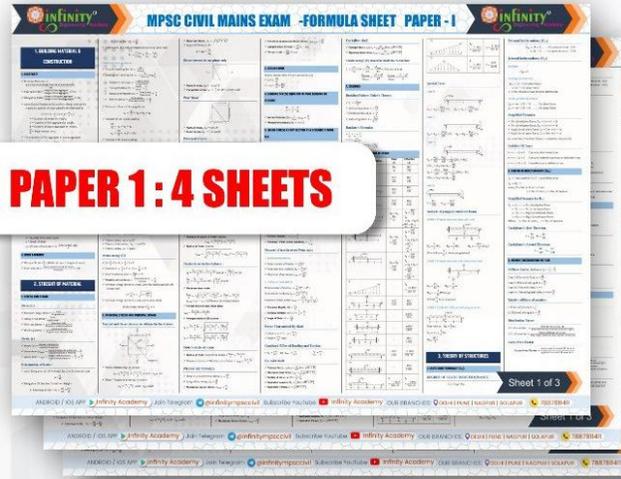
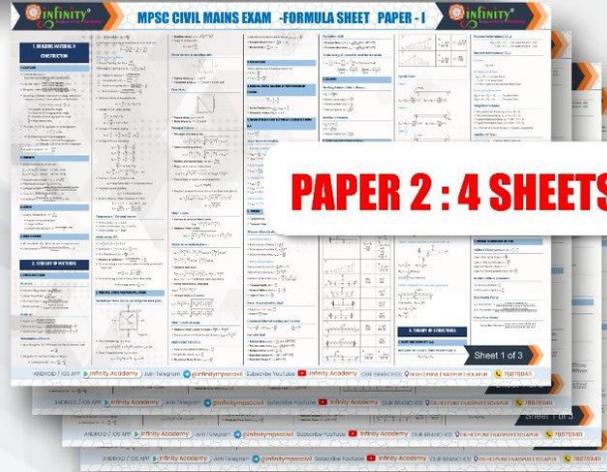


FORMULA SHEETS [A2 SIZE]



PAPER 1 : 4 SHEETS



PAPER 2 : 4 SHEETS

COVER ALL 20 SUBJECT FORMULAE

Infinity Academy Office



पुणे

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1. BUILDING MATERIALS & CONSTRUCTION

1. AGGREGATE

- Flattens modulus = $\frac{\text{Flattens coverage} \times \text{volume} \times \text{unit weight}}{\text{Flattens area}}$
- Flattens Index = $\frac{\text{Flattens coverage} \times \text{volume} \times \text{unit weight}}{\text{Flattens area}} \times 100$
- Flattens Index = $\frac{\text{Flattens coverage} \times \text{volume} \times \text{unit weight}}{\text{Flattens area}} \times 100$
- According to flammability of aggregate, the maximum quantity of water added in the first batch is $0.3P + 0.1Y + 0.02Z - \frac{W}{100} + F$
- P = Quantity of cement by weight
- Y = Quantity of fine aggregate by weight
- Z = Quantity of coarse aggregate by weight
- W = Water cement ratio
- The proportion of the aggregate to coarse aggregate $P = \frac{100}{100 + 100}$
- x = Flammability modulus of coarse aggregate
- y = Flammability modulus of fine aggregate
- z = Flammability modulus of combined aggregate
- Angularly Number = $40 - \frac{100}{100}$

2. CONCRETE

- Modulus of elasticity of concrete: $E_c = 5000 \sqrt{f_{ck}}$ (IS 456: 2000)
- $E_c = 5700 \sqrt{f_{ck}}$ (IS 456: 1978)
- Flexural tensile strength: $f_{ct} = 0.7 \sqrt{f_{ck}}$
- Direct tensile strength: $f_{ct} = 0.25 f_{ck}$
- Creepage Factor = $\frac{\text{change in length} \times \text{original length}}{\text{original length} \times \text{time}}$
- Flow % = $\frac{\text{spread (cm)} - 10}{10} \times 100$
- % Bulking = $\frac{\text{increase in volume} - \text{initial volume}}{\text{initial volume}} \times 100$

