ROOF TRUSSES - HOW THEY WORK AND THE SELECTION OF ROOF TRUSSES

The Romans found that if they leant stones against one-another in the shape of an arch, (Fig- 1) they could span greater distances than by using the stone as simple lintels or beams. In an arch the stones are in compression. The arch will perform as long as the supports or buttresses at each end of the arch provide restraint, and do not spread apart. Timber beams can also be propped against one-another to form arches. The timber members will be in compression and will also act as simple beams. To turn the arch into a truss all that is required is to provide a tie between the two buttresses to stop them from being pushed apart by the arch. The arch, beam, tie combinations is self supporting – **we call this structure a truss.**

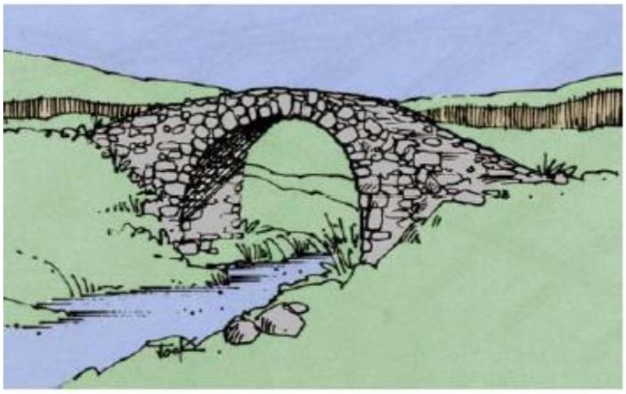
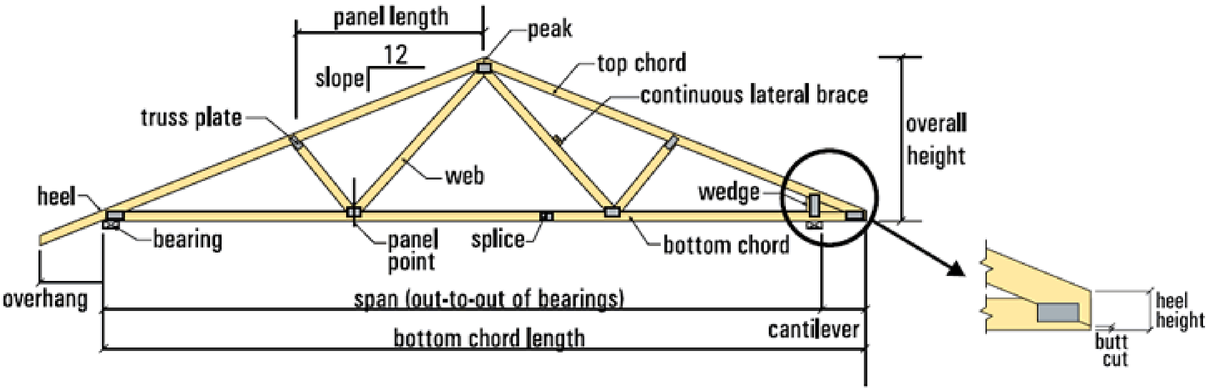


