FORMULAE HAND BOOK FOR STRENGTH OF MATERIALS

By

R.Kailasam ME
G.Nirmal kumar ME
B.Rajesh Kannan (BE)

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SIMPLE STRESS AND STRAIN

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Stress(σ)	$\sigma \; = \frac{P}{A}$	Where, σ =stress in N/mm^2 P= Load in N A=Area in mm^2
Strain (e)	$e \; = \frac{\Delta L}{L}$	Where, e =strain ΔL= Change in length or elongation in mm L=Original length or gauge length in mm
Youngs modulus(E)	$E = \frac{\sigma}{e}$	Where, E= Youngs modulus or modulus of elasticity in N/mm^2 σ =stress in N/mm^2 e =strain
Factor of safety(FoS)	$FOS = \frac{\sigma u}{\sigma}$	Where, σ_u =Ultimate stress in N/mm^2 σ =Working stress in N/mm^2

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Area(A)	$A = \pi/4 \times d^2$ $A = \pi/4 \times (D^2 - d^2)$ $A = b \times t$	Where, A=area in mm^2 D= Major diameter or outer diameter in mm d= Minor diameter or inner diameter in mm b= breadth or wide in mm t= Thickness in mm

UTM (TENSILE TEST)

Yield Stress(σy)	$\sigma y = \frac{Py}{A}$	Where, σ_y = Yield stress in N/mm^2 P_y= Yield Load in N A=Area in mm^2
Ultimate Stress(σu)	$\sigma u = \frac{Pu}{A}$	Where, σ_u= Ultimate stress in N/mm^2 P_u= Ultimate Load in N A=Area in mm^2
Breaking Stress(σB)	$\sigma B = \frac{Pb}{A}$	Where, σ_B= Breaking stress in N/mm^2 P_B= Breaking Load in N A=Area in mm^2
% of Elongation (%ΔL)	$\%\Delta L = \frac{(LF - LI)}{LI} \times 100$	Where, L_F= Final length in mm L_I= Initial length in mm
% of Reduction area (%ΔA)	$\%\Delta A = \frac{A - a}{A} \times 100$	Where, A= Initial area in mm^2 a= Final area or area of neck in mm^2

VOLUMETRIC STRAIN

Volumetric strain (e_v)	$ev = \Delta V/V$ $= e lin \times (1 - 2 \times 1/m)$	Where, e_V = Volumetric strain ΔV= Change in volume in mm^3 V=Original volume in mm^3 1/m = Poisson's ratio e_{lin}= Linear strain
Volume (V)	$V = A \times L$	Where, A= Area in mm2 L= Length in mm
Poisson's ratio (1/m)	$1/m = eLat \,/\, elin$	Where, e_{Lat}= Linear strain e_{Lin}= Linear strain or Longitudinal strain
Lateral strain (e_{Lat})	$eLat = \Delta d/d\ (or)\ \Delta b/b\ (or)\ \Delta t/t$	Where, Δd= Change in diameter in mm d= Original diameter in mm Δb = Change in breadth or width in mm b= Original breadth or width in mm

		Δt = Change in thickness in mm t = Original thickness in mm
Linear strain (e_{Lin})	$eLin = \Delta L/L$	Where, ΔL= Change in length or elongation in mm L=Original length or gauge length in mm

ELASTIC CONSTANTS (E,G &K)

Young's modulus (E)	**Bulk modulus (K)**	**Rigidity modulus (C or N or G)**
$E = \frac{\sigma}{e}$	$\boldsymbol{K} = \frac{\sigma d}{eV}$	$\boldsymbol{C} = \boldsymbol{N} = \boldsymbol{G} = \frac{\sigma S}{eS}$
Where, E= Youngs modulus or modulus of elasticity in N/mm^2 σ =stress in N/mm^2 e =strain	Where, K= Bulk modulus or in N/mm^2 σ_d = Direct stress in N/mm^2 e_V = Volumetric strain	Where, C=N=G=Modulus of rigidity or shear modulus in N/mm^2 e_s= Shear strain
Relationship between E,G,K		
$E = 2G \times (1 + 1/m)$		

$$E = 3K \times (1 - 2 \times 1/m)$$

$$E = 9KG \;/\; (3K + G)$$

OMPOSITE BAR

Condition (i)	$\mathbf{P} = P_1 + P_2$ $\mathbf{P} = \sigma_1 A_1 + \sigma_2 A_2$	Where, P=Total load acting on the composite in N σ_1=Stress induced in Material -1 σ_2=Stress induced in Material -2 A_1= Mareial-1 cross sectional area in mm^2 A_2= Mareial-2 cross sectional area in mm^2
Condition (ii)	$e1 = e2$ $\sigma 1/E1 = \sigma 2/E2$	Where, σ_1=Stress induced in Material -1 σ_2=Stress induced in Material -2 E_1= Young’s modulus of Material -1 E_2= Young’s modulus of Material -2

