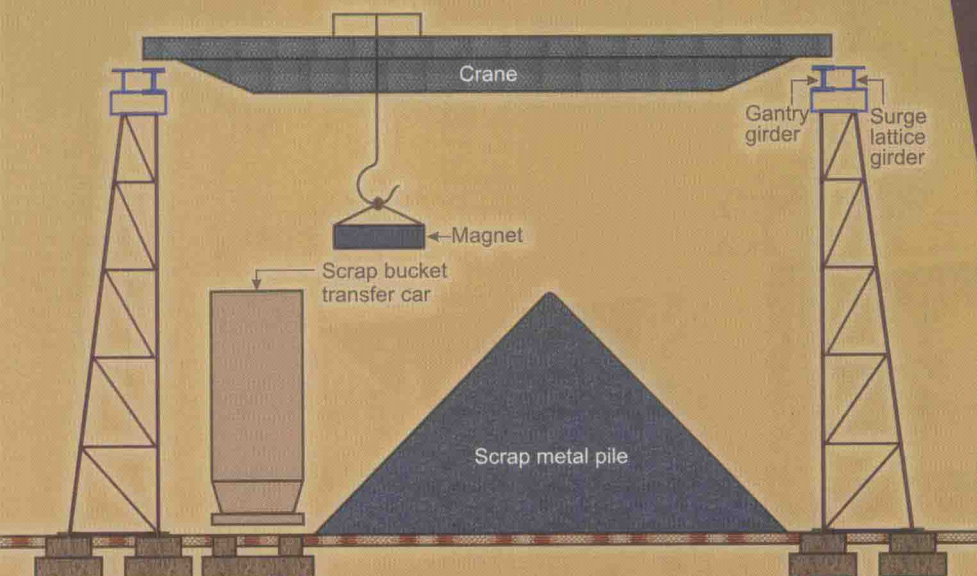


Second Edition

Eastern
Economy
Edition



Analysis and Design Practice of **STEEL** **STRUCTURES**



Karuna Moy Ghosh

Analysis and Design Practice of Steel Structures

SECOND EDITION

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ANALYSIS AND DESIGN PRACTICE OF STEEL STRUCTURES, Second Edition

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Preface

The second edition of this book entails the analyses and design of steel structures based on Indian Standard code of practice IS 800:2007. It addresses, in particular the behaviour of the structural elements in some structures under the actions of moving loads due to electric overhead travelling (EOT) cranes and wind loads.

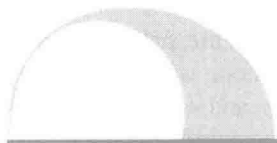
In this edition, the analyses of structures have been carried out as a whole and every component of the structure comprising the beams and columns has been designed in compliance with the code IS 800:2007. The results of the structural members in compliance with IS 800:2007 are compared with the results of the members of structures previously analysed and designed in compliance with Eurocode EC 3: Part 1-1.

The following steel structures already analysed and designed in accordance with Eurocode EC 3: Part 1-1 have been considered for the analysis and design of structural beams and columns in compliance with Indian Standard code of practice IS 800:2007 and results obtained from the two codes have been compared:

- Scrap yard structures
- Conveyor structural system from HBI building to mill building
- A turbo-generator building

As the second edition is written based on the latest Indian Standard code of practice IS 800:2007 and the structural calculations are presented in a simple and lucid manner, including sufficient design sketches and references wherever necessary. I believe this edition will be immensely popular in the entire Asian continent, particularly in Indian subcontinent among the final year university undergraduates and also freshly qualified graduate engineers attached to the design offices and field.

Karuna Moy Ghosh



Preface to the First Edition

This book is a comprehensive presentation of the analysis and design of steel structures. It seeks to link the theory of structures with practical applications in this field.

Before discussing the aspects of analysis and design, due consideration has been given to the theoretical and practical aspects, involving mainly the general principles and practices, functional aspects of structures, alternative arrangements in relation to the equipment and service, clarity of structural behaviour, basic design concepts, and calculations of loadings on the structures—including dynamic wheel loads from overhead electric travelling cranes, dead and imposed loads, wind loads, etc.

