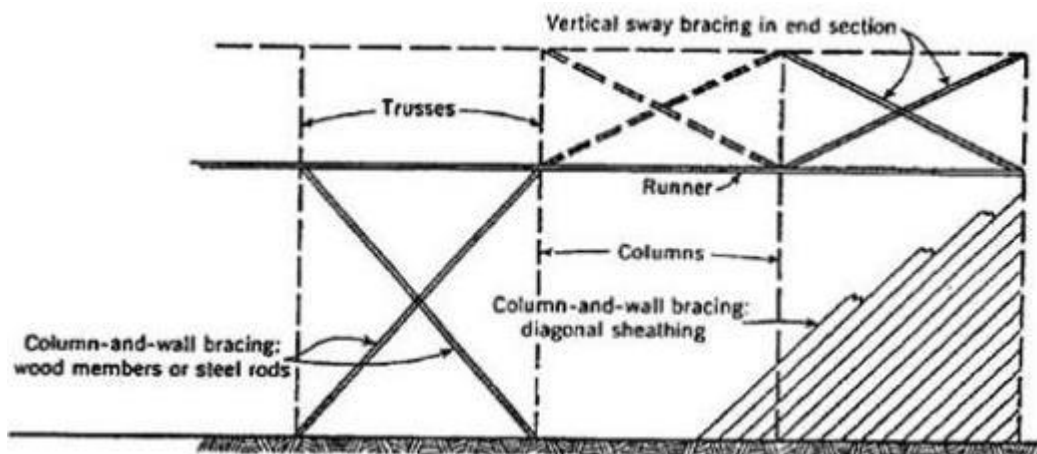
- Bracing and anchorage is necessary to hold trusses and truss members in proper position so that they can resist vertical loads as well as lateral loads such as wind, impact, or earthquake.
- Although roof framing will usually serve as lateral bracing for the top-chord members, it is important that adequate lateral supports be provided for the bottom chord members (Fig 2), and also that consideration be given to the possible need for vertical- sway bracing between top and bottom chords of adjacent trusses (Fig.3).
- Horizontal cross-bracing is sometimes required in the plane of either the top and bottom chord, particularly in long buildings in which the diaphragm action of the roof framing is not adequate for end-wall forces, or in which side-wall loads are resisted by end walls or truss and its support are not designed as a bent to resist the lateral load.
- Trusses must be securely anchored to properly designed walls or columns and

columns in turn anchored to foundations.

- Unless some other provision made for lateral loads on the side walls and on the vertical projection of the roof-such as for diaphragm action in walls and roof sheathing- lateral resistance should be provided in the column members by means of knee braces or fixity at the column base.
- The bracing should be designed and detailed with the same care as the truss itself and not left to the judgment of the contractor.
- The bracing requirements here suggested are minimums, and are not dependent on actual lateral load analysis or on local code requirements.
- Vertical cross-bracing should be installed at the bottom chord at the location of the vertical bracing and be continuous from end.



**Fig 2 Horizontal Bracing**



**Fig 3. Vertical Bracing**

Design conditions vertical sway bracing is to be used in end section as a minimum, possibly two sections at each end and near mid span for long buildings. Column-and-wall bracing should be used where possible, it may consist of diagonal sheathing with studs or girt or cross-bracing.

## WELDING CONTINUED

### ANALYSIS AND DESIGN OF FILLET WELDS

Fillet welds are provided for connecting two members which are overlapping each other. Shear stresses are usually the type of stress in the case of fillet welded connection. Direct stresses to which the connections are subjected to are usually of lesser importance. Concave fillet weld was favoured because it offers a smoother path for the flow of stress. But concave fillet weld up on cooling shrinks and cause tension to the surface which may cause cracks in the joint. On the other hand, shrinkage of weld will cause compression in the case of convex fillet weld. Concave fillet welds are more suitable under alternating stresses.

### Size of Fillet weld

Cl.10.5.2.1 of IS800-2007 specifies the size of normal fillets shall be taken as the minimum weld leg size. For deep penetration welds, where the depth of penetration beyond the root run is a minimum of 2.4 mm, the size of the fillet should be taken as the minimum leg size plus 2.4 mm. Figure 23 shows the leg length of fillet weld for various cases.

