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DESIGN OF STEEL STRUCTURES

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Design Of Steel Structures

TSPSC AEE SYLLABUS

Design of Steel Structures : Properties of steel sections, permissible stresses, IS Specifications; Riveted and welded joints and connections; Design of simple and compound Beams and Columns, Column bases, Roof trusses, Plate and Gantry Girders; Plate Girder Lattice Girder Railway bridges, and Bearings. Plastic analysis.

APPSC AEE SYLLABUS

Design of Steel Structures : Principles of working stress method.Design of bolted and welded connections, axially and eccentrically loaded joints,Simple connection of bracket plates to columns, beam to beam and beam to columnconnections, design of framed, unstiffened and stiffened seat connections Design ofindustrial roofs. Principles of ultimate load design. Design of simple members.

SSC-JE SYLLABUS

Design of Steel Structures : Steel design and construction of steel columns, beams roof trusses plate girders

1 MATERIALS AND SPECIFICATIONS OF STEEL

- Steel is an alloy of Iron, Carbon and other elements. Because of its high tensile strength and low cost, it is a major component used in buildings, tools,ships, infrastructure etc.
- Steel structures are made up of structural steel.

STRUCTURAL STEEL

- It is a category of steel used for making construction materials in a variety of shapes.
- Many structural steel shapes take the form of an elongated beam having a profile of a specific cross section.

Advantages:

- It has high strength
- It has higher strength to weight ratio
- It allows easy modifications and repairs
- Excellent ductility and Seismic resistance
- Rapid construction (or) erection
- Longer life
- Elasticity, Uniformity of material
- High scrap value
- High quality

Disadvantages

- Steel structures are subjected to corrosion, when placed in exposed conditions.
- Steel structures need fire proof treatment, because they have lesser fire resistance
- Steel may loose its ductility at places of stress concentration in the sections under certain conditions.

Types of structural steel :

IS:226	Standard Quality
IS:961	High Tensile Steel
IS:1977	Ordinary Quality
IS:2062	Fusion Welding Quality
IS:8500	Medium & High Strength Qualities

Classification of structural steel based on ductility

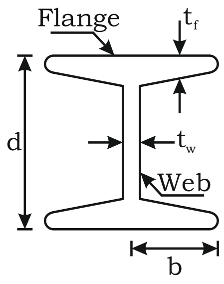
- Low carbon steel
- Medium carbon steel
- High carbon steel

Applications

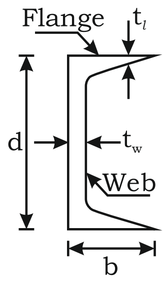
- Long span structures
- Multi-storey & High rise buildings
- Buildings of heavy duty plants
- Tower & mast structures
- Portal frames
- Bridges
- Infrastructures etc.

Types of Standard Rolled Sections

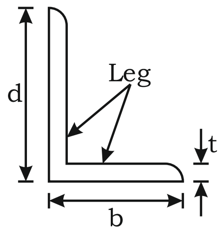
- Rolled Steel I-Sections
- Rolled Steel Channels
- Rolled Steel T-sections
- Rolled Steel angle sections
- Rolled Steel bars
- Rolled Steel flats
- Rolled Steel Plates
- Rolled Steel sheets
- Rolled Steel tubular sections
- Rolled Steel strips



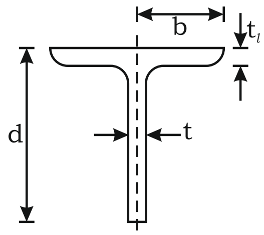
Rolled Beams and Columns



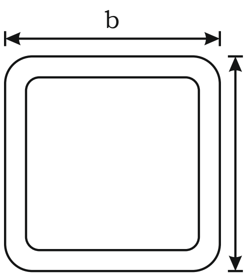
Rolled Channels



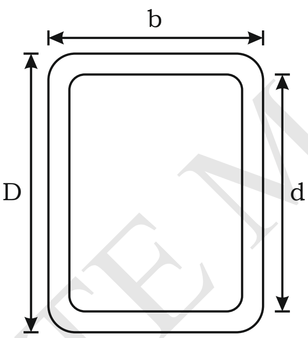
Angles (Unequal)



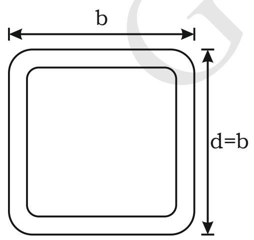
Tees



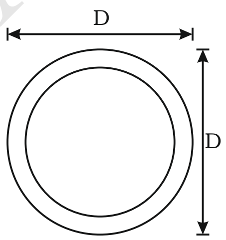
Square Hollow Section (SHS)



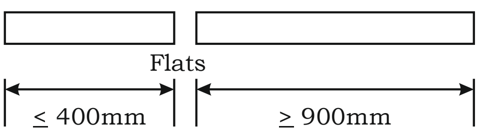
Rectangular Hollow Section (RHS)



Square



Circular bars



Physical Properties of Structural Steel

Specific gravity	7.85
Modulus of Elasticity	2×10^5 MPa
Poisson's ratio	0.25(IS:800-1984) 0.30 (IS:800-2007)
Coefficient of thermal Expansion	$12\times10^{-6}/^{0}C$