To help students get acquainted with the various types of structures subjected to various types of loadings, the author has considered three specific types of steel structures in different categories on the basis of functional aspects as follows:

1. The scrap yard structures of a storage yard storing scrap metal on short-term basis are subjected to heavy duty overhead electric travelling cranes of 2×250 kN capacity having high vertical dynamic impact (minimum 25%) and 10% horizontal transverse crane surge on the crane girders, and subsequently strong impact on the supporting members.
2. The conveyor structural system transports heavy briquette iron to the mill building (melting shop). The conveyor bridge structures are supported on trestles at about 30 m spacing with a maximum height of about 39 m from the ground level. The vertical trusses of conveyor bridges are connected at the top and bottom chord levels by horizontal wind trusses. The conveyor bridge has been provided with roof and side coverings.
3. A turbo-generator building comprises the following modules:
 - (i) The main turbo-generator building
 - (ii) The annexed (ancillary) lean-to roof building.

The main turbo-generator building houses a 10 MW turbo-generator and a 5 MW diesel generator. An overhead electric travelling crane of 250 kN capacity, with 25% vertical dynamic impact and 10% transverse horizontal crane surge on the gantry girder and the supporting structural members, runs along the turbo-generator hall for the maintenance of the generators.

I believe that this book will have much to offer to the reader due to the presentation of calculations (based on the practices of latest Eurocodes) in a simple way along with step-by-step design procedures, including numerous sketches and tables where necessary, and will be immensely useful to the advanced undergraduate students in civil engineering and postgraduate students in structural engineering as well as to the professional engineers in these fields.

Karuna Moy Ghosh



List of Symbols

A	gross cross-sectional area
A_{net}	net cross-sectional area of stiffener in mm^2
A	maximum amplitude of seismic forces
A_e	effective cross-sectional area in N/mm^2
A_c	area at root of threads in N/mm^2
A_n	net tensile stress area in mm^2 as specified in Indian Standard
A_{sb}	shank area of bolt in mm^2
A_f	area of top flange = $b \times t_f$ in mm^2
φ	dynamic factor used in overhead gantry cranes
H_t	horizontal transverse thrust applicable in gantry cranes
ρ	air density in kg/m^3
V_b	basic wind velocity in m/s
V_z	design wind speed at any height z in m/s
V_{peak}	peak velocity pressure at 21.5 m from ground level in kN/m^2
q_{pe}	effective wind pressure on vertical surface in kN/m^2
MM	modified Mercalli intensity numbers applied in seismic forces
M	magnitude of seismic forces, measured on the Richter scale
ULS	Ultimate Limit State method
SLS	Serviceability Limit State method
E	modulus of elasticity in $\text{kN/m}^2 = 200 \text{ kN/mm}^2$
μ	Poisson's ratio
μ_t	coefficient of thermal expansion = $12 \times 10^{-6}/^\circ\text{C}$

