NOTATIONS

Linear Dimensions

a = depth of rectangular stress block ; shear span

a_1 = cover to the longitudinal bar, measured from the bottom face of the beam to the centre of the bar

a_2 = cover to the longitudinal bar, measured from the nearest vertical face of the beam to the centre of the bar

a_3 = cover to the stirrup, measured from the nearest vertical face of the beam to the centre line of the vertical leg of the stirrup

a_4 = cover to the stirrup, measured from the bottom face of the beam to the centre line of the horizontal leg of the stirrup

b = length of the shorter side of a rectangular section

b_W = length of the shorter side of the web of L-, T- or I-sections

b_F = length of the shorter side of the overhanging flange of L-,T- or I-sections

b_1 = length of the shorter side a component rectangle forming flanged sections

b_c = length of the shorter side of the concrete core

B = total width of the flange of L-,T- or I-sections

C_1 = length of the projection of the neutral axis on the longitudinal axis of a member in Failure Scheme No. 1

C_2 = length of the projection of the neutral axis on the longitudinal axis of a member in Failure Scheme No. 2

D = diameter of a circular section

d = effective depth

d'	=	distance between centres of top and bottom longitudinal steel
d_c	=	length of the longer side of the concrete core
d_1	=	depth of compressed concrete
d_2	=	depth of non-compressed concrete
e	=	eccentricity of the applied load, measured from the centre line of the web of a flanged section
h	=	length of the longer side of a rectangular section
h_w	=	length of the longer side of the web of L-, T- or I-sections
h_F	=	length of the longer side of the overhanging flange of L-, T- and I-sections
h_1	=	length of the longer side of a component rectangle forming a flanged section
jd	=	internal lever arm
$\sum 0$	=	sum of the perimeters of all tension bars
P	=	perimeter of a section
P_0	=	perimeter of the area enclosed by lines joining the centres of longitudinal corner bars
r_c	=	distance from the hinge to the critical bar
s	=	spacing of stirrups
s_1	=	spacing of transverse reinforcing bars near the face of width 'b'
s_2	=	spacing of transverse reinforcing bars near the face of depth 'd'
x_1	=	length of the shorter leg of a stirrup, measured centre-to-centre
y_1	=	length of the longer leg of a stirrup, measured centre-to-centre

Z_1 = depth of the compression zone in Failure Scheme No. 1

Z_2 = depth of the compression zone in Failure Scheme No. 2

Areas

A = area of cross-section

A_c = area of concrete core

A_L = total area of longitudinal steel

A'_L = 'effective' area of total longitudinal steel in torsion

A_0 = area enclosed by the line joining the centres of longitudinal corner bars

A_w = cross-sectional area of one leg of stirrup

A'_w = 'effective' area of transverse steel in torsion

A_s = area of longitudinal tension steel

A'_s = area of longitudinal compression steel

A_{st} = cross-sectional area of spiral reinforcement

A_{Lt} = area of top longitudinal steel

A_{Lb} = area of bottom longitudinal steel

A'_{w0} = minimum area of transverse steel required to sustain torsional strength of plain concrete

A_{LT} = 'available' total longitudinal steel area for resisting torsion

A_{WT} = 'available' transverse steel area for resisting torsion

A_{LM} = area of total longitudinal steel for balanced condition in torsion

A_{WM} = area of transverse steel for balanced condition in torsion

Bending Moments

M = applied bending moment

M_U = ultimate bending moment

M_{UO} = pure bending capacity

Twisting Moments

T = torsional capacity ; applied torque

T_e = elastic torsional strength of plain concrete

T_w = allowable twisting moment

T_c = allowable torsional resistance of concrete

T_s = allowable torsional resistance of reinforcement

T_U = ultimate torsional capacity

T_{UP} = ultimate torsional capacity of plain concrete

T_{UO} = ultimate torque in pure torsion

T_{CU} = contribution of concrete to ultimate torsional resistance

T_{SU} = contribution of reinforcing steel to ultimate torsional resistance

T_{cr} = torque at first diagonal cracking

T_{U_1} = calculated ultimate torque ; ultimate torque corresponding to Mode 1 failure

T_{U2} = calculated ultimate torque for $\frac{T}{M} < \frac{T_{UP}}{M_{UO}}$; ultimate torque corresponding to Mode 2 failure

