PRACTICAL RAILWAY ENGINEERING

This page is intentionally left blank

PRACTICAL RAILWAY ENGINEERING

Clifford F Bonnett

C. Eng., F. I. C. E., F. I. Struct. E.

ICP

Imperial College Press

Published by

Imperial College Press
516 Sherfield Building
Imperial College
London SW7 2AZ

Distributed by

World Scientific Publishing Co. Pte. Ltd.
P O Box 128, Farrer Road, Singapore 912805
USA office: Suite 1B, 1060 Main Street, River Edge, NJ 07661
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

PRACTICAL RAILWAY ENGINEERING

Copyright © 1996 by Imperial College Press

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

ISBN 1-86094-012-9

Printed in Singapore.

This book is dedicated to my wife

JEAN

*without whose support and encouragement
this book could not have been written.*

This page is intentionally left blank

Foreword

As we approach a new millenium, transport of people and materials takes on an even greater significance world-wide than it has in the immediate past. The birth and evolution of railways during the last two centuries has had an immeasurable influence on industrial, social and economic development.

Engineers of all backgrounds and professional disciplines have played a leading role in the development, operation and management of railways. In future the contribution of railway engineers should be even more significant.

I am delighted to be able to write this foreword to Cliff Bonnett's book. I have known him now for seventeen years. His wide experience 'on the ground' with British Rail, London Underground and Docklands Light Railway, over almost thirty five years, ensures that this textbook has a sure foundation.

Recent years lecturing on a part-time basis at Imperial College have also shown that Cliff is well able to communicate in a simple and concise manner. I commend this book to all who wish to get a good overview of Railway Engineering.

Tony M Ridley, CBE, PhD, FEng, FICE, FCIT,
Professor of Transport Engineering
Centre for Transport Studies
Imperial College of
Science Technology & Medicine
University of London

This page is intentionally left blank

Preface

The need for this textbook arose out of the author's experience whilst co-ordinating the optional subject 'Railway Engineering Concepts' for the Intercollegiate MSc Course in Transport run jointly by Imperial College and University College, London University.

The stated objective of this optional subject is;

'To develop an understanding of the engineering concepts involved, for all disciplines, in the planning, design, construction, equipping, maintenance and renewal of all types of railway.'

The author quickly discovered that there are many textbooks which give detailed information on various aspects of railway engineering, usually confined to one or two main disciplines, but none that give a general 'broad brush' approach to the subject as a whole.

This textbook is designed to fill this gap, not only for the student on this or similar courses but to be a useful reference book to all who need to expand their knowledge in this field to cover a wide spectrum.

The author wishes to acknowledge extensive help he has received from many practicing engineers and in particular those who regularly have contributed lectures on this subject to students on the London University course.

This page is intentionally left blank

Acknowledgements

The author wishes to express his thanks to the Professors, lecturers and staff of the Centre for Transport Studies of the University of London for the practical help given in the production of this textbook.

In particular, he would also wish to record thanks to the following external lecturers who have assisted with material outside his own railway practical experience:

Eddie Goddard
Chris Hardie
Dr. Bob Holmes
Chris Holmes
Dr. John Medhurst
Terry Mahoney
John Vint

Appreciation is also expressed to British Rail, London Underground Ltd, Docklands Light Railway Ltd, The Science Museum, the Institution of Railway Signal Engineers and the Permanent Way Institution for assistance with the gathering of facts, information and illustrations.

I am particularly grateful to Professor Tony Ridley who has been a great encourager and has written the Foreword during his very busy year as President of the Institution of Civil Engineers.