μ_f	slip factor
G	modulus of rigidity in $\text{kN/m}^2 = 76.9 \text{ kN/mm}^2$
f_y	yield stress in N/mm^2
f_u	ultimate tensile stress in N/mm^2 of parent material or weld
s	size of fillet weld in mm
a	throat size of fillet weld in mm
f_{cd}	design compressive stress in N/mm^2
f_{wd}	design strength of fillet weld in N/mm^2
f_u	ultimate stress of fillet weld in N/mm^2
f_b	calculated stress in bending in butt weld in N/mm^2
f_{br}	calculated stress in bearing in butt weld in N/mm^2
f_{wn}	f_u/γ_{mw}
γ_{mw}	factor of safety for weld material in resistance to connection = 1.25
f_a	calculated normal stress due to axial force in weld in N/mm^2
f_e	equivalent stress in weld in N/mm^2
q	shear stress due to shear or tension in N/mm^2
P	force transmitted (axial or shear) in weld in kN
a_e	effective throat thickness of weld in mm
l_w	effective length of weld in mm
$F_{w, Ed}$	design value of weld force per unit length in kN
$F_{w, Rd}$	design weld resistance per unit length in kN
$f_{vw, d}$	design shear stress of weld in N/mm^2
β_w	correction factor. For normal weldable steel grade E250 = 0.85
T_b	a bolt subjected to a factored tensile force in bolt in kN
T_{nb}	nominal tensile capacity of the bolt in kN = $0.9 \times f_{ub} \times A_n$
T_{db}	design tension capacity (T_{nb}/γ_{mb})
f_{ub}	ultimate tensile stress of the bolt in N/mm^2
f_{yb}	yield stress of the bolt in N/mm^2
γ_{m0}	partial factor of safety for material resistance governed by yielding = 1.1
γ_{m0}	partial safety factor for material resistance to buckling = 1.1
γ_{m1}	partial safety factor for material resistance governed by ultimate stress = 1.25
γ_{mb}	factor of safety for material resistance to bolt bearing connection = 1.25
γ_{mf}	partial safety factor for material resistance of connection bolt friction
V_{sb}	factored shear force acting on the bolt in kN
V_{db}	design shear capacity of bolt in kN
V_{sf}	factored design shear force in slip resistance (HSFG) bolt in kN
V_{nsf}	nominal shear capacity as governed by slip for friction type connection
μ_f	coefficient of friction (slip factor)

n_e	number of effective interface offering frictional resistance to slip
K_h	a factor relating to clearance of holes
F_o	minimum bolt tension (proof load) on slip resistance bolt in kN
f_o	proof stress ($0.7f_{ub}$) in N/mm^2
T_f	a factored tension force of a friction bolt in kN
T_{nf}	nominal tensile strength of the friction bolt in kN
γ_{fG}	partial safety factor for dead loads (DL) for ultimate states
γ_{fQ}	partial safety factor for leading live load (LL) for ultimate states
γ_{fQ1}	partial safety factor for accompanying live loads (LL) for ULS
γ_{fk}	partial safety factors for different loads
Q_d	design actions
Q_{ck}	loads of different actions in kN
S_d	design strength in kN
S_u	ultimate strength in kN
a	imperfection factor
P_d	design compressive strength in kN
P	factored applied axial load in kN
ϕ	value to determine the reduction factor χ
χ	reduction factor for relevant buckling mode
λ	non-dimensional effective slenderness ratio
f_{cc}	Euler buckling stress in N/mm^2
KL/r	effective slenderness ratio in appropriate radius of gyration
KL	effective length of compression member
L	effective length of prismatic compression members
L_e	effective length of compression member
r	radius of gyration
L_{LT}	effective length for lateral torsional buckling
a, b, c, d	buckling classes of cross sections
$M_{v, \max}$	unfactored maximum vertical dynamic moment in kNm
$M_{h, \max}$	unfactored maximum horizontal dynamic moment in kNm
V_{\max}	unfactored maximum vertical dynamic shear in kN
$V_{h\max}$	unfactored maximum horizontal dynamic shear in kN
R_{\max}	unfactored maximum vertical dynamic reaction in kN
$M_{v, Ed}$	ultimate vertical design moment in kNm
$V_{v, Ed}$	ultimate vertical design shear in kN
h	overall depth of cross section in mm
h_w	depth of web without flanges in mm
d	depth of web between fillets in mm