3. STONES

- Quantity of Explosive: $A = \frac{L^3}{1000}$
- A = quantity of explosive (kg)
- L = length of blast
- Co-efficient of hardness = $20 - \frac{\text{length} \times \text{weight}}{10}$

4. DOOR & WINDOW

- Window Width = $\frac{1}{2} \times (\text{Width of room} + \text{Height of room})$
- Floor area ratio = $\frac{\text{Total Covered area of all floors}}{\text{Floor area}} \times 100$

2. STRENGTH OF MATERIAL

1. STRESS AND STRAIN

Stress (σ)

- Nominal / Engg. stress = $\frac{\text{Load}}{\text{Original area}}$
- Actual / True stress = $\frac{\text{Load}}{\text{Actual area}}$
- Ultimate Stress = $\frac{\text{Maximum load}}{\text{Original cross-sectional area}}$
- Working stress = $\frac{\text{Design load}}{\text{Original cross-sectional area}}$

Strain (ϵ)

- Strain (ϵ) = $\frac{\text{change in dimension}}{\text{original dimension}}$
- Linear strain (ϵ_{long}) = $\frac{\text{change in longitudinal dimension}}{\text{original longitudinal dimension}}$
- Lateral strain (ϵ_{lat}) = $\frac{\text{change in lateral dimension}}{\text{original lateral dimension}}$

Deflection of Beams:

- Actual Elongation (Δ) of Prismatic Bar Due To External Load

$\Delta = \frac{PL}{AE}$

- Elongation Of Bar Due To Its Own Weight
- A. Rectangular Bar: $\Delta = \frac{W L^3}{8 E A^2}$
- B. Circular Bar: $\Delta = \frac{W L^3}{8 E A^2}$
- Deflection of a body of stepped axis due to an axial load: $\Delta = \frac{W}{E} \left(\frac{L_1}{A_1} + \frac{L_2}{A_2} + \frac{L_3}{A_3} \right)$
- Uniformly Varying Section:
 - Circular Tapering Bar: $\Delta = \frac{W L^3}{8 E A^3} \ln \frac{D_1}{D_2}$
 - Rectangular Tapering Bar: $\Delta = \frac{W L^3}{8 E A^3} \ln \frac{B_1}{B_2}$
- Poisson's ratio (μ) = $\frac{\text{Lateral strain}}{\text{Longitudinal strain}}$
- Young Modulus (E) = $\frac{\text{Stress}}{\text{Strain}}$
- Modulus of rigidity (G) = $\frac{\text{Shear stress}}{\text{Shear strain}}$
- Bulk modulus = $\frac{\text{Volume stress}}{\text{Volume strain}}$
- Volumetric Strain of Rectangular bar: $\epsilon_v = \frac{\Delta L}{L} + \frac{\Delta B}{B} + \frac{\Delta D}{D}$
- Concept Of Uni-Axial Loading:
 - $\frac{\Delta L}{L} = \epsilon_x + \epsilon_y + \epsilon_z$
 - $\epsilon_x = \frac{\Delta L}{L} = \mu (1 - 2\mu)$
- Concept Of Bi-Axial Loading:
 - $\epsilon_x = \frac{\Delta L}{L} = \mu \left(\frac{\Delta L}{L} + \frac{\Delta B}{B} \right) = \frac{\Delta L}{L} - \mu \frac{\Delta B}{B}$
- Concept Of Tri-Axial Loading:
 - $\epsilon_x = \frac{\Delta L}{L} = \mu \left(\frac{\Delta L}{L} + \frac{\Delta B}{B} + \frac{\Delta D}{D} \right)$
 - $\epsilon_y = \frac{\Delta B}{B} = \mu \left(\frac{\Delta L}{L} + \frac{\Delta B}{B} + \frac{\Delta D}{D} \right)$
 - $\epsilon_z = \frac{\Delta D}{D} = \mu \left(\frac{\Delta L}{L} + \frac{\Delta B}{B} + \frac{\Delta D}{D} \right)$
 - $\frac{\Delta L}{L} = \frac{\Delta B}{B} = \frac{\Delta D}{D} = \mu (1 - 2\mu)$
- Volumetric Strain of Cylindrical bar: $\epsilon_v = \text{longitudinal strain} + 2(\text{diametric strain})$
- Volumetric Strain of sphere: $\epsilon_v = 3 \times \text{diametric strain}$
- Relation Between Elastic Constants E, G & K:
 - $E = 2G(1 + \mu) = 3K(1 - 2\mu)$
 - $E = \frac{9KG}{3K + G}$, $\mu = \frac{3K - 2G}{6K + 2G}$
- Temperature / Thermal stresses:
 - Thermal strain, $\epsilon_t = \alpha \Delta T$
 - Thermal deformation, $\Delta L = (\alpha \Delta T)L$
 - Thermal stress, $\sigma_t = E \alpha \Delta T$
- Strain energy (U):
 - $U = \frac{1}{2} P \times \Delta L = \frac{1}{2} P \times \epsilon \times L$
 - Resilience = $\frac{1}{2} \times P \times \Delta L = \frac{W}{2} \times V$
 - Proof Resilience (U_p) = $\frac{W_p}{2} \times V$
 - Modulus of resilience = $\frac{\text{Proof Resilience}}{\text{Volume}}$
 - For strain energy stored in a body when the load is applied with impact load: $U = \frac{W}{2} \left(1 + \sqrt{1 + \frac{2H}{L}} \right)$
 - For strain energy stored in a body due to stress: Strain energy stored = $\frac{\sigma^2}{2E} \times V$

