DESIGN OF WELDED STRUCTURES

BY

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THE JAMES F. LINCOLN ARC WELDING FOUNDATION
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KAPOON CHANDRANGSU.

PREFACE

WELDED STRUCTURAL CONNECTIONS have long been used in the construction of buildings, bridges, and other structures. The first welded buildings were erected in the '20s—the greatest application being in low-level buildings of many types. The American Welding Society first published specifications for welded bridges in 1936. But early progress came slowly.

During that year, 1936, The James F. Lincoln Arc Welding Foundation was created by The Lincoln Electric Company to help advance the progress in welded design and construction. Through its award programs and educational activities, the Foundation provided an exchange of experience and gave impetus to the growing application of welding.

Thus, within the last decade and particularly the past few years, unitized welded design has become widely accepted for high-rise buildings and bridges of nobler proportions in addition to the broad base of more modest structures.

Now, the Foundation publishes this manual for further guidance and challenge to architects, structural engineers, fabricators and contractors who will build the structures of tomorrow . . . and to the educators who will prepare young people for these professions. This material represents an interpretation of the best in accumulated experience of all who have participated in prior Foundation activities. The author has coordinated this with a continuing study of current welding research conducted both in the United States and Europe, and against a background of participation on various code-writing committees. Much of the direct instructional information that resulted has been pretested in over 70 structural seminars attended by over 4000 engineers.

The production of this manual has spanned several years during which constant effort was made to eliminate errors. The author will appreciate having called to his attention any errors that have escaped his attention and invites correspondence on subjects about which the reader may have questions. Neither the author nor the publisher, however, can assume responsibility for the results of designers using values and formulas contained in the manual since so many variables affect every design.

Charles Herbruck, Secretary

The James F. Lincoln Arc Welding Foundation

June 1966

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LIST OF SYMBOLS AND DEFINITIONS

α = angular acceleration (radians/sec/sec); included angle of beam curvature (degrees); form factor
Δ = perpendicular deflection (in.), bending (Δ_b) or shear (Δ_s)
ϵ = unit strain, elongation or contraction (in./in.)
ϵ_s = unit shear strain (in./in.)
ν = Poisson's ratio (steel = 0.3 usually); unit shear force
ω = leg size of fillet weld (in.); rate of angular motion about an axis (radians/sec)
ϕ = unit angular twist (radians/linear inch); included angle; angle of rotation
Σ = sum
σ = normal stress, tensile or compressive (psi); strength (psi)
σ_b = bending stress (psi)
σ_y = yield strength (psi)
τ = shear stress (psi); shear strength (psi)
θ = angle of twist (radians; 1 radian = 57.3 degrees); angle of rotation (radians); slope of tapered girder; any specified angle

a = area of section beyond plane where stress is desired or applied (in.^{2}); length of plate (in.); acceleration or deceleration (ft/min, ft/sec); clear distance between transverse stiffeners of girder (in.)
b = width of section (in.); distance of area's center of gravity to reference axis (in.)
c = distance from neutral axis to extreme fiber (in.); distance of elastic center from reference axis
d = depth of section (in.); moment arm of force (in.); distance (in.); distance between centers of gravity of girder flanges (in.)
d_w = clear distance between girder flanges (in.)
e = eccentricity of applied load (in.); total axial strain (in.); moment arm of force (in.); effective width (in.); length of Tee section in open-web girder (in.)
f = force per linear inch of weld (lbs/in.); horizontal shear force (lbs/in.); (vectorial) resultant force (lbs/in.); allowable strength of weld (lbs/in.)
f_c' = compressive strength of concrete (psi)
g = acceleration of gravity (386.4″/sec^2)
h = height; height of fall; distance of expansion on open-web girder (in.)
k = any specified constant or amplification factor
m = mass; statical moment of transformed concrete (composite construction)
n = distance of section's neutral axis from reference axis (in.); number of units in series
p = internal pressure (psi)
q = allowable force on shear connector
r = radius (in.); radius of gyration
s = length of curved beam segment (in.); clear distance between ends of increments of weld (in.)

t = thickness of section (in.); time (min.); time interval (sec)
u = material's tensile modulus of resilience (in.-lb/in.^{3})
u_u = material's ultimate energy resistance (in.-lb/in.^{3})
w = uniformly distributed load (lbs/linear inch)
x = length of moment arm (curved beam)
y = distance of area's center of gravity to neutral axis of entire section (in.)

A = area (in.^{2}); total area of cross-section
C = stiffness factor used in moment distribution; any specified constant
E = modulus of elasticity, tension (psi); arc voltage (volts)
E_s = modulus of elasticity in shear (psi)
E_t = tangential modulus of elasticity (psi)
E_k = kinetic energy
E_p = potential energy
F = total force (lbs); radial force (lbs)
I = moment of inertia (in.^{4}); welding current (amps)
J = polar moment of inertia (in.^{4}); heat input (joules/in. or watt-sec/in.)
K = ratio of minimum to maximum load (fatigue); ratio of web depth to web thickness; distance from outer face of beam flange to web toe of fillet (in.); thermal conductivity; any specified constant
L = length of member (in. or ft.); span between supports (in.)
L_e = effective length of column
M = bending moment (in.-lbs)
M_o = applied bending moment (in.-lbs)
M_p = plastic moment at connection (in.-lbs)
N = number of service cycles; minimum bearing length of beam on seat (in.)
P = concentrated load (lbs)
Q = shear center; statical moment of cover plate area about neutral axis of cover-plated beam section
R = reaction (lbs); torsional resistance of member (in.^{4}); weld cooling rate (°F/sec)
S = section modulus (in.^{3}) = I/c
T = torque or twisting moment (in.-lbs); temperature (°F)
U = stored energy
V = vertical shear load (lbs); shear reaction; velocity; volume; arc speed (in./min)
W = total load (lbs); weight (lbs); total width (in.)
Y = effective bearing length on base plate (in.)
Z = plastic section modulus (in.^{3})

C.G. = center of gravity
HP = horsepower
N.A. = neutral axis
RPM = revolutions per minute