b	width of flange in mm
t_w	thickness of web in mm
t_f	thickness of flange in mm
c	outstand of flange in mm
ε	yield stress ratio
$M_{y, Ed}$	maximum ultimate vertical design moment in major axis in kNm
$M_{z, Ed}$	maximum ultimate horizontal design moment in minor axis in kNm
$V_{y, Ed}$	maximum ultimate vertical design shear in major axis in kN
$V_{pl, Rd}$	plastic shear capacity in kN
$M_{pl, y, Rd}$	plastic moment of resistance in major axis
$W_{pl, y}$	plastic section modulus of section in major axis in cm ³
$W_{pl, z}$	plastic section modulus of section in minor axis in cm ³
$\bar{\lambda}_f$	resulting slenderness of the equivalent compression flange
W_y	section modulus in major axis in cm ³
$i_{f,z}$	radius of gyration of the equivalent compression flange in cm
k_c	slenderness correction factor for moment distribution
$\bar{\lambda}_{c0}$	slenderness limit of the equivalent compression flange
$\bar{\lambda}_{LT,0}$	non-dimensional slenderness = 0.4 (maximum recommended value for rolled sections)
λ_1	slenderness value to determine relative slenderness
L_c	buckling length in m
n	constant value which depends on location; recommended value is 5 at the end of a member to determine bearing capacity of unstiffened web
k	length of web to carry vertical reaction at the end of girder in mm
b_1	assumed width of stiff bearing plate in mm
L	allowable length of web in mm
L_{cr}	buckling length in mm
I_y	moment of inertia in y - y axis
$I_{w,y}$	moment of inertia of web about y - y axis in mm ⁴
$I_{s,y}$	moment of inertia of stiffener about y - y axis in mm ⁴
$N_{Rd,s}$	bearing capacity of end stiffener in kN
$N_{Rd,w}$	bearing capacity of web in kN
N_{Rd}	total load bearing capacity of end bearing stiffener in kN
$N_{b,Rd}$	buckling resistance of the compression member in kN
s	spacing of stiffener in mm
t_s	thickness of stiffener in mm
h_1	height of stiffener excluding flange thickness in mm
V_{Ed}	maximum ultimate shear at a section of member in kN

Δ	deflection in mm
Δ_p	allowable deflection in mm
$N_{c,Ed}$	ultimate compression in chord member in kN
k_1	probability factor (risk factor)
k_2	terrain height and structure factor
k_3	topography factor
q_b	basic wind velocity pressure in kN/m ²
p_z	design wind pressure in kN/m ²
$c_e(z)$	wind pressure factor
$q_p(z)$	peak velocity wind pressure in kN/m ²
f_{ck}	characteristic compressive cylinder strength of concrete at 28 days in N/mm ²
f_{bk}	bearing strength of concrete in N/mm ²
T_{Ed}	maximum ultimate tension (factored) in kN
T_{Rd}	design strength of a member in tension in kN
f_{ub}	ultimate tensile stress in tension resistance in N/mm ²
f_{uv}	ultimate tensile stress in shear resistance in N/mm ²
A_s	tension area at the shank of bolt in mm ²
$F_{t,Rd}$	ultimate tension resistance in bolt in kN
$F_{v,Rd}$	ultimate shear resistance of bolt in kN
α_v	reduction factor
N_{Ed}	ultimate design compress in kN
β_w	correction factor
$F_{s,Rd}$	slip resistance of a preloaded HSFG (high strength friction grip) bolt in kN
k_s	types of holes
σ_u	maximum contact stress in N/mm ²
p	load per unit length of roller bearing in kN
c_f	external force coefficient
ψ	shelter factor
ϕ	solidity ratio
$C_{p,net}$	pressure coefficient
$C_{p,net,s}$	resulting net pressure coefficient on leeward face
q_{pe}	resultant effective wind pressure on the vertical face in kN/m ²
C_{pe}	external pressure coefficient
C_{pi}	internal pressure
$N_{u,Rd}$	design ultimate resistance on net section in kN
T_{dn}	ultimate design resistance in tension member in kN
$M_{c,Rd}$	design resistance in bending in kN