2. PRINCIPAL STRESS AND PRINCIPAL STRAIN

- Normal and Shear stresses on oblique plane
- Normal stress (σ_n) on a plane: $\sigma_n = \left(\frac{\sigma_x + \sigma_y}{2} \right) + \left(\frac{\sigma_x - \sigma_y}{2} \right) \cos 2\theta + \tau_{xy} \sin 2\theta$

Direct stresses in one plane only

Pure Shear

Principal Stresses

- Normal stress, $\sigma_x = \sigma \cos^2 \theta$
- Shear stress, $\tau_x = -\tau \sin 2\theta$
- Maximum principal stress

Mohr's circle of strains

- Radius of Mohr's circle for strain = $\frac{\sigma_x - \sigma_y}{2} + \frac{\tau_{xy}}{2}$
- Distance of centre of Mohr's circle of strain = $\frac{\sigma_x + \sigma_y}{2}$

PRESSURE VESSELS

- hoop or circumferential stress, $\sigma_c = \frac{p r}{t}$
- Longitudinal stress, $\sigma_l = \frac{p r}{2t}$
- Maximum shear stress, $\tau_{max} = \frac{p r}{4t}$
- Absolute maximum shear stress, $\tau_{max} = \frac{p r}{4t}$
- Longitudinal Strain = $\frac{\Delta L}{L} = (1 - 2\mu)$
- Hoop strain = $\frac{\Delta r}{r} = (2 - \mu)$

S.F.D AND B.M.D

Relation between S.M, S.F and load intensity (w)

- S.F = $\frac{dM}{dx}$
- $-w = \frac{d^2M}{dx^2} = \frac{d^2S.F}{dx^2}$

BENDING STRESS EQUATION OF PURE BENDING OR FLEXURE

$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$

Section Modulus (Z) = $\frac{I}{y_{max}} = \frac{M}{\sigma_{max}}$

Angle of Twist: $\theta = \frac{TL}{GJ}$

Power Transmitted By Shaft

- Power = $\omega \times T$ ($\omega = \frac{2\pi N}{60}$)
- Power = $\frac{2\pi N T}{60}$ watts

Combined Effect of Bending and Torsion:

- $\sigma_c = \frac{M y}{I} + \tau_{max} = \frac{M y}{I} + \frac{16 T r}{\pi d^3}$

For solid shaft

- Principal Stress, $\sigma_1, \sigma_2 = \frac{\sigma_c}{2} \pm \sqrt{\left(\frac{\sigma_c}{2} \right)^2 + \tau_{max}^2}$
- Maximum shear stress, $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{\sigma_c}{2} \sqrt{1 + \left(\frac{2\tau_{max}}{\sigma_c} \right)^2}$
- Position of stress, $\tan 2\theta = \frac{2\tau_{max}}{\sigma_c}$
- Equivalent moment, $M_e = \frac{16}{\pi d^3} \sqrt{M^2 + T^2}$
- Equivalent Torque, $T_e = \sqrt{M^2 + T^2}$