METHODS OF DESIGN

- Working stress method
- Ultimate strength method
- Limit state method

Working Stress Method (WSM)

- In this method Stress and Strain relation is consider linear till the yield stress.
- The member will be designed for different load combinations and designed for working loads.
- To take care uncertainities in the design, permissible stress is kept as a fraction of yield stress.
- Working stresses due to DL+LL ≤ permissible stress
- Working stresses due to DL+WL ≤ Permissible stress
- Working stresses due to DL+LL+WL ≤ 1.33 × Permissible stress

Permissible (or) Allowable stresses

- Permissible average shear stress = $0.40f_y$
- Permissible maximum shear stress = $0.45f_y$
- Permissible axial tensile stress = $0.60f_y$
- Permissible bending tensile stress = $0.66f_y$
- Permissible bending compressive stress = $0.66f_y$

- Permissible bearing stress = 0.75 f_y
- Permissible combined bearing and bending stress = 0.90 f_y.

Limit State Method (LSM)

- The acceptable limit for the safety and serviceability requirement before failure occurs is called Limit state.
- It is basically statistical method and used for determination of load and material properties with small probability of structure reaching Limit state of strength and serviceability.

Limit State :

- ***Limit State of Strength***
  - Strength (Yielding, Buckling)
  - Stability against Over turning and sway
  - Fracture due to Fatigue, Plastic collapse
  - Brittle Fracture
- ***Limit State of Serviceability***
  - Deflection
  - Vibration
  - Fatigue checks
  - Corrosion
  - Fire

Design requirement

- Design action (S_d) $\leq$ Design strength (R_d)

  S_d = Design value of internal forces and moments caused by the design loads, F_d

- $F_d = \gamma_f \times$ characteristic load

  γ_f = a load factor which is determined on probabilistic basic

  γ_m = a material facor, which is determined on probabilistic basic

- Partial safety factors [Load factors γ_f]

Load Combination	L.S of Strength			L.S of Serviceability		
	DL	LL	WL/EL	DL	LL	WL/EL
DL + LL	1.5	1.5	-	1.0	1.0	-
DL + WL/EL	1.5 (or) 0.9*	-	1.5	1.0	-	1.0
DL + LL + WL/EL	1.2	1.2	1.2	1.0	0.8	0.8

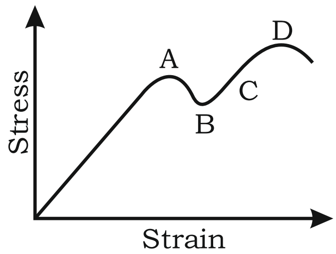
- This value is to be considered when stability against overturning (or) stress reversal is critical Partial safety factors (γ_m)
- Resistance governed by yielding, γ_{mo}=1.10
- Resistance governed by ultimate stress, γ_{m1}=1.25

Resistance of connection	Shop	Field
Bolts-friction type, γ_{mf}	1.25	1.25
Bolts-bearing type, γ_{mb}	1.25	1.25
Rivets, γ_{mr}	1.25	1.25
Welds, γ_{mw}	1.25	1.5

Practice Questions

Level - 1

1. The stress strain diagram for mild steel subjected to tensile load is given below. Now consider the following statements:



    1. The diagram represents average stress strain diagram.
    2. The diagram represents actual stress strain diagram.
    3. A represents upper yield point
    4. B represents lower yield point.

    Which of these statements are correct?

    a) 1, 2 and 4 b) 1, 3 and 4
    c) 2, 3 and 4 d) 1, 2 and 3

2. Upper yield point in the stress-strain curve in structural steel can be avoided by

    a) cold working b) hot working
    c) quenching d) galvanizing

3. The order of elongation which a specimen of mild steel undergoes before fracture is

    a) 0.1 % b) 1% c) 10% d) 100%

4. A ductile structure is defined as one for which the plastic deformation before fracture

    a) is smaller than the elastic deformation
    b) vanishes
    c) is equal to the elastic deformation
    d) is much larger than the elastic deformation

5. Consider the following statements:

    compared to mild steel, aluminium has

    1. lesser ductility
    2. lesser value of Young's modulus
    3. lesser tensile strength
    4. no definite yield point

    Which of these statements are correct?

    a) 1 and 3 only b) 1, 2 and 3 only
    c) 1, 2, 3 and 4 d) 1 and 4 only

6. Rolled steel beams are designed by Indian standards in terms of

    a) Weight per meter and width of the flange
    b) Width of the flange and weight per meter
    c) Weight per meter and depth of the section
    d) Depth of the section and weight per meter