A_w	area of web
$F_{b,Rd}$	bearing capacity of bolt
$M_{b,Rd}$	buckling resistance moment (lateral torsional buckling)
$N_{c,Rd}$	compressive resistance
d	depth of straight portion of web
M_{Ed}	design bending moment
$N_{net,Rd}$	design plastic resistance to normal force of net cross-section
$N_{pl,Rd}$	design plastic resistance to normal force
$F_{p,Cd}$	design preload force
$N_{c,Rd}$	design resistance to normal force
$F_{v,Ed}$	design shear force per bolt
$V_{c,Rd}$	design shear resistance
e	edge or edge distance
A_{eff}	effective cross-sectional area
$F_{s,Rd}$	friction grip bearing capacity of bolt
A_g	gross bolt sectional area
I_z	moment of inertia about minor axis
$A_{f,net}$	net area of tension flange
$M_{N,Rd}$	reduced moment capacity in presence of axial force
W_z	section modulus about minor axis
$V_{c,Rd}$	shear capacity of member
A_v	shear area of member
$F_{s,Rd}$	slip resistance provided by a pre-loaded bolt
$N_{t,Ed}$	tensile axial force



Contents

Preface xi

Preface to the First Edition xiii

List of Symbols xv

1 Design Philosophy and Practices

1–7

- 1.1 Introduction 1
- 1.2 Structural System 1
- 1.3 Design Philosophy and Practice 2
 - 1.3.1 Functional Aspects of Structures 2
 - 1.3.2 Alternative Structural Arrangement and Choice of Spacing of Frames in Industrial Projects 3
 - 1.3.3 Alternative Choices of Open and Covered Structures 3
 - 1.3.4 Selection of Construction Materials 3
 - 1.3.5 Choice of Shop and Site Connection in Steel Structures 4
 - 1.3.6 Sequence and Method of Erection of Steel Structures 4
 - 1.3.7 Design Concept 5
 - 1.3.8 Methods and Procedures in Analysis and Design 5
 - 1.3.9 Buildability and Sustainability 6
 - 1.3.10 Environmental Impact 6
- 1.4 Structural Systems to be Analysed and Designed 7

2 Design Data, Design Strength and Bolt and Weld Connections

8–18

- 2.1 General 8
- 2.2 Loadings 8

2.3	Design Strength, Properties and Specifications of Material	12
2.3.1	General	12
2.3.2	Characteristic Strengths and Properties for Structural Steel in Buildings Based on Eurocode (EC) 3	12
2.3.3	Partial Safety Factors (γ_i)	13
2.3.4	Design of Welded and Bolted Connections Based on Eurocode 3: Part 1-8 [2.10]	14
2.4	Conventions of Member Axes Based on Eurocode 3	18
2.5	Abbreviations	18
	References	18

3 Scrap Yard Structures

19–124

3.1	Design Philosophy	19
3.2	Analysis and Design of Structural Members	22
3.2.1	Gantry Girder (Member in Bi-axial Bending and Shear)	23
3.2.2	Loadings on Gantry Girder	23
3.2.3	Moment Influence Lines for Moving Wheel Loads	25
3.2.4	Characteristic Maximum Dynamic Moments (Unfactored)	26
3.2.5	Characteristic Maximum Dynamic Shear at Support (Unfactored)	26
3.2.6	Characteristic Maximum Dynamic Reaction (Unfactored)	26
3.2.7	Characteristic Maximum Design Moment and Shear Due to Self-weight of Gantry Girder	26
3.2.8	Ultimate Design Moment (ULS)	26
3.2.9	Total Ultimate Design Shear (ULS)	27
3.2.10	Maximum Ultimate Horizontal Longitudinal Tractive Force	27
3.3	Design of Section	27
3.3.1	Design Strength	27
3.3.2	Initial Sizing of Section	27
3.3.3	Classification of Cross-section	28
3.3.4	Moment Capacity	29
3.3.5	Check for Moment Buckling Resistance Due to Lateral Torsional Buckling	31
3.3.6	Web Bearing Capacity, Buckling Resistance and Stiffener Design: Behaviour of Stress Distribution in Web of Deep Gantry Girder	33
3.4	Horizontal Surge Girder (Compression and Tension)	46
3.4.1	Design Considerations	46
3.4.2	Ultimate Horizontal Moment Due to Surge	47
3.4.3	Design of Section	47
3.5	Gantry A frames (Compression)	48
3.5.1	Design Assumptions	48
3.5.2	Loadings	49
3.5.3	Characteristic (Unfactored) Vertical Loads on Trestle Columns	52
3.5.4	Ultimate Vertical Design Load on Columns	53
3.5.5	Design of Section of Members	54
3.5.6	Design of Thickness and Size of Base Plate of Frame A: See Part (e) Showing Section A-A	56
3.5.7	Design of Holding-down Bolts	59
3.5.8	Weld Connection between Base Plate and Column	60
3.5.9	Bolted Connections	61