For hollow shaft

- Principal Stress, $\sigma_1, \sigma_2 = \frac{\sigma_c}{2} \pm \sqrt{\left(\frac{\sigma_c}{2} \right)^2 + \tau_{max}^2}$
- Maximum shear stress, $\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{\sigma_c}{2} \sqrt{1 + \left(\frac{2\tau_{max}}{\sigma_c} \right)^2}$

Strain energy (U) stored in shaft due to torsion:

$U = \left(\frac{1}{2} \right) T \theta = \frac{T^2 L}{2 G J} = \frac{1}{2} \times \text{Volume of shaft} \times \frac{T^2}{G J}$

$\frac{U_{torsion}}{U_{bending}} = \frac{D^2 + d^2}{D^2 - d^2} \times \frac{T_{torsion}^2}{T_{bending}^2}$

COLUMNS

Buckling Failure: Euler's Theory

$P_c = \frac{\pi^2 E I}{L^2}$

Special Cases

Case 1)

$\theta_A = \theta_B = \frac{W L^2}{2 E I}$, $\theta_B = \theta_A = \frac{W L^2}{2 E I}$

Case 2)

$\theta_A = \theta_B = \frac{W L^2}{8 E I}$, $\theta_B = \theta_A = \frac{W L^2}{8 E I}$

3. THEORY OF STRUCTURES

1. STATIC INDETERMINACY (D_s)

DEGREE OF STATIC INDETERMINACY

$D_s = D_u + D_e$

External Indeterminacy (D_e)

$D_e = (R - 3) \dots$ For plane structure

$= (R - 6) \dots$ For space structure

Internal Indeterminacy (D_i)

For beam: $D_i = 0$

For rigid jointed frame

$D_i = 3C - R$ For plane frame

$= 6C - R$ For space frame

C = No. of cuts to make structure determinate

For pin jointed plane frame

$D_i = m - (2j - 3) \dots$ For plane frame

$D_i = m - (2j - 6) \dots$ For space frame

Simplified Formulae:

For pin jointed plane frame, $D_s = (m + j) - 3$

For rigid jointed plane frame, $D_s = (3m + j) - 3$

For rigid jointed space frame, $D_s = (6m + j) - 6$

8. SLOPE AND DEFLECTION OF BEAM :

Types of beam and loading	Slope (θ)	Deflection (δ)
1.	$\frac{WL}{EI}$	$\frac{WL^2}{2EI}$
2.	$\frac{WL^2}{2EI}$	$\frac{WL^3}{3EI}$
3.	$\frac{WL^2}{6EI}$	$\frac{WL^4}{8EI}$
4.	$\frac{WL^2}{24EI}$	$\frac{WL^4}{30EI}$
5.	$\theta_A = \theta_B = \frac{W L}{4EI}$	$\delta_A = \frac{W L^3}{24EI}$ $\delta_B = \frac{W L^3}{24EI}$ $\delta_C = \frac{W L^3}{48EI}$
6.	$\theta_A = \theta_B = \frac{W a^2}{2EI}$	$\delta_A = \frac{W a^3}{3EI}$ $\delta_B = \frac{W a^3}{3EI}$ $\delta_C = \frac{W a^3}{6EI}$
7.	$\theta_A = \theta_B = \frac{W a^2}{6EI}$	$\delta_A = \frac{W a^3}{6EI}$ $\delta_B = \frac{W a^3}{6EI}$ $\delta_C = \frac{W a^3}{12EI}$
8.	-	$\delta_A = \frac{11 WL^4}{120 EI}$
9.	$\frac{WL^2}{16EI}$	$\frac{WL^3}{48EI}$

$\theta = \frac{ML}{2EI}$, $\delta_{max} = \frac{ML^2}{8EI}$

Analysis of propped cantilever beam

CASE 1. Propped cantilever beam with u.d.l

$R_A = \frac{5}{8} WL$, $R_B = \frac{3}{8} WL$, $M_A = -\frac{WL^2}{8}$ (hog)