T_{U3} = calculated ultimate torque for $\frac{T}{V} < \frac{T_{UP}}{V_{UO}}$; ultimate torque corresponding to Mode 3 failure

T_O = ultimate torque in pure torsion

$T_{U\alpha}$ = average ultimate torque in case of varying torque

$T_{UP(W)}$ = torsional strength of the web of plain concrete

$T_{UP(F)}$ = torsional strength of the overhanging flange of plain concrete

T_{UM} = ultimate torque corresponding to balanced condition

Shear Forces

V = applied shear force ; shear capacity

V_U = ultimate shear strength

V_{cb} = shear strength at diagonal cracking under combined bending and shear

V_{UO} = shear capacity in absence of torsion

V_m = shear force corresponding to the fully plastic moment in absence of torsion

$V_{U\alpha}$ = average ultimate shear force in case of distributed loading

Stresses

τ = maximum torsional shear stress

τ_u = ultimate torsional shear stress

v = transverse shear stress

v_u = ultimate transverse shear stress

v_{cb} = ultimate transverse shear stress in combined bending and shear

v_{uc} = permissible ultimate transverse shear stress in concrete

f'_c = compressive stress of concrete cylinder

f'_t = tensile strength of concrete

f'_{ts} = splitting tensile strength of concrete

f_R = modulus of rupture of concrete

f_{st} = tensile stress in spirals

f_w = tensile stress in stirrups

f_{wy} = yield stress of stirrups

f_{Ly} = yield stress of longitudinal steel

f_s = stress in longitudinal tension steel

f'_s = stress in longitudinal compression steel

f_{sy} = yield stress of longitudinal tension steel

f'_{sy} = yield stress of longitudinal compression steel

f_{Lb} = stress in bottom longitudinal steel

f_{Lt} = stress in top longitudinal steel

f_{Lby} = yield stress in bottom longitudinal steel

f_{Lty} = yield stress in top longitudinal steel

σ = normal stress due to bending

Angles

θ = angle of twist per unit length

θ_e = angle of twist per unit length at elastic torque

θ_U = angle of twist per unit length at ultimate torque

θ_{UP} = angle of twist per unit length of plain concrete member at ultimate torque

θ_{cr} = angle of twist per unit length at diagonal cracking

ϕ = total angle of twist

Constants, Co-efficients, Ratios and Parameters

α	=	factor depending on h/b ratio for determination of torsional strength
α_ω	=	value of α for the web of a flanged section
α_F	=	value of α for the overhanging flange of a flanged section
m	=	ratio of longitudinal steel to transverse steel by volume
m_b	=	value of m for balanced condition
m'	=	ratio of longitudinal steel force to transverse steel force
p	=	steel ratio $= A_s / bd$
p_t	=	ratio of total steel to concrete by volume
p_{to}	=	minimum total steel as per cent by volume of concrete, required to sustain torque capacity of plain concrete
p_t'	=	$p_t - p_{to}$
p_{tb}	=	total steel as per cent by volume of concrete for balanced condition
n	=	factor depending on y_1 / x_1 ratio for determination of contribution of steel to torsional strength
K_t	=	torsional stiffness
K_{tO}	=	initial torsional stiffness
K_{tcr}	=	torsional stiffness after cracking
K_{tcr}'	=	secant torsional stiffness just before cracking
K_{tOD}	=	initial torsional stiffness based on average torqu
K_{tUP}	=	secant torsional stiffness of plain concrete at failure torque

β	=	factor depending on the value of m' for modifying steel contribution to torsion resistance
E	=	modulus of elasticity
G	=	shear modulus
μ	=	Poisson's ratio
γ	=	ratio of torque to bending moment, T / M
ψ	=	2T / Vb
I	=	moment of inertia
ξ	=	factor depending on h / b ratio for determination of torsional stiffness
X	=	stirrup parameter $= x_1 y_1 A'_w f_{wy} / s$
X_0	=	value of X corresponding to minimum steel required
X_M	=	value of X corresponding to balanced condition
$X_{M(W)}$	=	value of X_M considering web only

N.B. If not otherwise specified, the various dimensional units will be as follows :

	FPS system	MKS system
Linear dimensions	inch	centimetre
Area	square inch	square centimetre
Force	pound	kilogram
Moment	inch-pound	kilogram-centimetre
Stress	pound/sq.in.	kilogram/sq.cm.