3.6	Longitudinal Bracing System along frame A to Resist Crane's Longitudinal Traction Force	64
3.6.1	Design of Bracing Members	64
3.6.2	Bolt Connections to Bracings	66
3.7	Design of Bearings of Gantry Girder	66
3.7.1	Design Considerations	66
3.7.2	Material Properties	67
3.7.3	Design of Bearings	67
Indian Standard Code of Practice IS 800:2007		70
3.8	Mechanical Properties of Structural Steel	70
3.8.1	Bolts, Nuts and Washers	71
3.8.2	Welding Consumable Arc Welding	71
3.8.3	Design of Welded and Bolted Connections	71
3.8.4	Method of Connection	72
3.8.5	Design of Fillet Weld and Welding	72
3.8.6	Bolted Connections	74
3.8.7	High Strength Friction Grip or Slip Resistance Type Bolting	76
3.8.8	Case When Slip between Bolted Plates Cannot be Tolerated at Working Loads (Slip Critical Connections)	76
3.8.9	Slip Resistance	76
3.8.10	Capacity After Slipping	77
3.8.11	Tension Resistance	77
3.8.12	Combined Shear and Tension	78
3.9	Structural Analysis and Design	78
3.9.1	Ultimate Limit State Method	78
3.9.2	Serviceability Limit State	78
3.9.3	Design Actions	79
3.9.4	Design Strength	79
3.9.5	Factors Governing the Ultimate Strength in Ultimate Limit State Design Method	80
3.9.6	Serviceability Limit State Design Method	80
3.10	Design of Members	81
3.10.1	Design of Compression Members	81
3.11	Analysis and Design of Crane Girder and Components	83
3.11.1	Gantry Girder (in Biaxial Bending and Shear)	83
3.11.2	Loadings on Gantry Girder	84
3.11.3	Moment Influence Lines for Moving Wheel Loads	85
3.11.4	Characteristic Maximum Dynamic Moments (Unfactored)	85
3.11.5	Characteristic Maximum Dynamic Shear at Support (Unfactored)	85
3.11.6	Characteristic Maximum Dynamic Reaction (Unfactored)	85
3.11.7	Characteristic Maximum Design Moment and Shear Due to Self-weight of Gantry Girder	86
3.11.8	Total Ultimate Design Moment	86
3.11.9	Total Ultimate Design Shear	86
3.12	Design of Section	86
3.12.1	Design Strength	86
3.12.2	Initial Sizing of Section	87
3.12.3	Classification of Cross Section	87

3.12.4	Moment Capacity	88	
3.12.5	Check for Moment Buckling Resistance Due to Lateral Torsional Buckling		90
3.12.6	Web Bearing Capacity, Buckling Resistance and Stiffener Design: Behaviour of Stress Distribution in the Web of Deep Gantry Girder		91
3.13	Horizontal Surge Girder (Compression and Tension Members)		101
3.13.1	Design Considerations	101	
3.13.2	Ultimate Horizontal Moment Due to Surge	101	
3.13.3	Design of Section	102	
3.14	Gantry a Frames (Compression)	103	
3.14.1	Design Considerations	103	
3.14.2	Loadings	103	
3.14.3	Characteristic (Unfactored) Vertical Loads on Trestle Columns		106
3.14.4	Ultimate Vertical Design Load on Columns	107	
3.14.5	Design of Section of Members	108	
3.14.6	Design of Thickness and Size of Base Plate of Frame A		112
3.14.7	Design of Holding-down Bolts	113	
3.14.8	Weld Connection between Base Plate and Column		115
3.14.9	Bolted Connections	116	
3.15	Longitudinal Bracing System along Frame A to Resist Crane Longitudinal Traction Force	118	
3.15.1	Design of Bracing Members	118	
3.15.2	Bolt Connections to Bracings	121	
3.16	Design of Bearings of Gantry Girder		121
3.16.1	Design Considerations	121	
3.16.2	Material Properties	121	
3.16.3	Design of Bearings	122	
	References	123	