SF = 0 @ $x = \frac{3}{8} L$ from propped end

CASE 2. Propped cantilever with central point load

$R_A = \frac{11}{16} W$, $R_B = \frac{5}{16} W$

$M_A = -\frac{3}{16} WL$ (hog)

POC @ $\frac{3L}{11}$ from fixed end

CASE 3. S.S.B with UDL and with prop at centre

$D_k = NJ - r$

where, N = No. of D.O.F. of Joint

J = No. of Joint, r = No. of reaction

Simplified formula for D_k :

- $D_k = 2J - r \rightarrow$ Pin jointed plane frame
 - $= 3J - r \rightarrow$ Pin jointed space frame
 - $= 3J - r \rightarrow$ Rigid jointed plane frame
 - $= 6J - r \rightarrow$ Rigid jointed space frame
- Where, J = No. of joints, r = No. of reactions.

Castigliano's first Theorem:

$P = \frac{\partial U}{\partial \Delta}$, $M = \frac{\partial U}{\partial \theta}$

Castigliano's Second Theorem:

$\Delta = \frac{\partial U}{\partial P}$, $\theta = \frac{\partial U}{\partial M}$

3. MOMENT DISTRIBUTION METHOD

Stiffness Factor: Stiffness (k) = $\frac{F}{\Delta} = \frac{M}{\theta}$

Case i) If far end is fixed, $k = \frac{4EI}{L}$

Case (i) If far end is hinged, $k = \frac{EI}{l}$
 Case (ii) If far end is fixed, $k = 0$
 Case (iii) If far end is roller, $k = \frac{EI}{2l}$

Relative stiffness of member
 (i) If far end is fixed, $k = \frac{EI}{l}$
 (ii) If far end is hinged, $k = \frac{EI}{2l}$

Distribution Factor
 D.F. of a member = $\frac{\text{Stiffness of a member (K)}}{\text{Total stiffness of all members at the joint } (\Sigma K)}$
 D.F. of a member = $\frac{\text{Stiffness of member at the joint}}{\text{Sum of stiffness of all members at the joint}}$

Carry Over Factor = $\frac{\text{carry over moment @ far end}}{\text{applied moment @ near end}}$

1. SLOPE DEFLECTION METHOD

Slope Deflection Equation
 $M_{AB} = M_{FAB} + \frac{2EI}{L}(\theta_A + \theta_B - \frac{\Delta}{L})$
 $M_{BA} = M_{FBA} + \frac{2EI}{L}(2\theta_B + \theta_A - \frac{3\Delta}{L})$

FORMULAE FOR FIXED END MOMENTS

Diagram	M_{AB}	M_{BA}
	$-\frac{PL}{8}$	$-\frac{PL}{8}$
	$-\frac{Pa^2}{2L}(\frac{3L-2a}{2})$	$-\frac{Pa^2}{2L}(\frac{3L+a}{2})$

4. STRUCTURAL ANALYSIS

1. ARCH

Three hinged arch

1. Three hinged parabolic arch carrying UDL over entire span
 ✓ Reaction: $R_A = R_B = \frac{wL}{2}$
 ✓ Horizontal Thrust: $H = \frac{wL^2}{8h}$
 ✓ Equation of Parabolic arch: $y = \frac{4hx}{L^2}(L-x)$
 ✓ Radial shear: $S_x = Wx - H \tan \theta$
 ✓ Normal thrust: $N_x = Wx \cos \theta - H \sin \theta$
 $D_x = 0$
 $R.M. = 0$