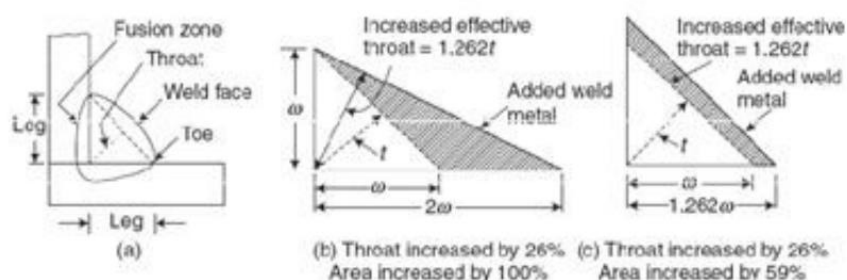


Figure 23 Leg Length of Fillet Weld

Cl.10.5.2.3 of IS800-2007 restricts minimum size of fillet welds to be 3 mm. The minimum size of the first run or of a single run fillet weld shall be as given in Table 21 of IS800-2007, to avoid the risk of cracking in the absence of preheating. Table 21 of IS800-2007 is reproduced for ready reference as Table 6.

As per Cl.10.5.8.3 of IS800-2007, where the size specified for a fillet weld is such that the parent metal will not project beyond the weld, no melting of the outer cover or covers shall be allowed to occur to such an extent as to reduce the throat thickness (see Fig. 18 of IS800:2007). The figure is reproduced here as Figure 25.

Cl.10.5.8.5 of IS800-2007 specifies for end fillet weld, normal to the direction of force shall be of unequal size with a throat thickness not less than  $0.5t$ , where  $t$  is the thickness of the part, as shown in Fig. 19 of IS800-2007. The difference in thickness of the welds shall be negotiated at a uniform slope. Fig. 19 of IS800-2007 is reproduced here as Figure 26.

Table 6 Minimum size of first run or of a single run fillet weld

Sl. No.	Thickness of thicker part (mm)		Minimum size (mm)
	Over	Up to and including	
1	-	10	3
2	10	20	5
3	20	32	6
4	32	50	8 of 1st run, 10 for minimum weld size

Cl.10.5.8 of IS800-2007 specifies the maximum size of fillet weld applied to the edge of a plate or section. Cl.10.5.8.1 specifies where a fillet weld is applied to the square edge; the specified size of the weld should generally be at least 1.5 mm less than the edge thickness (see Fig. 17A of IS800:2007). This figure is reproduced here as Figure 24(a).

Cl.10.5.8.2 of IS800-2007 gives the specification where the fillet weld is applied to the rounded toe of a rolled section; the specified size of the weld should generally not exceed  $3/4$  of the thickness of the section at the toe (see Fig. 17B of IS800:2007). This figure is reproduced here as Figure 24(b).

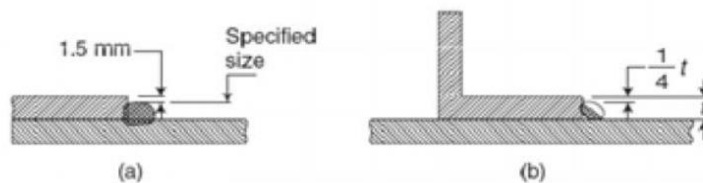


Figure 24 Fillet Welds on square edge of plate or round toe of rolled section

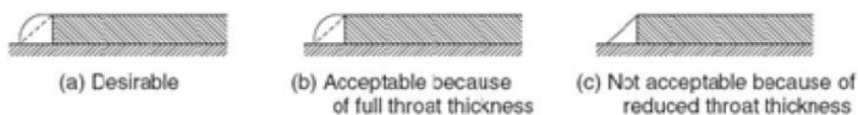
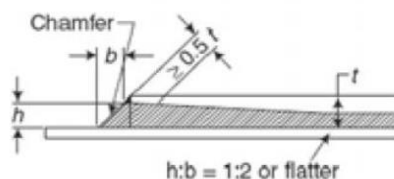


Figure 25 Full size Fillet Weld applied to the edge of a Plate or a Section



### Effective throat thickness of fillet welds

Cl.10.5.3 of IS800-2007 gives the specification for Effective Throat Thickness. Cl.10.5.3.1 specifies the effective throat thickness of a fillet weld not to be less than 3 mm and shall generally not exceed 0.7t, or 1.0t under special circumstances, where t is the thickness of the thinner plate of elements being welded. Further, Cl.10.5.3.2 of the code specifies the effective throat thickness. For the purpose of stress calculation in fillet welds joining faces inclined to each other, the effective throat thickness shall be taken as K times the fillet size, where K is a constant, depending upon the angle between fusion faces, as given in Table 22 of IS800-2007. Table 22 of IS800-2007 is reproduced here as Table 7 for ready reference.