4 Conveyor Structural System from HBI (Heavy Briquette Iron) Building to Mill Building

125–178

4.1	Design Philosophy	125	
4.2	Brief Description	125	
4.2.1	Functions	125	
4.2.2	Choice of Open or Covered Structure	127	
4.2.3	Selection of Construction Materials	127	
4.2.4	Choice of Shop and Site Connection	127	
4.2.5	Sequence and Method of Erection of Steel Structure	127	
4.2.6	Analysis and Design of Conveyor Structural System	127	
4.3	Analysis and Design of Conveyor Bridge (compression and tension)		128
4.3.1	Design Considerations	129	
4.3.2	Design Data	129	
4.3.3	Loadings: Characteristic Vertical Dead and Live Loads		130
4.3.4	Forces in Members	136	
4.3.5	Design of Section of Members Based on EC 3: Part 1–1 [4.3]		140
4.4	Analysis and Design of Trestle (Compression and Tension)		142
4.4.1	Design Considerations	142	
4.4.2	Design Data	142	

4.4.3	Loadings	143
4.4.4	Analysis of Forces in Members	146
4.4.5	Analysis and Design of Portal Frame at 32.2 m Level	154
Indian Standard Code of Practice IS 800:2007		161
4.5	Design of Section of Members	161
4.5.1	Vertical Truss	161
4.6	Analysis and Design of Trestle (Members Subjected to Compression and Tension)	164
4.6.1	Design Considerations	164
4.6.2	Design Data	164
4.6.3	Loadings	164
4.6.4	Analysis of Forces in Members	166
4.6.5	Analysis and Design of Portal Frame at 32.2 m Level	172
References		178

5 A Turbo-generator Building

179–309

5.1	Brief Description	179
5.2	Design Philosophy and Practice	181
5.2.1	Functional Aspects of Structure	181
5.2.2	Alternative Structural Arrangement and Choice of Spacing of Frames	182
5.2.3	Alternative Choice of Open or Covered Structure	182
5.2.4	Selection of Construction Materials	182
5.2.5	Choice of Shop and Site Connection in Steel Structure	183
5.2.6	Buildability	184
5.2.7	Sequence and Method of Erection of Steel Structures	184
5.3	Analysis of Structural Frames	184
5.3.1	Design Concept	184
5.3.2	Analysis of Structure	185
5.3.3	Procedures of Analysis	185
5.3.4	Preparing Structural Model	185
5.3.5	Loadings	186
5.3.6	Analysis of Structural Portal Frames	195
5.4	Analyses of Main Portal Frame of Turbine Hall	204
5.4.1	Procedures in Analyses of Various Loadings	204
5.5	Design of Structural Members	213
5.5.1	Codes to be Followed and Steel to be Adopted	213
5.5.2	Main Portal Frame	213
5.5.3	Effective Characteristic Maximum Design Values of Moments and Thrust in Members at End of Splay	213
5.5.4	Design Load Combinations (ULS Method) for Column at End of Splay	216
5.5.5	Design of Section of Column (Based on EC 3)	216
5.5.6	Design of Section of Roof Beam at End of Splay	222
5.5.7	Design of Section of Members of Lean-to Roof Frame	222
5.6	Design of Floor Beams in Annexed Lean-to Roof Building	223
5.6.1	Design Considerations	223
5.6.2	Loadings	223