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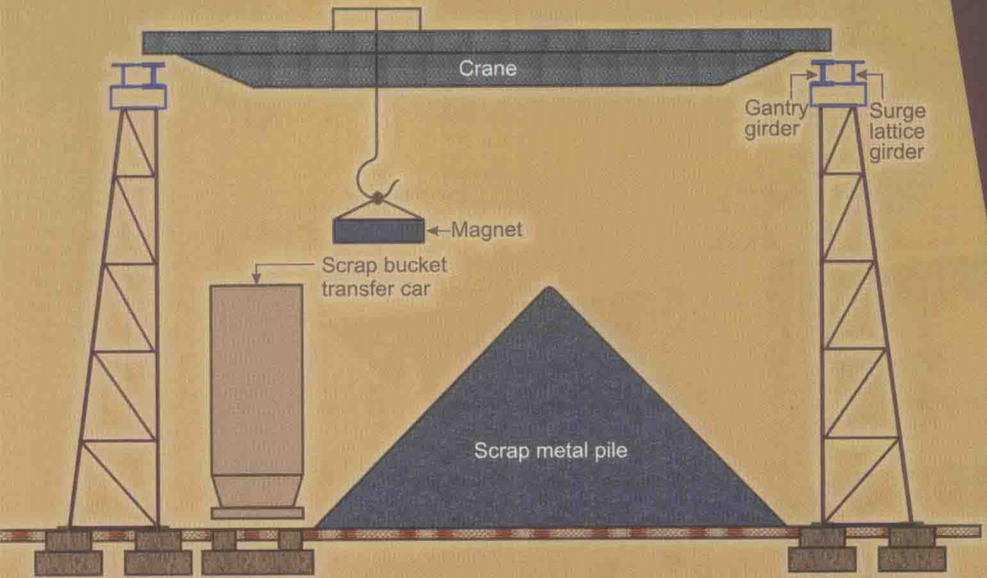

Analysis and Design Practice of STEEL STRUCTURES

PHI

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Analysis and Design Practice of Steel Structures

SECOND EDITION

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PHI Learning Private Limited

Delhi-110092

2014

₹ 350.00

ANALYSIS AND DESIGN PRACTICE OF STEEL STRUCTURES, Second Edition
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ISBN-978-81-203-4937-7

Third Printing (Second Edition) ... ... February, 2014

Published by Asoke K. Ghosh, PHI Learning Private Limited, Rimjhim House, 111, Patparganj Industrial Estate, Delhi-110092 and Printed by Baba Barkha Nath Printers, Bahadurgarh, Haryana-124507.

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 $kN/m^2 = 200\ kN/mm^2$
μ	Poisson's ratio
μ_t	coefficient of thermal expansion = $12 \times 10^{-6}/°C$

μ_f	slip factor
G	modulus of rigidity in kN/m^2 = 76.9 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
$F_{w,\mathrm{Ed}}$	design value of weld force per unit length in kN
$F_{w,\mathrm{Rd}}$	design weld resistance per unit length in kN
$f_{\mathrm{vw},d}$	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_{vmax}	unfactored maximum vertical dynamic shear in kN
V_{hmax}	unfactored maximum horizontal dynamic shear in kN
R_{vmax}	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
$M_{y,\text{ Ed}}$	maximum ultimate vertical design moment in major axis in kNm
$M_{z,\text{ Ed}}$	maximum ultimate horizontal design moment in minor axis in kNm
$V_{y,\text{ Ed}}$	maximum ultimate vertical design shear in major axis in kN
$V_{\text{pl, Rd}}$	plastic shear capacity in kN
$M_{\text{pl},\, y,\text{ Rd}}$	plastic moment of resistance in major axis
$W_{\text{pl},\, y}$	plastic section modulus of section in major axis in cm^3
$W_{\text{pl},\, z}$	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
$N_{\text{Rd},s}$	bearing capacity of end stiffener in kN
$N_{\text{Rd},w}$	bearing capacity of web in kN
N_{Rd}	total load bearing capacity of end bearing stiffener in kN
$N_{b,\text{Rd}}$	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
$N_{c,\mathrm{Ed}}$	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 $\mathrm{kN/m^2}$
p_z	design wind pressure in $\mathrm{kN/m^2}$
$c_e(z)$	wind pressure factor
$q_p(z)$	peak velocity wind pressure in $\mathrm{kN/m^2}$
f_{ck}	characteristic compressive cylinder strength of concrete at 28 days in $\mathrm{N/mm^2}$
f_{bk}	bearing strength of concrete in $\mathrm{N/mm^2}$
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 $\mathrm{N/mm^2}$
f_{uv}	ultimate tensile stress in shear resistance in $\mathrm{N/mm^2}$
A_s	tension area at the shank of bolt in $\mathrm{mm^2}$
$F_{t,\mathrm{Rd}}$	ultimate tension resistance in bolt in kN
$F_{v,\mathrm{Rd}}$	ultimate shear resistance of bolt in kN
α_v	reduction factor
N_{Ed}	ultimate design compress in kN
β_w	correction factor
Fs,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 $\mathrm{N/mm^2}$
p	load per unit length of roller bearing in kN
c_f	external force coefficient
ψ	shelter factor
ϕ	solidity ratio
$C_{p,\mathrm{net}}$	pressure coefficient
$C_{p,\mathrm{net},s}$	resulting net pressure coefficient on leeward face
q_{pc}	resultant effective wind pressure on the vertical face in $\mathrm{kN/m^2}$
C_{pe}	external pressure coefficient
C_{pi}	internal pressure
$N_{u,\mathrm{Rd}}$	design ultimate resistance on net section in kN
T_{dn}	ultimate design resistance in tension member in kN
$M_{c,\mathrm{Rd}}$	design resistance in bending in kN

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

Contents