7. In a situation where torsion is dominant, which one of the following is the desirable section ?

    a) Angle section
    b) Channel section
    c) I-section
    d) Box type section

8. Which one of the following is correct?

Steel structures are ideally suitable for impact loads because they have high

a) toughness value

b) elastic modulus

c) design stress

d) plastic modulus

9. Which one of the following methods of design is not suitable for structures subjected to impact and fatigue?

a) Simple design b) Semi-rigid design

c) Rigid design d) Plastic design

10. Which of the following statements is/are correct?

1. A steel structure designer can guarantee the safety of the structure

2. Working stress method of design of steel structures offers a safer and economical structure.

3. Strength and serviceability of a structure cannot be predicted on account of several unforeseen factors

a) 1, 2 and 3 b) 3 only

c) 2 only d) 1 only

11. As per the elastic theory of design, the factor of safety is the ratio of

a) working stress to stress at the limt of proportionality

b) yield stress to working stress

c) ultimate stress to working stress

d) ultimate load to load at yield

12. Factor of safety adopted by IS:800-1984 while arriving at the permissible stress in axial compression is

a) 2.00 b) 1.00 c) 1.87 d) 1.50

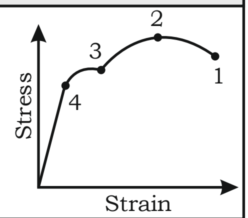
13. Permissible bending tensile stress in high yield strength deformed bars of grade 415 in a beam is

a) 190 N/mm^2 b) 230 N/mm^2

c) 140 N/mm^2 d) None of the above

Level - 2

1. Match **List-I** (Properties) with **List-II** (stress points labelled 1, 2, 3 and 4) in the stress-strain figure and select the correct answer using the codes given below the lists.

List - I	List - II
A. Yield Point B. Proportional Limit C. Rupture Strength D. Ultimate Strength	

Codes :

	A	B	C	D
a)	3	4	1	2
b)	4	3	1	2
c)	3	4	2	1
d)	4	3	2	1

2. Some steels do not show yield point and show continuous curve. For such steel, how is the yield strength obtained?

a) By drawing 0.2% offset of the strain

b) By drawing 0.5% offset of the strain

c) By drawing initial tangent

d) By drawing initial secant modulus

3. **Assertion (A) :** In the working stress design method the internal stresses at a section of member are computed for factored loads.

Reason (R) : In the working stress design method it is ensured that the internal stresses due to working loads are less than the allowable stresses.

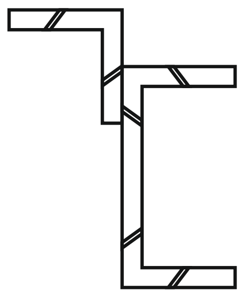
a) Both A and R are true and R is the correct explanation of A

b) Both A and R are true but R is not a correct explanation of A

c) A is true but R is false

d) A is false but R is true

4. An angle is connected to the back of the flange of a channel section to be used as a beam as shown in the diagram below.



This is done to

a) increase the compression flange area

b) increase the moment of inertia about the major axis

c) increase the moment of inertia about the minor axis

d) make the load pass through the shear centre

5. The heavies I-section for same depth is

a) ISMB b) ISLB

c) ISHB d) ISWB

Level - 1

KEY

01. b 02. a 03. c 04. d 05. c 06. d 07. d 08. a 09. d 10. a 11. b 12. c 13. b

Level - 2

KEY

01. a 02. a 03. d 04. d 05. c

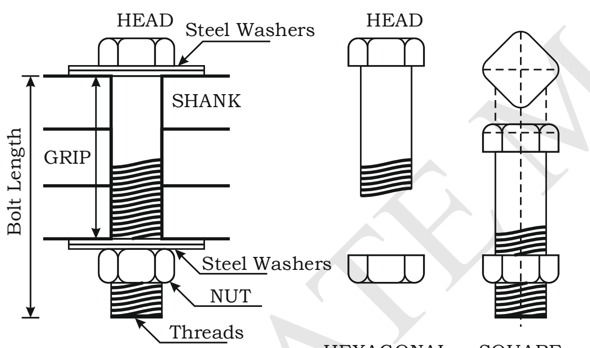
2 BOLTED CONNECTIONS

Introduction:

- One of the important aspects of steel structures is the joining of various members of a structure so that they act as an integral unit.
- The different techniques used to join steel members are rivetting, bolting and welding.
- Rivetting is the old practice, due to many internal demerits, which has been to a large extent, replaced by bolting and welding.

Bolt and Bolting

- Bolt is defined as metal pin with head at one end and a shank threaded at other end to receive a nut.
- Steel washers are usually provided under bolt as well as under the nut to distribute the clamping pressure on the bolted member and to prevent the threaded portion of the bolt from bearing on the connected pieces.



BOLT ASSEMBLY HEXAGONAL HEAD BOLT SQUARE HEAD BOLT

Classification of Bolted Connections

- Based on resultant force transferred
  - Concentric connections
  - Eccentric connections
- Based on force experienced by the bolts
  - Shear connections
  - Tension connections
  - Combined shear and tension connections.
- Based on force transfer mechanism
  - Bearing type
  - Friction type

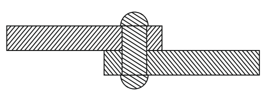
Type of bolts

- **Black bolts (or) unfinished bolts**
  - These are ordinary, rough (or) common bolts
  - They are least expensive bolts and are made of low carbon steels
  - These bolts are used in light structures under static loads such as small trusses, purlins, bracings.
  - For bolt of a grade (or) class 4.6, represents the ultimate tensile strength of 400 N/mm^2 and yield strength is 0.6 times of 400 N/mm^2, which is 240 N/mm^2.
- **High strength friction grip [HSFG] bolts.**
  - These are made from bars of medium carbon heat treated steel
  - The bolt property class 10.9S and 12.9S are commonly used in steel connections
  - These bolts are available in sizes from 16 mm to 36 mm and are designated as M16, M20,M24 & M30
  - These are most suitable for bridges where the stress reversal may occur and also for seismic loading and for fatigue loading.