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SHEAR FORCE AND BENDING MOMENT DIAGRAM

DIAGRAM SHORT CUT (SFD AND BMD)

LOAD	SFD	BMD
Point	Horizontal	Inclination
U.D.L	Inclination	Parabola
U.V.L	Parabola	Parabola

CALCULATIONS (SFC AND BMC)

BEAM	LOAD	SFC	BMC
Cantilever, Simply supported	Point	W	W×D
Cantilever, Simply supported	U.D.L	W×D	W×D×(D/2+G)
Cantilever, Simply supported	U.V.L	1/2bh	$\frac{1}{2} \times bh \times \left(\frac{1}{3} \times d + G\right)$ Or $\frac{1}{2} \times bh \times \left(\frac{2}{3} \times d + G\right)$
Where, W= Load in N or KN, D= Distance in m or mm, G= Gap in m or mm			

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THEORY OF SIMPLE BENDING

Bending equation	$\frac{M}{I} = \frac{\sigma b}{y} = \frac{E}{R}$	Where, M=Bending moment or moment of resistance in N-mm I= Moment of in inertia in mm^4 σ_b = Bending stress in N/mm^2 y= Distance in mm E= Youngs modulus or modulus of elasticity in N/mm^2 R= Radius of curvature in mm

BEAM	LOAD	BENDING MOMENT (M)
Cantilever	Point	$\boldsymbol{WL}$
Cantilever	U.D.L	$\boldsymbol{\frac{WL^2}{2}}$
Simply supported	Point	$\boldsymbol{\frac{WL}{4}}$
Simply supported	U.D.L	$\boldsymbol{\frac{WL^2}{8}}$

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BEAM SECTION	MOMENT OF INERTIA (I)	DISTANCE (y)	SECTION MODULUS (Z=I/y))
Solid circular	$\frac{\pi}{64} \times d\text{^}4$	d/2	$\pi/32\times d^3$
Hollow circular	$\frac{\pi}{64} \times (D\text{^}4 - d\text{^}4)$	D/2	$\pi/32\times(D^4-d^4)/D$
Rectangular	$\frac{bd\text{^}3}{12}$	d/2	$bd^2/6$
Square or cube	$\frac{a\text{^}4}{12}$	a/2	$a^3/6$

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TORSION

Torsional Equation	$T/J = f_S / R = C\theta/L$	Where, T=Torque or twisting moment in N-mm J= Polar Moment of in inertia in mm^4 f_S = Shear stress in N/mm^2 R= Radius in mm C=N=G=Modulus of rigidity or shear modulus in N/mm^2 θ= Angle of twist in radians

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Power(P)	**$P=2\pi NT/(60\times10^3)$**	Where, P= Power in Watts T=Torque or twisting moment in N-mm N=Speed in Rpm θ= Angle of twist in radians
Torque(T)	**$T=\pi/16\times f_s\times d^3$** **For solid shaft**	Where, T=Torque or twisting moment in N-mm f_S = Shear stress in N/mm^2 d= Diameter in mm
	$T=\pi/16\times f_s\times(D^4- d^4/D)$ **For Hollow shaft**	Where, T=Torque or twisting moment in N-mm f_S = Shear stress in N/mm^2 D=Major diameter in mm d= Minor Diameter in mm
Polar moment of inertia (J)	**$J=\pi/32\times d^4$** **For solid shaft**	Where, J=Polar moment of inertia moment in N-mm d= Diameter in mm
	$J=\pi/32\times(D^4-d^4)$ **For Hollow shaft**	Where, J=Polar moment of inertia moment in N-mm D=Major diameter in mm d= Diameter in mm
Radius (R)	**R=d/2 For solid shaft** **R=D/2 For Hollow**	Where, d= Diameter in mm