2. Three hinged parabolic arch having abutments at different levels carrying UDL over entire span

3. When it is subjected to UDL
 $R_A = R_B = \frac{wL}{2}$
 $H = \frac{wL^2}{8h}$

4. When it is subjected to concentrated load
 $R = \frac{wL}{2}$
 $H = \frac{wL^2}{8h}$

5. Three hinged parabolic arch subjected to Point load at crown

6. Three hinged parabolic arch subjected to UDL over half span

7. Three hinged parabolic arch subjected to UDL over entire span

8. Three hinged semi-circular arch of radius R

9. Three hinged parabolic arch subjected to UDL over half span

10. Three hinged parabolic arch subjected to UDL over entire span

11. Three hinged semi-circular arch of radius R

12. Three hinged parabolic arch subjected to UDL over entire span

13. Three hinged parabolic arch subjected to UDL over entire span

14. Three hinged parabolic arch subjected to UDL over entire span

15. Three hinged parabolic arch subjected to UDL over entire span

16. Three hinged parabolic arch subjected to UDL over entire span

17. Three hinged parabolic arch subjected to UDL over entire span

18. Three hinged parabolic arch subjected to UDL over entire span

19. Three hinged parabolic arch subjected to UDL over entire span

20. Three hinged parabolic arch subjected to UDL over entire span

21. Three hinged parabolic arch subjected to UDL over entire span

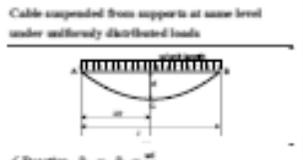
22. Three hinged parabolic arch subjected to UDL over entire span

23. Three hinged parabolic arch subjected to UDL over entire span

24. Three hinged parabolic arch subjected to UDL over entire span

2. CABLE

Cable suspended from supports at same level under uniformly distributed loads



✓ Reaction: $R_A = R_B = \frac{wL}{2}$
 ✓ Horizontal Thrust: $H_A = H_B = H = \frac{wL^2}{8h}$
 ✓ Maximum tension at supports
 $T_{max} = \frac{wL}{2} \sqrt{1 + (\frac{L}{4h})^2}$
 $T_{min} = \frac{wL}{2} \sqrt{1 + (\frac{L}{4h})^2}$
 ✓ Length of the cable: $L_c = L + \frac{8d^2}{3L}$

Temperature effect on cables
 ✓ Change in dip, $\delta = (\frac{\alpha \Delta T}{E}) \times L$
 ✓ Decrease in horizontal thrust = $\frac{H}{E} \times H$

3. MATRIX METHOD

Flexibility
 $f = \frac{\delta}{P} = \frac{1}{EA} \int \frac{1}{A} dx$

where, f = Flexibility, P = Force, δ = Displacement, E = modulus, A = Area, L = Length

Stiffness
 $K = \frac{P}{\delta} = \frac{EA}{L}$

Results

Diagram	Flexibility
	$\frac{L^3}{48EI}$

PLASTIC ANALYSIS

Load factor: $\lambda = \frac{\text{collapse load}}{\text{service load}}$

Welding in material: $\left[\frac{1}{\lambda} - \frac{\text{area required by plastic theory}}{\text{area required by elastic theory}} \right] \times 100$

Plastic section modulus: $Z_p = A_1 \bar{y}_1 + A_2 \bar{y}_2$

5. STEEL STRUCTURE

Slenderness factor: $\lambda = \frac{L_e}{r}$

Load factor = factor of safety \times shape factor

Reserve strength: $\lambda = \frac{M_u}{M_n}$

Length of plastic hinge: For slab carrying concentrated load: $L_p = \frac{1}{2}$ for rectangular section
 $L_p = \frac{1}{2}$ for I-section = $L \left[1 - \frac{d}{L} \right]$
 For slab carrying UDL: $L_p = L \sqrt{1 - \frac{d}{L}}$

Collapsing loads:
 ✓ SSB with concentrated load at center: $M_u = \frac{wL^2}{8}$
 ✓ SSB with UDL: $M_u = \frac{wL^2}{8}$
 ✓ Propped cantilever with concentrated load at center: $M_u = \frac{wL^2}{4}$
 ✓ Propped cantilever with concentrated load at center: $M_u = \frac{wL^2}{4}$
 ✓ Fixed beam with concentrated load at center: $M_u = \frac{wL^2}{8}$
 ✓ Fixed beam with eccentric loading: $M_u = \frac{wL^2}{8}$
 ✓ Fixed beam with UDL: $M_u = \frac{wL^2}{8}$
 ✓ Fixed beam with hydrostatic loading: $M_u = \frac{wL^2}{8}$
 ✓ Continuous beam with UDL: $M_u = \frac{wL^2}{8}$