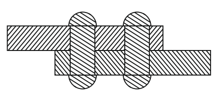
TYPES OF SHEAR CONNECTIONS

- Lap connection
- Butt connection

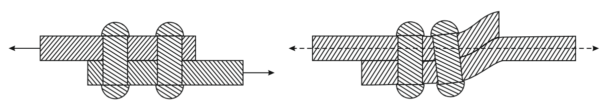
- ***Lap connection***
  - The two members to be connected are over lapped and connected together
  - The load in a lap joint has eccentricity



Single Riveted lap connection



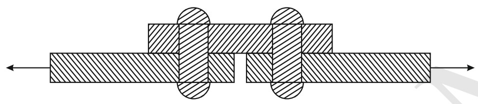
Double Riveted lap connection



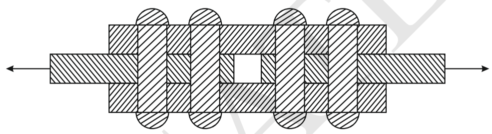
Double Bolted Lap Joint

- ***Butt Joint***
  - Two members to be connected placed end to end.
  - Additional cover plate/plates are provided
  - If cover plate is provided on one side of main plate then it is called Single Cover butt joint.
  - If cover plates are provided on both sides of main plate, then it is called Double Cover butt joint
  - In double cover butt joint, no eccentricity of load, hence no bending effect.
  - For single cover butt joint, cover plate thickness required is 1.25 times the main plate thickness.
  - For double cover butt joint, each cover plate thicknes is

$\frac{5}{8}\times$ thick-ness of main plate



Single Cover Butt Joint (Single Bolted)



Double Cover Butt Joint (Double Bolted Butt Joint)

SPECIFICATIONS

Diameter of hole (or) Gross diameter (d_h)

d_h = d+1mm $\rightarrow$ if d = 12 mm to 14 mm

= d+2mm $\rightarrow$ if d = 16 mm to 24 mm

= d+3mm $\rightarrow$ if d > 24 mm

d = Nominal diameter of bolt

Pitch (p):

Distance between centre of two consecutive bolts measured parallel to the direction of the force

Minimum pitch (p_{min})

p_{min} = 2.5 $\times$ nominal diameter of bolt

Maximum Pitch (p_{max})

- **For plates**
  - p_{max}=16 t (or) 200mm, whichever is less for tension member.
  - p_{max}=12t (or) 200 mm, whichever is less for compression member.
  - 32t (or) 300 mm, whichever is less for tacking (or) stitch bolts, when plates are not exposed to weather
  - 16 t (or) 200 mm, whicherer is less for tacking (or) stitch bolts, when plates are exposed to weather.
- **For angles**
  - Not exceeding 600 mm for compression members
  - Not exceeding 1000 mm for tension members.
- **Gauge (g)**
  - Centre to centre distance between two consecutive bolts measured at right angles to the direction of force
  - The gauge length 'g' should not be more than (100+4t) (or) 200 mm, whichever is less
- **Bolt line**
  - It is the line along which bolts are placed.
- **Edge Distance (e)**
  - Distance between the centre of bolt hole to the nearest edge of main member (or) cover plate edge measured parallel to the direction of a load in member.

Minimum edge distance (e_{min})

e_{min} = 1.5 $\times$ Gross diameter of bolt $\rightarrow$ Machine cut

= 1.7 $\times$ Gross diameter of bolt $\rightarrow$ Hand cut

Maximum edge distance (e_{max})

e_{max}=12tε & (4t+40mm)

It should not exceed following

- 12tε,

Where

$$\varepsilon = \sqrt{\frac{250}{f_y}}$$

- (40+4t), if exposed to corrossive environments

  Where

  t = thickness of thinner outside plate in mm

Failure of bolted connections

- Shearing failure of bolt
- Bearing failure of bolt
- Tension failure of bolt
- Bearing failure of plate
- Tearing failure of plate
- Block shear failure

Design Shear Strength of Bolts (V_{dsb})

$$V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}}$$

γ_{mb} = Partial safety factor for bolt

= 1.25 (for both shop and field bolting)

V_{nsb} = Nominal shear strength of bolt

$$V_{nsb} = \frac{f_{ub}}{\sqrt{3}}[n_n A_{nb} + n_s A_{sb}]$$

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}[n_n A_{nb} + n_s A_{sb}]$$

f_{ub} = Ultimate tensile strength of the bolt

n_n = Number of shear planes with threads intercepting the shear plane

n_s = Number of shear planes without threads intercepting the shear plane

A_{sb} = Nominal plain shank area of the bolt

$= \frac{\pi}{4}d^2$

A_{nb} = Net tensile area at threads

$\simeq 0.78\, A_{sb}$

- For bolts in single shear, either n_n(or)n_s is one
- For bolts in double shear, the sum of n_n and n_s is two
- The nominal shear strength of bolt will be reduced in case of long joint, grip & packing plate.

$$V_{nsb} = \frac{f_{ub}}{\sqrt{3}}[n_n A_{nb} + n_s A_{sb}]\ \beta_{\ell j} \times \beta_{\ell g} \times \beta_{pkg}$$