		D=Major diameter in mm

GEOMETRICAL SECTIONS

Centroid	$\boldsymbol{\overline{X} = \frac{a1x1 + a2x2 + a3x3}{a1 + a2 + a3}}$ $\boldsymbol{\overline{Y} = \frac{a1y1 + a2y2 + a3y3}{a1 + a2 + a3}}$	**Where,** **a_1 = Section 1 area in mm^2** **a_2 = Section 2 area in mm^2** **a_3 = Section 3 area in mm^2**
Moment of inertia	**$I_{xx}=b_1d_1^3/12+ b_2d_2^3/12+ b_3d_3^3/12+a_1\times(\bar{y}-y_1)^2+ a_2\times(\bar{y}-y_2)^2+ a_3\times(\bar{y}-y_3)^2$** **$I_{yy}=d_1b_1^3/12+ d_2b_2^3/12+ d_3b_3^3/12+a_1\times(\bar{x}-x_1)^2+ a_2\times(\bar{x}-x_2)^2+ a_3\times(\bar{x}-x_3)^2$**	
Radius of gyration	$\boldsymbol{Kxx = \sqrt{\frac{Ixx}{A}}}$ $\boldsymbol{Kyy = \sqrt{\frac{Iyy}{A}}}$ $\boldsymbol{A = a1 + a2 + a3}$	

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Cylinder and spherical shells

Cylindrical shell

Hoop stress or Circumferential stress (σ_1)	$\boldsymbol{\sigma 1 = \frac{Pd}{4t}}$	**Where,** **P= Internal Pressure in N/mm^2** **d= Internal diameter in mm** **t=Thickness of the cylinder in mm** **Δd= Change in diameter in mm** **ΔL= Change in length in mm** **E= Young's modulus in N/mm^2** **1/m= Poisson's ratio**
Longitudinal Stress (σ_2)	$\boldsymbol{\sigma 2 = \frac{Pd}{2t}}$	
Maximum shear stress(τ)	$\boldsymbol{\tau = \frac{Pd}{8t}}$	
Circumferential strain (e_1)	$\boldsymbol{e1 = \frac{\Delta d}{d} = \frac{\sigma 1}{E} \times \left(1 - \frac{1}{2} \times \frac{1}{m}\right)}$	
Longitudinal strain (e_2)	$\boldsymbol{e2 = \frac{\Delta L}{L} = \frac{\sigma 1}{E} \times \left(\frac{1}{2} - \frac{1}{m}\right)}$	
Volumetric Strain(e_v)	$\boldsymbol{ev = \frac{\Delta V}{V} = e2 + 2e1}$ $\boldsymbol{V = A \times L}$ $A = \pi/4 \times d^2$	

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Spherical shell

Hoop stress or Circumferential stress (σ_1)	$\boldsymbol{\sigma 1 = \frac{Pd}{4t}}$	**Where,** **P= Internal Pressure in N/mm^2** **d= Internal diameter in mm** **t=Thickness of the cylinder in mm** **Δd= Change in diameter in mm** **E= Young's modulus in N/mm^2** **1/m= Poisson's ratio**
Circumferential strain (e_1)	$\boldsymbol{e1 = \frac{\Delta d}{d} = \frac{\sigma 1}{E} \times \left(1 - \frac{1}{m}\right)}$	
Volumetric Strain(e_v)	$\boldsymbol{\Delta V = 3e1 \times V}$ $\boldsymbol{V = \pi/6 \times d^\wedge 3}$	

Slope and deflection of the beam

Double integration method

Beam	Load	Slope (θ)	Deflection (y)
Cantilever	Point load at free end	$\frac{WL^2}{2EI}$	$\frac{WL^3}{3EI}$
Cantilever	Point load apart from fixed and free end	$\frac{Wa^2}{2EI}$	$\frac{Wa^3}{3EI}+\frac{Wa^2}{2EI}\times\ (L-a)$
Cantilever	UDL distributed at entire length	$\frac{WL^3}{6EI}$	$\frac{WL^4}{8EI}$
Cantilever	UDL distributed from fixed end to “a” distance	$\frac{Wa^3}{6EI}$	$\frac{Wa^4}{8EI}+\frac{Wa^3}{6EI}\times\ (L-a)$
Simply supported	Point load at mid span	$\frac{WL^2}{16EI}$	$\frac{WL^3}{48EI}$

Simply Supported	**UDL distributed at entire length**	$\frac{WL^3}{24EI}$	$\frac{5WL^4}{384EI}$