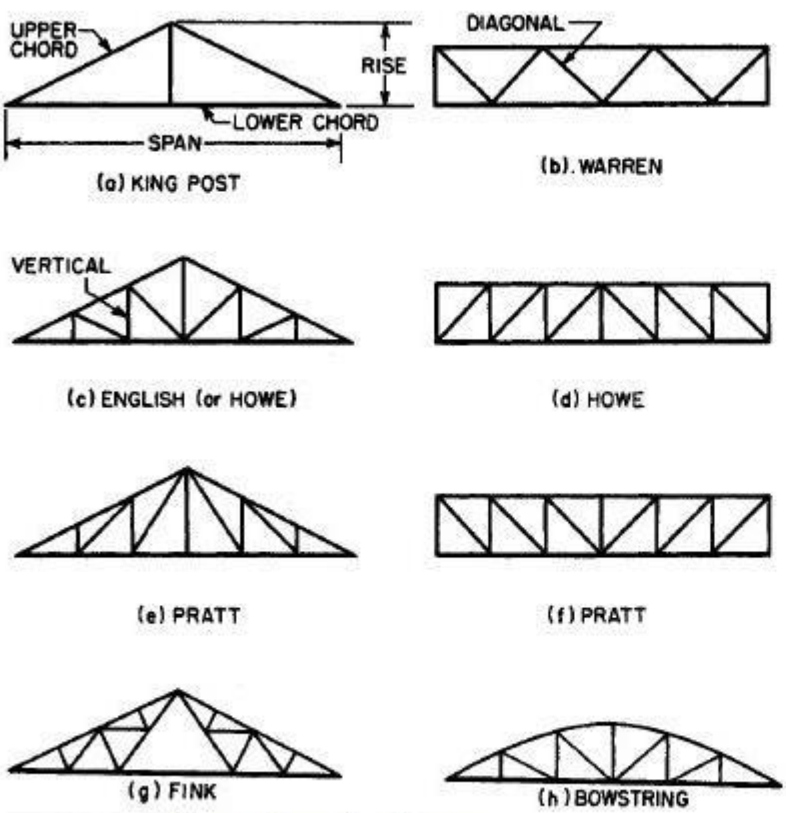
Fig 1 Roman Arch Bridge

SELECTION OF ROOF TRUSSES

• Architectural style, types of roofing material, methods of support of column framing, and relative economy are the principal factors influencing a choice among the three basic types of trusses bowstring, pitched, and flat.
• In addition, side- and end-wall height and type, roof shape, and bracing requirements must be considered. Other factors being equal, economy is the prime consideration. Economy is dependent upon efficiency in use of material relative to truss type and proportions and to fabrication labour. Theoretically, the three basic types in order of relative efficiency are bowstring, pitched, and flat.
• The function of a truss is to transfer load from point of application to the supports as directly as possible.
• Thus for a concentrated load at the centre line of a span, a simple “A” frame is

the most efficient.
• Like-wise, if only two equal and symmetrically placed concentrated loads are involved, a truss similar to the queen-post type is the most efficient.
• In both trusses, the load is transferred to the support directly through the sloping top-chord members without the need for web members.





Common types of roof trusses.

Economic factors

• The maximum economical span of any given type of truss will vary with
• The material available
• Loading conditions
• Spacing
• Type of truss
• Ratio of labour to material cost &
• Fabrication methods.

WELDED CONNECTIONS

1. INTRODUCTION

When two members are connected by means of welds, such a connection is known as welded connection. Welding offers an opportunity to the designer to achieve a more efficient use of the materials. Earlier designers considered welds as less fatigue resistant. It was believed that attaining good welds at site is impossible. Now a day, with the advances in the field of non destructive testing methods (NDT), testing and quality control of welds became easier. This gives the designers enough courage to explore the possibilities and capabilities of welded connections. Speedy construction is facilitated by using welded connections. Weight of welded connections is relatively low and hence cuts cost of construction. Since there is no reduction of holes the gross cross section is effective in carrying loads.

2. TYPES OF WELDED CONNECTIONS

The basic types of welded joints can be classified depending on the types of welds, position of welds and type of joint.

1. Based on the type of weld

Based on type of weld, welds can be classified in to fillet weld, groove weld (or butt weld), plug weld, slot weld, spot weld etc. Various types of welds are shown in Figure 15.

1.1. Groove welds (butt welds)

Groove welds (butt welds) and fillet welds are provided when the members to be joined are lined up. Groove welds are costlier since it requires edge preparation. Groove welds can be employed safely in heavily stressed members. Square butt welds are provided up to a plate thickness of 8mm only. Various types of butt welds are shown in Figure 16.

1.2. Fillet welds

Fillet welds are provided when two members to be jointed are in different planes. Since this situation occurs more frequently, fillet welds are more common than butt welds. Fillet welds are easier to make as it requires less surface preparation. Nevertheless, they are not as strong as the groove welds and cause concentration of stress. Fillet welds are preferred in lightly stressed members where stiffness rather than strength governs the design. The various types of fillet welds are shown in Figure 17.

1.3. Slot and plug welds

Slot and plug welds are used to supplement fillet welds where the required length of fillet weld cannot be achieved.

2. Based on the position of weld

Based on the position of weld, welds can be classified in to flat weld, horizontal weld, vertical weld, overhead well etc.

3. Based on the type of joints

Based on the type of joints, welds can be classified in to butt welded joints, lap welded joints, tee welded joints and corner welded joints.