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\gamma_{mb}}[n_n A_{nb} + n_s A_{sb}]\ \beta_{\ell j} \times \beta_{\ell g} \times \beta_{pkg}$$

$\beta_{\ell j}$ = Reduction factor for long joints

- In long joints, the distance between the first and the last bolt exceeding 15d in the direction of load

$$\beta_{\ell j} = 1.075 - \frac{\ell_j}{200d} \qquad (0.75 \le \beta_{\ell j} \le 1.0)$$

$\beta_{\ell g}$ = Reduction factor for long grip when grip length of bolts exceeds five times the nominal diameter, then

$$\beta_{\ell g} = \frac{8d}{3d + l_g} \qquad \ell_g = \text{Grip length}$$

β_{pkg} = Reduction factor for packing plates

When

Packing thickness is more than 6 mm then

β_{pkg} = 1.0-0.0125 t_{pkg}

Design Bearing Strength of Bolt (V_{dpb})

$$V_{dpb} = \frac{V_{npb}}{\gamma_{mb}}$$

V_{npd} = Nominal bearing strength of a bolt = 2.5 k_b dt f_u

$$V_{dpb} = \frac{2.5 k_b d t f_u}{\gamma_{mb}}$$

d_h = diameter of hole

k_b = smaller of $\left\{\frac{e}{3d_h},\right.$

$$\left(\frac{p}{3d_h}-0.25\right), \frac{f_{ub}}{f_u} 1.0\Big\}$$

- e&p = edge and pitch distance
- f_{ub} = Ultimate tensile strength of bolt
- f_u = Ultimate tensile strength of plate
- d = Nominal diameter of bolt
- t = thickness of thinner plate in lap joint
  = Smaller of thinner main plate thickness and sum of cover plates thickness → butt joint

Design Tensile Strength of Bolt (T_{db})

$$T_{db} = \frac{T_{nb}}{\gamma_{mb}}$$

T_{nb} = Nominal tensile strength of bolt

$$= 0.9 \frac{f_{ub} A_{nb}}{\gamma_{mb}} \le \frac{f_{yb} A_{sb}}{\gamma_{mo}}$$

- f_{ub} = Ultimate tensile strength of bolt
- f_{yb} = Yield stress of bolt
- γ_{mo} = 1.10 & γ_{mb} = 1.25

Design Strength of Bolt (V_{db})

It is least value of design strength of bolt in Shear (V_{dsb}), Pearing (V_{dpb}) & Tension (T_{db})

Number of bolts (n)

If the connection is subjected to concentric design axial load (P), the no of bolts (n) required to support design load is

$$n = \frac{\text{Design (or) factored axial load}}{\text{Design strength of one bolt}} = \frac{P}{V_{db}}$$

Design Tensile Strength of Plate (T_{dp})

$$T_{dp} = \frac{T_{np}}{\gamma_{m1}}$$

T_{np} = Nominal tensile strength of plate

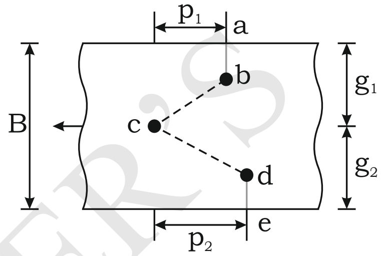
$= 0.9\, A_n f_u$

$$T_{np} = \frac{0.9 \times A_n \times f_u}{\gamma_{m1}}$$

A_n = Net sectional area of plate

$= [b - nd_h]t \rightarrow$ Chain patten of bolting

$\left[b - nd_h + \frac{p_1^2}{4g_1} + \frac{p_2^2}{4g_2}\right]t \rightarrow$ Zig zag (or) staggerd pattern of bolting



(Hole diameter d_0 & n=3)

Design strength of bolted connection (V_{dc})

V_{dc} = Smaller of V_{dsb}, V_{dpb}, T_{db} (if exists) & T_{dp}

Efficiency of the bolted joint (η)

$$\eta = \frac{\text{Design strength of bolted connection}(V_{dc})}{\text{Design strength of solid plate}(T_{sp})}$$

Design strength of solid plate

$$T_{sp} = \frac{A_g f_y}{\gamma_{m1}}$$

A_g = Gross area of plate
= B.t

WORKING STRESS METHOD CONCEPT

- Rivet is a ductile steel pin with a manufactured head at one end and a straight portion known as Shank.
- The process of rivetting starts with drilling of holes into the metal parts to be joined, the diameter of which are slightly greater than the diameter of the shank of the rivet.

  Rivets are made of mild steel (or) high tensile steel

  Rivet consists of head and shank

  Gross dia of rivet (or) hole diameter of rivet

$d = \phi + 1.5\text{mm, if } \phi \leq 25 \text{ mm}$

$= \phi + 2.0 \text{ mm, if } \phi > 25 \text{ mm}$

Where

ϕ = Nominal diameter of rivet

Classification of rivets :

- ***Based on method of driving force***
  - Power driven rivets
  - Hand driven rivets

  Power driven rivets have strength higher than hand driven rivet
- ***Based on method of heating***
  - Hot driven rivets
  - Cold driven rivets

  Cold driven rivet has more strength compared to hot driven rivet.
- ***Based on method of placing***
  - Work shop rivets
  - Field driven rivets