Table 7 Values of K for different angles

Angle between fusion faces in degrees	60-90	91-100	101-106	107-113	114-120
Constant, K	0.70	0.65	0.60	0.55	0.50

### Effective length of fillet welds

Effective Length of Weld is considered in accordance with Cl.10.5.4 of IS800-2007. As per Cl.10.5.4.1, the effective length of fillet weld shall be taken as only that length which is of the specified size and required throat thickness. In practice the actual length of weld is made of the effective length shown in drawing plus two times the weld size, but not less than four times the size of the weld. So the effective length of the weld is considered as actual length minus twice the weld size. As per Cl.10.5.1.1, Fillet welds terminating at the ends or sides of parts should be returned continuously around the corners for a distance of not less than twice the size of the weld, unless it is impractical to do so. This is particularly important on the tension end of parts carrying bending loads.

### Effective area of fillet welds

The effective area of fillet welds is obtained as the product of effective throat thickness and effective length.

### Design strength of fillet welds

Cl.10.5.7.1.1 of IS800-200 deals with the strength of fillet welds. As detailed in this clause of the code, fillet welds shall be designed based on the throat area (effective area). The code specifies the design stress in the weld  $f_{dw} = f_{wn} / \gamma_{mw}$  where  $f_{wn}$  is partial safety factor of the material of the weld given by Table 5 of IS800-2007 and  $f_u$  is the ultimate stress of the material. Hence the design capacity of fillet welds is  $T_{dw} = L_w t \frac{f_u}{\sqrt{3} \gamma_{mw}}$  where  $L_w$  is the effective length of the weld and  $t$  is the throat thickness.

### Long joints

When the length of the welded joint,  $l_j$  of a splice or end connection in a compression or tension element is greater than  $150 t$ , the design capacity of weld,  $f_{dw}$  shall be reduced by the factor  $\frac{150 t}{l_j}$

## Fillet weld subjected to individual stresses

Cl.10.5.9 of IS800:2007 specifies the Stresses Due to Individual Forces. When subjected to either compressive or tensile or shear force alone, the stress in the weld is given by  $f_c, f_t, q = \frac{P}{A_{\text{weld}}}$

6.9.8. Fillet welds subjected to combination of stresses

As per Cl.10.5.10.1.1, when subjected to a combination of normal and shear stress, the equivalent stress  $f_e$  shall satisfy the condition

$$f_e = \sqrt{f_a^2 + 3q^2} \leq \frac{f_u}{\sqrt{3}\gamma_{mw}}$$

## FAILURE OF WELDS

Failure of welds of various types may be classified based on the types of welds.

### Butt weld

If the butt welds are reinforced properly, it is unlikely for the failure to obtain in the weld. The fracture normally occurs at some distance from the connection. However if the weld is ground flush with the surface of the plate, the position of the fracture depends on the relative strength of plate and weld. If the tensile strength and yield point of the weld metal are higher than that of the elements, the failure takes place away from the weld. Failure in the weld junction is unusual. Welds stiffened with reinforcements will hinder the failure of the joint under bending. If there is a wide difference in the properties of the materials on joint and member, the failure may occur at the junction.

### End fillet weld

The plane of failure in the case of a normal convex weld is along the diagonal from the root of the weld. The position of the plane of failure depends on the relative magnitude of tensile and shear stresses. If the fillet weld is having unequal legs, the plane of failure will be nearer to the leg having smaller length. The failure of end fillet welds occurs abruptly with very small deformations.

### Side fillet weld

In a side convex weld subjected to shear stress along the weld, failure occurs down the throat of the weld. Failure is initiated at the toe of the weld and progress with rotation of the plane associated with considerable deformations. Failure of the plates before the final failure is also usual.

## Lecture 04

### REFERENCE:

1. Steel Water Storage Tanks: Design, Construction, Maintenance, and Repair 1st Edition, Kindle Edition by Steve Meier, American Water Works Association.
2. Elementary Structural Design & Drawing (In 3 Vols.) Vol. I : Structural Design & Drawing Kindle Edition by D. Krishnamurthy (Author) Format: Kindle Edition
3. Structural Design & Drawing-Vol. 3 [Print Replica] Kindle Edition by D. Krishnamurthy (Author) Format: Kindle Edition
4. The Dock Manual: Designing/Building/Maintaining Jan 4, 1999 by Max Burns
5. Designing Steel Structures for Fire Safety May 6, 2009 by Jean Marc Franssen and Venkatesh Kodur
6. Reference Book: Design of Steel Structures by S K Duggal