Reduction factor:
 a) For long joint: $(L_j > 15 \phi)$
 $R_j = 1.05 - \frac{L_j}{1500}$ ($0.75 \leq R_j \leq 1.0$)
 b) For length of grip: $(L_j > 5 \phi)$
 $R_j = \frac{5 \phi}{L_j}$
 c) For thick packing plate: $(t_{ppl} > 4mm)$
 $R_j = 1 - 0.0125 t_{ppl}$
 $R_j = \frac{1}{\sqrt{3}} \left[\frac{A_n A_m}{A_g A_m} \right] R_j R_p R_{ppl}$

2. Bearing failure of bolt:
 + Nominal bearing strength of bolt
 $V_{ub} = 2.5 \phi \cdot t_{min} \cdot F_u$
 + Design bearing strength of bolt
 $V_{db} = \frac{V_{ub}}{\gamma_{mb}}$

3. Shear failure of bolt:
 + Nominal shear strength of bolt
 $V_{sb} = \frac{A_n A_m}{\sqrt{3}} \left[\frac{f_y}{A_g} + \frac{f_u}{A_m} \right]$
 + Design shear strength of bolt
 $V_{db} = \frac{V_{sb}}{\gamma_{mb}}$

4. Tensile failure of bolt:
 + Nominal tensile strength of bolt
 $T_{nb} = A_n \cdot f_u$
 + Design tensile strength of bolt
 $T_{db} = \frac{T_{nb}}{\gamma_{mt}}$

5. Shear and Tension interaction:
 $\frac{V_d}{V_{db}} + \frac{T_d}{T_{db}} \leq 1$

6. Block shear failure:
 + Nominal block shear strength of bolt
 $V_{ub} = 2.5 \phi \cdot t_{min} \cdot F_u$
 + Design block shear strength of bolt
 $V_{db} = \frac{V_{ub}}{\gamma_{mb}}$

7. Tearout failure:
 + Nominal tearout strength of bolt
 $T_{nb} = A_n \cdot f_u$
 + Design tearout strength of bolt
 $T_{db} = \frac{T_{nb}}{\gamma_{mt}}$

8. Edge distance:
 + Nominal edge distance of bolt
 $e_{min} = 1.5 \phi$
 + Design edge distance of bolt
 $e_{db} = \frac{e_{min}}{\gamma_{mb}}$

9. Spacing:
 + Nominal spacing of bolt
 $s_{min} = 3 \phi$
 + Design spacing of bolt
 $s_{db} = \frac{s_{min}}{\gamma_{mb}}$

10. End distance:
 + Nominal end distance of bolt
 $e_{max} = 12 \phi$
 + Design end distance of bolt
 $e_{db} = \frac{e_{max}}{\gamma_{mb}}$

11. Pitch:
 + Nominal pitch of bolt
 $p_{min} = 2.5 \phi$
 + Design pitch of bolt
 $p_{db} = \frac{p_{min}}{\gamma_{mb}}$

12. Edge distance:
 + Nominal edge distance of bolt
 $e_{min} = 1.5 \phi$
 + Design edge distance of bolt
 $e_{db} = \frac{e_{min}}{\gamma_{mb}}$

13. Spacing:
 + Nominal spacing of bolt
 $s_{min} = 3 \phi$
 + Design spacing of bolt
 $s_{db} = \frac{s_{min}}{\gamma_{mb}}$

14. End distance:
 + Nominal end distance of bolt
 $e_{max} = 12 \phi$
 + Design end distance of bolt
 $e_{db} = \frac{e_{max}}{\gamma_{mb}}$

15. Pitch:
 + Nominal pitch of bolt
 $p_{min} = 2.5 \phi$
 + Design pitch of bolt
 $p_{db} = \frac{p_{min}}{\gamma_{mb}}$

16. Edge distance:
 + Nominal edge distance of bolt
 $e_{min} = 1.5 \phi$
 + Design edge distance of bolt
 $e_{db} = \frac{e_{min}}{\gamma_{mb}}$