Work shop driven rivets have more strength than field rivets

- It is associated with high level of noise pollution
- It needs heating the rivet to red hot
- Inspection of connection is a skilled work
- Removing poorly installed rivets is costly
- Labour cost is high

Strength of Rivet in Shear (P_s)

$$P_s = \frac{\pi}{4} d^2 \times \tau_{vf} \rightarrow \text{Single shear}$$

$$P_s = 2 \times \frac{\pi}{4} d^2 \times \tau_{vf} \rightarrow \text{Double shear}$$

d = Diameter of hole

τ_{vf} = Permissible shear stress in rivet

Strength of Rivet in Bearing (P_b)

$P_b = d \times t \times \sigma_{pf}$

σ_{pf} = Permissible bearing stress in rivet

Rivet value (or) strength of rivet (R_v)

R_v = smaller of P_s & P_b

no of rivets required,

$$n = \frac{\text{working axial load}}{\text{Rivet value}} = \frac{P}{R_v}$$

Strength of plate in tension (P_t)

$P_t = A_{net} \times \sigma_{at}$

A_{net} = Net effective sectional area of plate

σ_{at} = Permissible axial tensile stress in plate

$= 0.6 f_y$

Strength of riveted joint (P_c)

P_c = It is smaller of P_s, P_b & P_t

Efficiency of the connection (η)

$$\eta = \frac{\text{Strength of riveted connection (or) joint}}{\text{Strength of solid plate}} \times 100$$

$$= \frac{P_C}{P_{sp}} \times 100$$

Strength of solid plate (P_{sp})

$P_{sp} = A_g \sigma_{at}$

A_g = Gross sectional area of plate = B.t

Chain pattern vs Diamond pattern

- Diamond pattern of riveting is more efficient than chain riveting
- Cover plate material may be saved using diamond pattern
- Width of main plate required for diamond pattern of riveting may be lesser as compared with chin Pattern of riveting.
- Nominal diameter of rivet based on Unwin's formula, $\phi = 6.05\sqrt{t}$

  t = thickness of plate in mm ϕ in mm

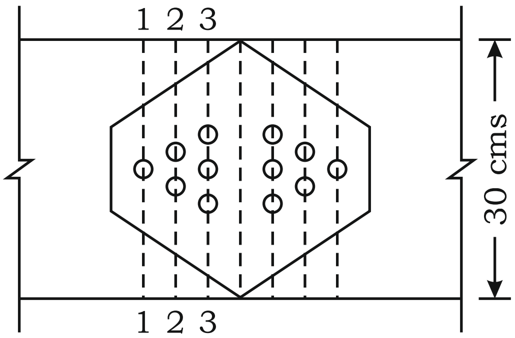
CLASSWORK

1. Width of tie plate and thickness of cover plate can be computed on the basis of
   a) Shear strength of rivet
   b) Bearing strength of rivet
   c) Tearing strength of rivet
   d) All of the above

2. A structural member carrying a pull of 700 kN is connected to a gusset plate using rivets. If the pulls required to shear the rivet, to crush the rivet and to tear the plate per pitch length are respectively 60 kN, 35 kN and 70 kN, then the number of rivets required will be
   a) 22 b) 20 c) 18 d) 12

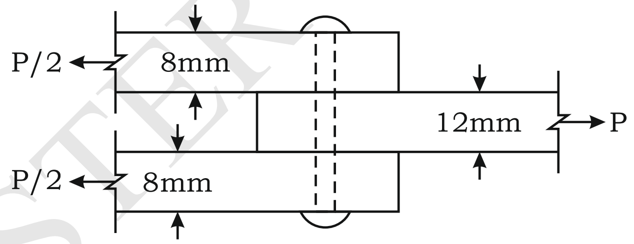
3. A mild steel flat subjected to a tensile force of 840 kN is connected to a gusset plate using rivets. If the permissible forces required per pitch length
   i) To shear a single rivet
   ii) To crush the rivet and
   iii) To tear the plate are 50 kN, 80 kN and 60 kN respectively then the number of rivets required is
   a) 12 b) 14 c) 16 d) 17

4. Two steel plates each of 12 mm thickness are connected by a double cover butt joint by rivets shown in the given figure. If the rivet diameter is 22 mm with rivet force value of 53150 N and permissible stress in tension of plate is 142 N/mm^2, which one of the following section is the most critical section?



   a) Section 1–1
   b) Section 2–2
   c) Section 3–3
   d) Both Section 1–1 and Section 2–2

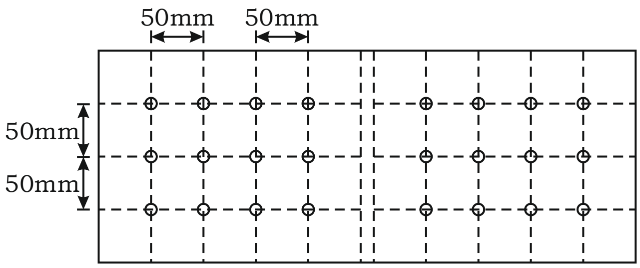
5. A 12mm thick plate is connected to two 8mm thick plates, on either side through a 16mm diameter power driven field rivet as shown in the figure below. Assuming permissible shear stress as 90MPa and permissible bearing stress as 270MPa in the rivet, the rivet value of the joint is



   a) 56.70 kN b) 43.29 kN
   c) 36.19 kN d) 21.65 kN

6. An angle ISA 50 × 50 × 6 is connected to a gusset plate 5 mm thick, with 16 mm bolts. What is the bearing strength of the bolt when the hole diameter is 16 mm and the allowed bearing stress is 250 MPa?
   a) 8 kN b) 20 kN
   c) 22.5 kN d) 24 kN