This page is intentionally left blank

Contents

Foreword	vii
Preface	ix
Acknowledgements	xi
1. Introduction	1
1.1 Early beginnings	1
1.2 Development and diversification	2
1.3 The customer	3
1.4 The operator	3
1.5 Overall planning	4
1.6 Choice of route and level	5
1.7 Resources required	5
2. Station Layout	9
2.1 The customer and the design process	9
2.2 The need for standards	10
2.3 Objectives of station planning	11
2.4 Concept of speed and flow	12
2.5 Consideration of time	13
2.6 Planning normal operation	14
2.7 Demand Matrix	15
2.8 Capacity requirements	17
2.9 Ticket halls	18
2.10 Access and interchange	21

2.11	Stairs, escalators and lifts	22
2.12	Platforms	23
2.13	Footbridges and subways	24
2.14	Station canopies	25
2.15	Access for the disabled	25
2.16	The 'Downgraded' station	26
2.17	Planning for hazards	27
2.18	Staff accommodation	28
2.19	Designing for maintenance	28
3.	Rolling Stock	31
3.1	Definition of railway rolling stock	31
3.2	Range of rolling stock	33
3.3	Evolution of steam	34
3.4	Advent of electric traction	37
3.5	Development of electric traction	39
3.6	Diesel traction	41
3.7	Evolution of wheel layout	42
3.8	Changes in locomotive maintenance	43
3.9	Carriages to modern carriages	43
3.10	Carriage structures	46
3.11	Train performance on main line	47
3.12	Train performance on metros/light rail	47
3.13	Freight rolling stock	49
3.14	Engineering rolling stock	50
3.15	Manufacturing methods	52
4.	Depots and Workshops	53
4.1	Proper maintenance of rolling stock	53
4.2	Maintenance considerations	54
4.3	Establishing a maintenance regime	54
4.4	Maintenance management	55
4.5	Balance between workshops and depots	56
4.6	Depot siting	57
4.7	Needs of the Maintainer	59
4.8	Basic requirements for depots	60

4.9 Performance indicators and audit	62
5. Track	63
5.1 Origin and development of railway track	63
5.2 Basic components	65
5.3 Track ballast	65
5.4 Materials for track ballast	66
5.5 Sleeper functions	67
5.6 Timber sleepers	67
5.7 Concrete sleepers (monobloc)	69
5.8 Twin block concrete sleepers	71
5.9 Steel sleepers	71
5.10 Rail fastenings	72
5.11 Rails	74
5.12 Rail wear	76
5.13 Desirability of removing rail joints	77
5.14 Introduction of track welding	78
5.15 Shop welding into long rails	79
5.16 Site welding into CWR	79
5.17 Rail stressing	81
5.18 Points, switches and crossings	81
5.19 Crossing design and manufacture	82
5.20 Points or turnouts	84
5.21 Driving, locking and detection	85
5.22 Conductor rails	85
5.23 Paved concrete track	86
5.24 Cast-in sleeper track	87
5.25 Floating slab track	87
5.26 Track installation and renewal	87
5.27 Day-to-day maintenance	88
6. Earthworks, Drainage and Fencing	91
6.1 Stability of earthworks	91
6.2 Short term considerations	92
6.3 Long term considerations	92
6.4 Slips	93

6.5	Detection of movement	94
6.6	Dealing with embankment slips	95
6.7	Dealing with cutting slips	97
6.8	Drainage of the track bed	98
6.9	Sand blankets	99
6.10	Side or cess drains	100
6.11	Centre drains	100
6.12	Drain cleaning	101
6.13	Ineffective drains	102
6.14	Railway fencing	102
7.	Bridges and Structures	105
7.1	Early railway structures and materials	105
7.2	Modern welded steelwork	108
7.3	Reinforced concrete structures	111
7.4	Prestressed concrete	113
7.5	Bridge reconstruction	116
7.6	Brick and masonry structures	119
7.7	Examination of structures	120
7.8	Structural maintenance	122
7.9	Strength assessment	122
8.	Tunnels and Tunnelling	125
8.1	History of tunnelling	125
8.2	Cut-and-cover tunnels	126
8.3	First tunnel shields	127
8.4	Modern tunnel shields	128
8.5	Differing ground conditions	129
8.6	Construction methods	129
8.7	Tunnel linings	130
8.8	Vertical and sloping shafts	132
8.9	Tunnel inspection and maintenance	133
9.	Electrification	135
9.1	Electricity as a form of motive power	135
9.2	Generation of electricity	136

