Concise Guide to Reinforced Concrete Design to Eurocode 2

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Patrick Purcell

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Preface

Prior to the early 1970s, concrete design was largely based on the long-established elastic theory of design. Since then, there have been sweeping changes in concrete technology based on an entirely new approach to design known as the limit state, in which materials are considered to be in an inelastic condition just before reaching ultimate failure. In the UK and Ireland, CP110, *The Structural Use of Concrete*, was followed by BS 8110 *Structural Use of Concrete*, ultimately leading to the adoption of the Eurocode 2: *Design of Concrete Structures*.

The purpose of this book is to explain the principles of reinforced concrete design to Eurocode 2 by means of simple worked examples. The author has taught this material for many years to undergraduate civil engineering and structural engineering students. While there are a considerable number of books on the topic, in the author's experience, many of these existing publications are directed at a more advanced audience. There is a need for a more concise publication at a more elementary level.

This book is neither a design manual nor a detailed interpretation of Eurocode 2. It is an introduction to concrete technology for students of engineering and architecture, and it should be useful as an aide for junior engineers, architects and draughtspersons. The book goes far enough such that a reader with no previous knowledge of reinforced concrete theory can attempt to design simple structures in accordance with Eurocode 2. The general approach adopted is to introduce the reader to the basic principles applicable to each section before working through typical design examples. Further practice problems and outline solutions will prove valuable to the reader. It is hoped that this publication may serve as a useful introduction and reference for those wishing to embark on a more detailed study of the subject.

Design charts, tables and formulae are included as design aids and, for ease of reference, each chapter contains a summary of the key structural design steps. The fundamental material required for students of reinforced concrete design is covered. Additionally, more in-depth coverage of structure-specific design is presented, which will be of benefit to practising engineers. A comprehensive list of topics is covered, as evident in the table of contents.

At the time of writing, a second generation of Eurocodes is in draft form. In respect of Eurocode 2, although there is no fundamental change in the design approach from the first-generation Eurocode 2, some details may change. The proposed changes are briefly outlined in Chapter 1.

I have endeavoured to acknowledge throughout the text the numerous sources on which I have drawn in the compilation of this book. I would like to make special reference to my current and former colleagues in the School of Civil Engineering at University College Dublin. The book is dedicated to my wife Mary and sons Pádraig, Dara and Sean.

P.J.P.
Dublin
January 2022

About the author

Patrick Purcell is a Chartered Engineer and Associate Professor in the School of Civil Engineering at University College Dublin, Ireland.

Notation

The notation presented is generally in accordance with Eurocode 2. The key parameters are listed below.

a	Distance to critical shear perimeter from column face
A	Cross-sectional area of a beam or slab
A_c	Cross-sectional area of a column
A_{sc}	Cross-sectional area of vertical reinforcement in a column
A_{cc}	Plan area of concrete in a column
A_s	Cross-sectional area of tensile reinforcement
A_{s1}	Cross-sectional area of tensile reinforcement in a doubly reinforced beam
A_{s2}	Cross-sectional area of compression reinforcement in a doubly reinforced beam
$A_{s,req}$	Cross-sectional area of tensile reinforcement required at ultimate limit state
$A_{s,prov}$	Cross-sectional area of tensile reinforcement provided at ultimate limit state
$A_{sc,prov}$	Cross-sectional area of vertical reinforcement provided in a column
A_{sw}	Cross-sectional area of shear reinforcement
b	Breadth of section
cs	clear span
c_{nom}	Nominal concrete cover for reinforcement
C	Column side dimension or compressive force on concrete
d	Effective depth of tensile reinforcement
d_1	Distance from column face to compression reinforcement or depth of tensile reinforcement in a doubly reinforced beam
d_2	Distance from column face to tensile reinforcement or depth of compression reinforcement in a doubly reinforced beam
e	Eccentricity
E	Modulus of elasticity
F	Tensile or compressive force
F_k	Characteristic load
f_{bd}	Anchorage bond stress
f_c	Tensile or compressive strength of a test specimen
f_{ck}	Characteristic cylinder strength of concrete
f_{cm}	Mean cylinder strength of concrete
f_k	Characteristic strength of a test specimen
f_m	Mean strength of a batch of test specimens
f_{net}	Actual ground pressure
f_{yk}	Characteristic yield strength of reinforcement
g_k	Characteristic permanent load per unit area or per unit length

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G_k	Characteristic permanent load
h	Gross depth of section
I	Second moment of area
K	$= M/f_{ck}bd^2$
l	Design span
L	Span of a beam or slab or anchorage length
L_0	Actual length of a column
L_e	Effective length of a column
L_{eq}	Equivalent anchorage length
M	Moment in a beam or slab
M_B	Demand bending moment
M_R	Moment of resistance
M_U	Ultimate moment of resistance
M_{bal}	Moment at balanced condition
M_{exc}	Moment in excess of balanced moment
M_{Ed}	Moment in a column
n	Number of test specimens
N_{Ed}	Design compression load
q_k	Characteristic variable load per unit area or per unit length
Q_k	Characteristic variable load
r	Radius of gyration
S	Spacing of shear reinforcement
T	Tensile force in steel reinforcement
U	Punching shear perimeter
V	Shear force
V_{Ed}	Maximum shear force
$V_{Rd,max}$	Maximum shear force in a concrete strut
V_{Wd}	Shear force in a link
v_{Ed}	Maximum intensity of shear stress
$v_{Rd,c}$	Shear capacity
w	Factored load
W	Unfactored load
x	Neutral axis depth
y	Depth from ground surface to top of footing or deflection
Z	Lever arm
α	Factor for calculating equivalent straight length
β	Factor for calculating column effective length
γ_c	Partial safety factor for concrete
γ_f	Partial safety factor for applied load
γ_G	Partial safety factor for permanent load
γ_m	Partial safety factor for material strength
γ_s	Partial safety factor for steel
γ_Q	Partial safety factor for variable load
ε	Strain
ρ_0	$= f_{ck}^{0.5}/1000$

ρ	$= A_{s,req}/bd$
σ	Stress or standard deviation
$\varnothing$	Bar diameter
ABP	Allowable bearing pressure
RABP	Residual allowable bearing pressure
TCP	Theoretical cut-off point
UDL	Uniformly distributed load