7. A double cover butt riveted joint is used to connect two flat plates of 200mm width and 14mm thickness as shown in the figure. There are twelve power driven rivets of 20mm diameter at a pitch of 50 mm in both directions on either side of the plate. Two cover plates of 10 mm thickness are used. The capacity of the joint in tension considering bearing and shear ONLY, with permissible bearing and shear stresses as 300MPa and 100MPa respectively is



a) 1083.6 kN b) 871.32 kN
c) 541.8 kN d) 433.7 kN

8. Two bolted plates under tension with alternative arrangement of bolt holes are shown in figures 1 and 2. The hole diameter, pitch, and gauge length are d, p and g, respectively

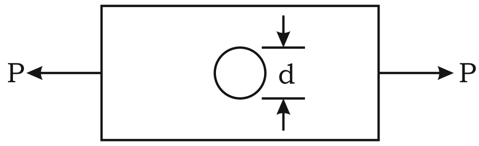


Figure - 1

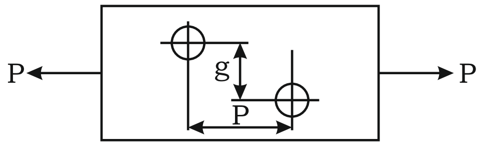


Figure - 2

Which one of the following conditions must be ensured to have higher net tensile capacity of configuration shown in figure I?

a) $p^2>2gd$ b) $p^2 < \sqrt{4gd}$

c) $p^2>4gd$ d) $p > 4gd$

Practice Questions

Level - 1

1. As per IS : 800-1984, the minimum pitch of rivets in a row is recommended as the diameter of the rivet times

   a) 2.0 b) 2.5 c) 3.0 d) 4.0

2. What is the maximum permissible longitudinal pitch in staggered riveted compression joints?

   a) 500 mm b) 400 mm
   c) 300 mm d) 100 mm

3. The maximum longitudinal pitch in bolted joints, subjected to tensile forces, where in t = thickness of the plate and D = diameter of bolt, is

   a) 32 D b) 16 D c) 32 t d) 16t

4. The maximum longitudinal pitch allowed in bolted joints of tension members is

   a) 16 times the diameter of the bolt
   b) 32 times the diameter of the bolt
   c) 16times the thickness of the plate
   d) 32times the thickness of the plate

5. Load on connection is not eccentric for

   a) lap joint
   b) single cover butt joint
   c) double cover butt joint
   d) all the joints mentioned in (a), (b) and (c) of the question

6. The common assumption that, 'all rivets share equally a non-eccentric load' is valid at a load

   a) below the working load
   b) equal to the working load
   c) above the working load
   d) equal to the failure load

7. Match **List - I** (failure mode) with **List-II** (Reason) and select the correct answer using the codes given below the lists :

   List - I
   a) Shear failure of plates
   b) Bearing failure of plates
   c) Tearing failure of plates
   d) Splitting failure of plates

   List - II
   1. Insufficient edge distance
   2. Strength of plate is less than that of the rivets

Codes :

	A	B	C	D
a)	1	1	2	1
b)	2	1	2	1
c)	1	2	2	1
d)	1	1	1	2

8. Rivet value is defined as

   a) lesser of the bearing strength of rivet and the shearing strength of the rivet
   b) lesser of the bearing strength of rivet and the tearing strength of thinner plate
   c) greater of the bearing strength of rivet and the shearing of the rivet
   d) lesser of the shearing strength of the rivet and the tearing strength of thinner plate

9. In a double - riveted double-cover butt joint, the strength of the joint per pitch length in shearing the rivets is n times the shear strength of one rivet in single shear, where 'n' is equal to

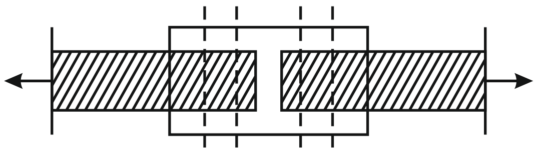
   a) 1 b) 2 c) 3 d) 4

10. In a steel plate with bolted connection, the rupture of the net section is a mode of failure under

    a) tension b) compression
    c) flexure d) shear

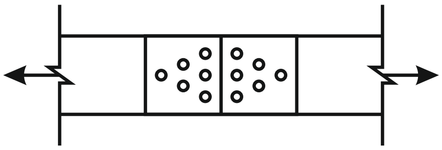
11. Identify the most effective butt joint (with double cover plates) for a plate in ten-

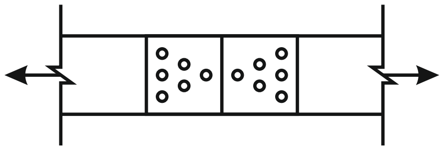
sion from the patterns (plan view) shown below, each comprising 6 identical bolts with the same pitch and gauge.