17. Spacing:
 + Nominal spacing of bolt
 $s_{min} = 3 \phi$
 + Design spacing of bolt
 $s_{db} = \frac{s_{min}}{\gamma_{mb}}$

18. End distance:
 + Nominal end distance of bolt
 $e_{max} = 12 \phi$
 + Design end distance of bolt
 $e_{db} = \frac{e_{max}}{\gamma_{mb}}$

19. Pitch:
 + Nominal pitch of bolt
 $p_{min} = 2.5 \phi$
 + Design pitch of bolt
 $p_{db} = \frac{p_{min}}{\gamma_{mb}}$

20. Edge distance:
 + Nominal edge distance of bolt
 $e_{min} = 1.5 \phi$
 + Design edge distance of bolt
 $e_{db} = \frac{e_{min}}{\gamma_{mb}}$

21. Spacing:
 + Nominal spacing of bolt
 $s_{min} = 3 \phi$
 + Design spacing of bolt
 $s_{db} = \frac{s_{min}}{\gamma_{mb}}$

22. End distance:
 + Nominal end distance of bolt
 $e_{max} = 12 \phi$
 + Design end distance of bolt
 $e_{db} = \frac{e_{max}}{\gamma_{mb}}$

23. Pitch:
 + Nominal pitch of bolt
 $p_{min} = 2.5 \phi$
 + Design pitch of bolt
 $p_{db} = \frac{p_{min}}{\gamma_{mb}}$

24. Edge distance:
 + Nominal edge distance of bolt
 $e_{min} = 1.5 \phi$
 + Design edge distance of bolt
 $e_{db} = \frac{e_{min}}{\gamma_{mb}}$

6. WELD

Force due to TM ($M = P \cdot e$) $F_s = \frac{M}{e}$

Resultant shear force:
 $F_s = \sqrt{F_v^2 + F_t^2} + 2F_v F_t \cos \theta$

Eccentrically loaded bending type bolted connection:
 Equivalent stress developed (F_s) under combined shear & bending
 $F_{s_{max}} = \sqrt{(F_v + F_t)^2 + (F_v - F_t)^2}$

where,
 F_v, F_t = Direct load
 F_v, F_t = Twisting moment

1. Fillet weld:
 a. Size of weld:
 $s = \text{minimum leg length}$
 b. Minimum size: (s_{min})
 $s_{min} < 3mm$
 $> \text{thickness of thicker part joined}$

2. Maximum size (s_{max}):
 Square edge (plate): $s_{max} = t_{min} - 1.5mm$
 Rounded edge: $s_{max} = \frac{t}{2}$, $t_{min} = 0.75 t_{max}$

3. Effective throat thickness (t_e):
 $t_{e_{min}} = 3mm$, $t_{e_{max}} = 0.75 t$
 $t_e = 0.5 t$
 For 90°, $t_e = \frac{s}{\sqrt{2}} = 0.707 s$

4. Effective length of weld (L_{we}):
 $L_{we} = L - 2.5 t$

5. Area of fillet weld:
 $A_w = L_{we} \cdot t_e$

6. Design strength of fillet weld:
 + Nominal strength of fillet weld
 $V_{nw} = A_w \cdot f_y$
 + Design strength of fillet weld
 $V_{dw} = \frac{V_{nw}}{\gamma_{mw}}$

7. Design axial strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $= \sigma_{tw} \cdot L_w \cdot t_e$... WSM

8. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $= \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

9. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

10. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

11. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

12. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

13. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

14. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

15. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

16. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

17. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

18. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM

19. Design tensile strength of fillet weld:
 $T_{dw} = \frac{f_y'}{\gamma_{mt}} \cdot L_w \cdot t_e$
 $T_{dw} = f_{tw} \cdot L_w \cdot t_e$... WSM

20. Design shear strength of fillet weld:
 $V_{dw} = \frac{f_{yw}}{\gamma_{mw}} \cdot L_w \cdot t_e$
 $V_{dw} = \frac{f_{yw}}{\sqrt{3} \gamma_{mw}} \cdot L_w \cdot t_e$... LSM
 $V_s = f_{sw} \cdot L_w \cdot t_e$... WSM