9.3	Railway electrification systems	136
9.4	The AC system connection of supply	138
9.5	AC feeder points	138
9.6	AC overhead equipment	139
9.7	Earthing on the AC system	140
9.8	Electrical interference	141
9.9	DC low voltage systems	141
9.10	AC power distribution for DC systems	142
9.11	DC power distribution	143
9.12	Effects of electrification	144
9.13	Inspection and maintenance	145
10.	Signalling and Train Control	147
10.1	Early history of signalling	147
10.2	Modern signalling	149
10.3	Track circuits	150
10.4	Point operation, locking and detection	151
10.5	Interlocking	152
10.6	Minimum headways	153
10.7	Home and distant signals	154
10.8	Subsidiary signals	154
10.9	Two aspect colour light signalling	155
10.10	Three aspect colour light signalling	156
10.11	Four aspect colour light signalling	157
10.12	Transmission based signalling	159
10.13	Proof of safety and safety standards	160
11.	Systems and Communications	163
11.1	Getting things done!	163
11.2	Human processes	164
11.3	Good feedback	164
11.4	Interface between operation and engineering	166
11.5	Interface between operation and the user	166
11.6	Railway systems pyramid	167
11.7	The railway signalling system	168
11.8	The public address system	169

11.9	Telephones and radio	170
11.10	Closed circuit TV	172
11.11	Equipment operation and maintenance	172
12.	Lifts, Escalators and Pumps	175
12.1	Vertical transportation	175
12.2	Development of early lifts	175
12.3	Development of escalators	176
12.4	Passenger flows to and from escalators and/or lifts	177
12.5	Achievable flow rates for modern lifts	178
12.6	Flow rates on escalators	179
12.7	Types of escalators	180
12.8	Compact type escalator	180
12.9	Semi-compact type escalators	182
12.10	Heavy duty public service escalators	182
12.11	Typical HDPS escalator dimensions	184
12.12	Types of modern lift	184
12.13	Application of lift types	185
12.14	Safety risks and human factors	185
12.15	Inspection and maintenance	186
12.16	Pumps	186
13.	Ventilation and Draught Relief	189
13.1	Is ventilation a problem on railways?	189
13.2	Movement of air	190
13.3	Deciding on exhaust or pressure	191
13.4	The 'piston' effect	192
13.5	Design and operation of tunnel fans	192
13.6	Smoke in tunnels	193
13.7	Draught relief	194
13.8	Maintenance and inspection of fans	195
14.	Future Trends	197
14.1	Engineering 'full circle'	197
14.2	The trend towards broader vision	199
14.3	The trend towards local accountability	199

14.4	Increasing Information Technology	200
14.5	Improved interchange between transport modes	201
14.6	A move towards design for Maintenance	202
14.7	Trends in comfort standards	202
15.	Conclusion	203
15.1	Retrospect	203
15.2	Postscript	204
	Subject Index	205