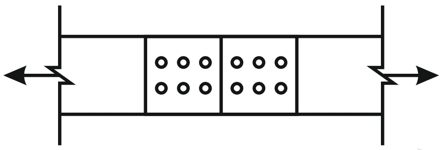


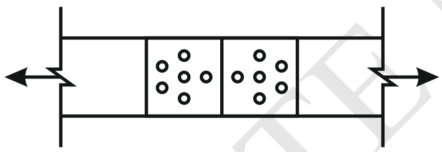
Common Elevation

(all plates have same thickness)

a) 

b) 

c) 

d) 

12. Consider the following statements:
    1. When analyzing by the Ultimate Load Method, the eccentrically loaded fastener group rotates about an instantaneous centre
    2. The rivet which is the farthest from the centre of gravity of the rivet group and may also be the nearest to the applied load line is the most 'critical' one.
    3. The deformation at each rivet is not proportional to its distance from the centre of rotation.

    Which of the above statements are correct?

    a) 1 and 3 only b) 2 and 3 only
    c) 1 and 2 only d) 1, 2 and 3

13. What is the ratio of the yield stress in power driven shop rivets relative to the permissible bearing stress of mild steel?

    a) 1.0 b) 0.8 c) 0.6 d) 0.4

14. For field rivets, the permissible stresses are reduced by what percentage?

    a) 10% b) 15% c) 25% d) $33\frac{1}{3}\%$

15. When the effect of wind or earthquake load is considered in the design of rivets and bolts for steel structures, by what percentage the permissible stresses may be exceeded?

    a) 15% b) 25%
    c) 33.33% d) 50%

16. A bolt designated as Hex bolt M16×70 NL will have

    a) diameter of 16 mm
    b) diameter of 70 mm
    c) length of 16mm
    d) cross-sectional area 16×70 cm^2

17. Bolt grade 4.6 has nominal yield strength of

    a) 460 MPa b) 400 MPa
    c) 360 MPa d) 240 MPa

18. Generally (fatigue life of welded steel structure/fatigue life of riveted steel structure) ratio is

    a) smaller than 1 b) equal to 1
    c) greater than 1 d) greater than 2.1

Level - 2

1. A steel plate is 30 cm wide and 10 mm thick. A rivet of nominal diameter 18 mm is driven. The net sectional area of the plate is

    a) 18.00 cm^2 b) 28.20 cm^2
    c) 28.05 cm^2 d) 32.42 cm^2

2. Which one of the following is the most important consideration in the design of a riveted joint between structural members when the centroid of the riv-

ets does not coincide with the axis of the load?

a) Direct shear force in each rivet is proportional to its radial distance from its centroid and the resultant force in each rivet should not exceed its rivet value.

b) Shear force caused in each rivet due to eccentricity of the load is proportional to its radial distance from its centroid and the direct shear force in each rivet should be limited to half the rivet value.

c) The shear force caused in each rivet due to eccentricity of the load is proportional to the radial distance of the rivet from the centroid of the rivet group and the maximum resultant force in any rivet should not exceed the rivet value.

d) The shear force caused in the rivet due to eccentricity of load as well as direct shear force caused in the rivet should not exceed rivet value individually.

3. A mild steel flat subjected to tensile force of 84 tonnes is connected to a gusset plate using rivets. If the forces required to shear a single rivet, to crush the rivet and to tear the plate per pitch length are 5000 kg. 8000 kg and 6000 kg respectively, then the number of rivets required is

a) 12 b) 14 c) 16 d) 17

4. Consider the following statements :

1. To insert a 28 mm nominal diameter rivet, 29.5 mm rivet hole is made.
2. Provision is made to allow temperature expansion of the bolt

Which of these statements are correct?

a) Both 1 and 2 b) 1 only

c) 2 only d) Neither 1 nor 2

5. In a diamond riveting, for a plate of width 'b' and rivet diameter 'd', the efficiency of the joint is given by

a) $\frac{(b-d)}{b}$ b) $\frac{(b-2d)}{b}$

c) $\frac{(b-d)}{d}$ d) $\frac{(b-2d)}{d}$

6. Consider the following statements regarding pin connections :

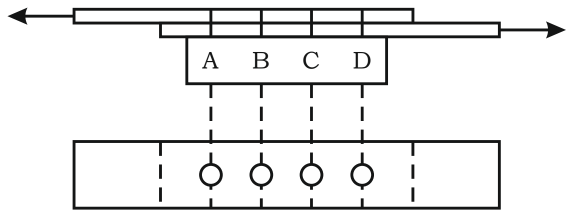
1. Moment at pin connection is zero
2. Only one pin is used in a connection
3. Secondary stresses do not occur.
4. They are rigid.

Which of these are advantages of pin connections?

a) 1, 3 and 4 b) 2, 3 and 4

c) 1, 2 and 3 d) 1 and 2

7. Which one of the following statements regarding the riveted joint shown in the given figure is correct?



a) In elastic theory all rivets carry equal forces.

b) In plastic theory all rivets carry equal forces

c) Both in elastic and plastic theories all rivets carry equal forces.

d) In plastic theory the outer rivets A and D carry greater proportion of load.

8. A 6 mm thick mild steel plate is connected to a 8 mm thick plate by 16 mm diameter shop rivets. What is the number of rivets required to carry an 80 kN load?

a) 2 b) 3 c) 4 d) 6