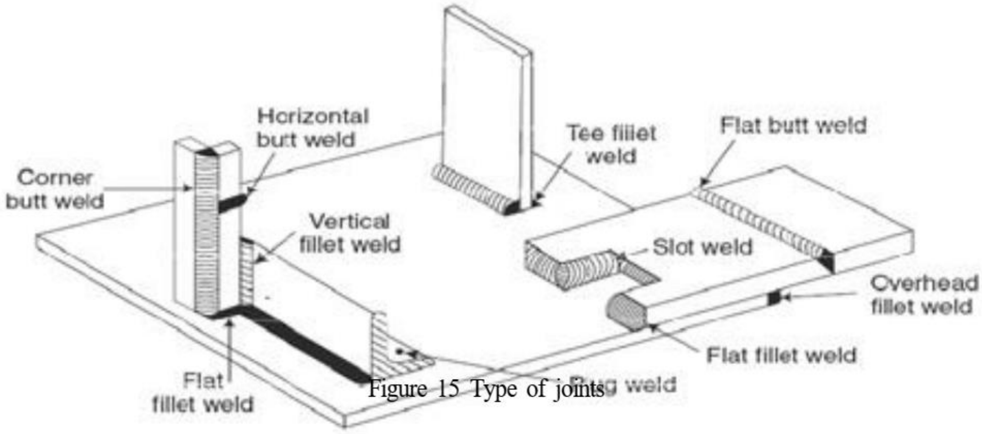


Figure 15 Type of joints

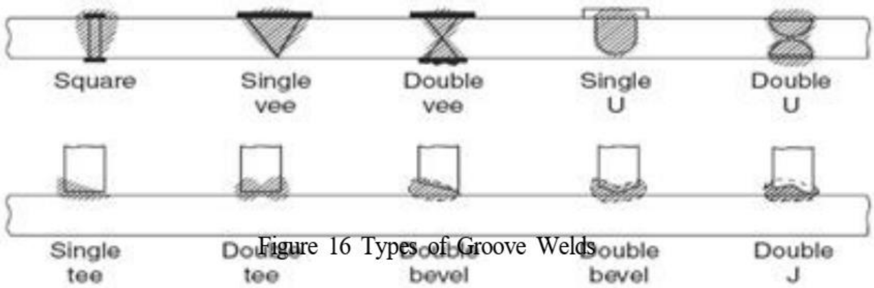


Figure 16 Types of Groove Welds

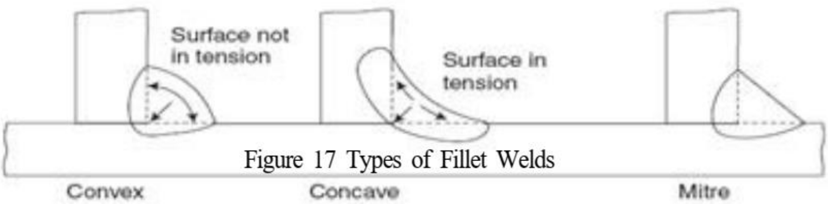


Figure 17 Types of Fillet Welds

ADVANTAGES AND DISADVANTAGES OF WELDED JOINTS

The following are the advantages of welded joints.

- Due to the absence of gusset plates and other connecters, the welds are usually lighter.
- Welding process is quicker as it requires no drilling of holes.
- Welding is more adaptable than other types of connections and can even be used in circular pipes.
- 100% efficiency can be achieved in welding where as the connection such as bolts can have a maximum efficiency of 70 - 80%.
- Noise produced during the welding process is relatively less.

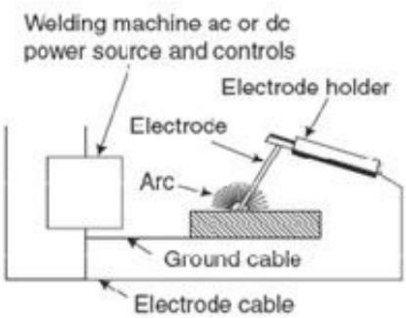
- Welds usually have good aesthetic appearance.
- Welded joints are air tight and water tight and can be used for water tanks and gas tanks.
- Welded joints are rigid.
- Mismatch of holes will never happen in welded connection.
- Alternation of joints can easily be made in the case of welded connecetions.

However the welded connection is having the following disadvantages.

- Due to the uneven heating and cooling, members are likely to distort in the process of welding.
- Possibility of brittle fracture is more in the case of welded connections.
- Welded connections are more prone to failure due to fatigue stresses.
- The inspection of welded joints is difficult and expensive. It can only be done by employing NDT.
- Highly skilled persons are required for welding.
- Proper welding in field conditions is difficult.
- Welded joints are over rigid.