List of Illustrations

Fig. 1.1	Early railway construction	2
Fig. 1.2	Underground railway construction at Blackfriars	4
Fig. 1.3	Concourse and roof at Paddington	6
Fig. 2.1	Typical country station	11
Fig. 2.2	Typical sub-surface booking hall	12
Fig. 2.3	Matrix of passenger flows	15
Fig. 2.4	Congestion at foot of escalator	16
Fig. 2.5	Pedestrian flow during crowding	16
Fig. 2.6	Different categories of passengers on a concourse	20
Fig. 2.7	Passenger movements during 'Dwell time'	23
Fig. 2.8	Lift for the disabled, Docklands Light Railway	26
Fig. 3.1	Early flanged wheels and rails	32
Fig. 3.2	'The Age of Steam'	33
Fig. 3.3	Euston Square station showing ventilation openings	36
Fig. 3.4	An early Underground DC electric locomotive	37
Fig. 3.5	Modern multiple unit tube train	38
Fig. 3.6	Southern Region(BR) multiple unit DC stock	39
Fig. 3.7	Channel Tunnel stock which can run on either DC third rail or AC overhead current collection	40
Fig. 3.8	Modern diesel-electric locomotive	41
Fig. 3.9	Typical 'slam door' compartment stock	44
Fig. 3.10	Modern open plan passenger coach	45
Fig. 3.11	Docklands Light Railway stock	45
Fig. 3.12	Specialist freight wagons	49
Fig. 3.13	Ballast tamping machine	50

Fig. 4.1 Diesel-electric depot/workshop	57
Fig. 4.2 Typical Metro depot for LUL	58
Fig. 4.3 DLR depot during construction	59
Fig. 4.4 Train Washing Machine	61
Fig. 5.1 Bullhead section rail	64
Fig. 5.2 Recommended ballast depths	66
Fig. 5.3 Individual renewal of timber sleepers on LUL	68
Fig. 5.4 Standard Prestressed Concrete Sleepers	70
Fig. 5.5 Flat Bottom Rail	72
Fig. 5.6 The Pandrol Clip	74
Fig. 5.7 Continuous Welded Track	80
Fig. 5.8 A crossover layout in BH rail	82
Fig. 5.9 Components of Points/Turnouts	84
Fig. 5.10 Modern main line track installation	88
Fig. 5.11 Day time Track Maintenance Gang at work	89
Fig. 6.1 Well maintained Embankment Slope	93
Fig. 6.2 Counterforts and Herring-bone Drainage	97
Fig. 6.3 A Sump Clearing Pump Train	101
Fig. 6.4 Drainage catchpit	103
Fig. 6.5 Fence for Third/Fourth Rail Electrified Railway	103
Fig. 7.1 Laminated timber arched bridge at Lancaster	106
Fig. 7.2 Hundred year old cast iron arches at Kilburn	107
Fig. 7.3 Reconstructed girder bridge at Kilburn	109
Fig. 7.4 Welded truss railway bridge	110
Fig. 7.5 Welded tubular station roof at Waterloo	110
Fig. 7.6 Reinforced concrete station portal frame (1930's)	111
Fig. 7.7 Railway bridge reconstructed using pretensioned prestressed concrete beams	114
Fig. 7.8 Concrete segmental box units	115
Fig. 7.9 Erection of new girders, Lune Viaduct	117
Fig. 7.10 100 Ton Rolling-in trolley	118
Fig. 7.11 Brick arched underbridge still giving service after 150 years	120
Fig. 8.1 Early Cut-and-cover construction in London	126
Fig. 8.2 Modern soft ground tunnel shield	128

Fig. 8.3	Expanded concrete linings	131
Fig. 8.4	Concrete lined vertical shaft	132
Fig. 9.1	Diagram of typical 25 kV Feeding Arrangement	139
Fig. 9.2	Modern 25 kV Overhead Equipment	140
Fig. 9.3	AC and DC distribution on a DC system	142
Fig. 10.1	Semaphore Signals	149
Fig. 10.2	The DC Track Circuit	150
Fig. 10.3	Diagram showing point locking and detection	151
Fig. 10.4	Headway distance and time	153
Fig. 10.5	Two Aspect signalling	155
Fig. 10.6	Three Aspect signalling	156
Fig. 10.7	Four Aspect signalling	158
Fig. 11.1	Open and closed loop systems	165
Fig. 11.2	The systems pyramid	167
Fig. 12.1	An early Underground escalator	177
Fig. 12.2	A modern railway design using escalators and lift	179
Fig. 12.3	Typical semi-compact escalator	181
Fig. 12.4	Heavy duty public service escalator	183