WELDING PROCESS

Welding consists of joining two steel sections by means of metallurgical bond between them by the application of pressure and/or fusion. The most commonly used welding process is fusion process. The bond is produced, in fusion process, by melting the surfaces to be joined and then allowing them to solidify in to a single joint. The most commonly used welding process is the arc welding process (Figure 18). In this process intense heat required (around 3600^0C) to melt the steel sections is produced by an electric arc. The tremendous heat at the tip of the electrode melts the base metal and the filler metal to form a pool of molten metal called crater which solidifies on cooling produce the joint required.



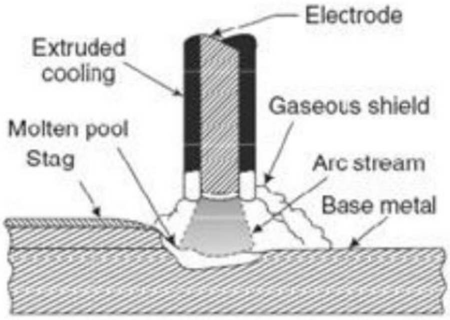


Figure 18 Welding Process

WELD DEFECTS

Defects in welding are inevitable in spite of using the good welding techniques, standard electrodes and preparation of joints. Some of the commonly observed welding defects (Figure 19) are detailed below.

1. Incomplete fusion

This happens when the base metal fails to completely fuse along with the weld metal. This can be caused by the rapid welding or by the presence of foreign material at the weld surface. See Figure 19(a).

2. Incomplete penetration

This type of failure occurs due to the failure of the weld metal to penetrate the complete depth of the joint. This is often observed in single V and bevel joints. This can also happen while using electrodes of larger size than is required. See Figure 19(b).

3. Porosity

Porosity occurs due to the voids or gas pockets entrapped in the welds while cooling. This results in stress concentration and reduced ductility of the joint. This is mainly due to careless use of backup plates, presence of moisture in the electrodes, presence of hydrogen in the electrodes and excessive current. See Figure 19(c).

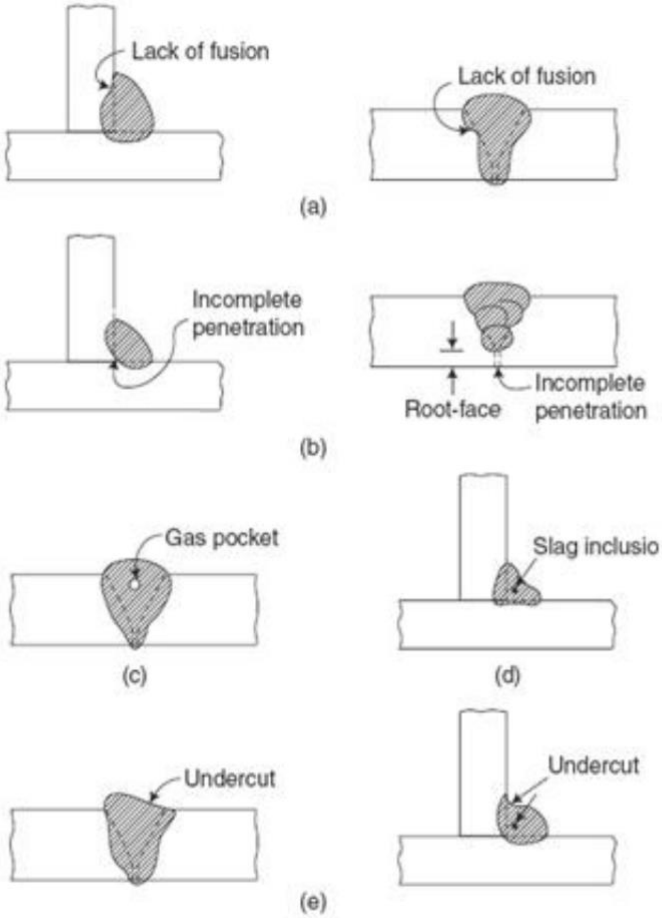


Figure 19 Weld Defects

4. Slag inclusion

Slag inclusions are metallic oxides and other solid compounds which are sometimes found as elongated or globular inclusions. The slag, being lighter than the molten material of weld, usually rise to the surface and can be removed after cooling of the weld. However if the weld is cooled rapidly possibilities are there to trap these in the weld. See Figure 19(d).

5. Undercutting

Undercutting is the local decrease in the thickness of parent metal at the weld toe. An undercut results in reduced section and acts like a notch. This can happen due to excessive current and/or long arc.

INSPECTION OF WELDS

As we have seen defects in welds are inevitable. Nevertheless, the poor weld quality leads to collapse. Therefore, proper inspection and quality control of welded joints is essential. Some of the commonly employed methods are discussed here.

1. Magnetic particle method

When iron fillings spread over the welded joint is subjected to electric current, the forms patterns which can be utilised for interpret and locating surface cracks.

2. Dye penetration method

A dye is spread over the surface of weld in this method and then the surplus is removed. Then dye absorber is placed on the surface which oozes out the dye in the crack revealing the depth of surface cracks.

3. Ultrasonic method

Defects like flaws, blow holes, slag inclusion and porosity of the welds can be evaluated by this method. When ultrasonic waves are sent through the weld, these defects interfere with the wave propagation of the waves affecting its travel time. The defects can be interpreted by observing the travel time of the waves.

..4. Radiography

In this method, X-rays and gamma rays are used to locate the defects. This is used in groove welds only.

ASSUMPTIONS IN THE ANALYSIS OF WELDED JOINTS

The following assumptions are made in the analysis of welded joints.

- Welds connecting various parts are homogeneous, isotropic and elastic.
- The parts connected by welds are rigid and their deformations are therefore neglected.
- Only stresses due to external loads are to be considered. Effects of residual stresses, stress concentrations and shape of welds are neglected.

ANALYSIS AND DESIGN OF BUTT(GROOVE) WELDS

Groove welds are usually provided when the member is subjected to tension or compression. Since there is no change in the section at the joint, this is the most suitable form of joint to transfer alternating stress. However when the welds are intended to take shear stress, careful consideration should also be made so that the shear stresses developed is taken care of. Figure 20 shows the typical cross section of a groove weld. Square groove welds are usually employed for sections of thickness up to 8mm. If sections with more than 8mm thickness, U, V, double U or double V butt welds are used.

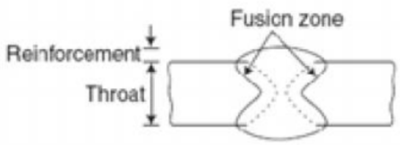


Figure 20 Groove Welds

1. Reinforcement in Groove Welds

Extra weld material which is deposited to make the throat thickness at least 10% more than the welded material is known as reinforcement (see Figure 20). This will increase the efficiency of the joint. Reinforcement will increase the strength of grove welds under static loading. In the case of dynamic loading, reinforcement may result in stress concentrations. So the reinforcement is usually dressed flush in the case of members subjected to dynamic loading. However subsequent removal of

reinforcement is not considered as reducing the strength of joint. The reinforcement is ignored in calculating the strength. In any case the reinforcement should not exceed 3mm.

2. Size of Groove Welds

Size of welded joint is usually specified by throat dimension. This is also called effective throat thickness. Groove welds may be classified in to full penetration groove welds (Figure 21) or partial penetration groove welds (Figure 22). Complete penetration is difficult to achieve in the case of single U, V, J and bevel welds. However, this can be achieved by using backing strips as shown in Figure 21.

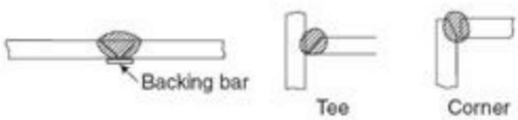


Figure 21 Complete Penetration Groove Welds

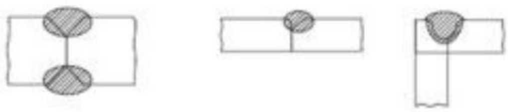


Figure 22 Partial Penetration Groove Welds

As per Cl.10.5.3.3 of IS800-2007, the effective throat thickness of a complete penetration butt weld shall be taken as the thickness of the thinner part joined, and that of an incomplete penetration butt weld shall be taken as the minimum thickness of the weld metal common to the parts joined, excluding reinforcements. However in the case where full penetration groove welds cannot be achieved, an effective throat thickness of $1/8^{th}$ of the thickness of thinner member is used. But for calculating the strength of the connection, a throat thickness of $5/6^{th}$ of the thinner member is usually assumed.

3. Effective area of Groove Welds

Effective area of weld is obtained as the product of effective length, of weld and effective thickness (throat thickness), of weld. As per Cl.10.5.4.2 of IS800-2007, the effective length of butt weld shall be taken as the length of the continuous full size butt weld, but not less than four times the

size of the weld

Lecture 03

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/MaintainingJan 4, 1999 by Max Burns

5. Designing Steel Structures for Fire SafetyMay 6, 2009 by Jean Marc Franssen and Venkatesh Kodur

6. Reference Book: Design of Steel Structures by S K Duggal