17th Edition

SOIL MECHANICS AND FOUNDATIONS

Dr. B.C. Punmia | Er. Ashok K. Jain | Dr. Arun K. Jain

SOIL MECHANICS
AND
FOUNDATIONS

SOIL MECHANICS AND FOUNDATIONS

By

Dr. B.C. PUNMIA
Formerly,
Professor and Head, Deptt. of Civil Engineering, &
Dean, Faculty of Engineering
M.B.M. Engineering College,
Jodhpur

Er. ASHOK KUMAR JAIN
Director,
Arihant Consultants,
Jodhpur

Dr. ARUN KUMAR JAIN
Assistant Professor
M.B.M. Engineering College,
Jodhpur

(INCLUDING LABORATORY EXPERIMENTS)

(ENTIRELY IN SI UNITS)

SEVENTEENTH EDITION

(Thoroughly Revised and Enlarged)

LAXMI PUBLICATIONS (P) LTD.
(An ISO 9001 : 2008 Company)
BENGALURU • CHENNAI • COCHIN • GUWAHATI • HYDERABAD
JALANDHAR • KOLKATA • LUCKNOW • MUMBAI • RANCHI • NEW DELHI
BOSTON (USA) • ACCRA (GHANA) • NAIROBI (KENYA)

SOIL MECHANICS AND FOUNDATION

© 1973, 1994, 2005 **B.C. PUNMIA**
© 1994, 2005 **ASHOK KUMAR JAIN, ARUN KUMAR JAIN**
All rights reserved including those of translation into other languages. In accordance with the Copyright (Amendment) Act, 2012, no part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise. Any such act or scanning, uploading, and or electronic sharing of any part of this book without the permission of the publisher constitutes unlawful piracy and theft of the copyright holder's intellectual property. If you would like to use material from the book (other than for review purposes), prior written permission must be obtained from the publishers.

Printed and bound in India
Typeset at Shubham Composer, Delhi
First Edition: July 1970, Second Edition: Sept. 1973, Third Edition: Sept. 1975, Fourth Edition: Aug. 1977
Fifth Edition: Feb. 1979, Sixth Edition: Oct. 1980, Seventh Edition: Jan. 1982, Eighth Edition: April 1983
Ninth Edition: Jan. 1985, Tenth Edition: Feb. 1987, Eleventh Edition: April 1988, Twelfth Edition: Jan. 1991
Thirteenth Edition: Nov. 1994, Fourteenth Edition: May 1998, Fifteenth Edition: May 2001
Sixteenth Edition: March 2005, Reprint: Jan. 2006, May 2007, Jan. 2008, June 2008, Oct. 2008
May 2009, April, Aug., Oct. 2010, Jan. 2011, May 2011, July 2012, Oct. 2012, Aprial 2013, Dec. 2013, May 2014,
Seventeenth Edition: 2017
ISBN 81-7008-791-0

Limits of Liability/Disclaimer of Warranty: The publisher and the author make no representation or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties. The advice, strategies, and activities contained herein may not be suitable for every situation. In performing activities adult supervision must be sought. Likewise, common sense and care are essential to the conduct of any and all activities, whether described in this book or otherwise. Neither the publisher nor the author shall be liable or assumes any responsibility for any injuries or damages arising here from. The fact that an organization or Website if referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers must be aware that the Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read.

All trademarks, logos or any other mark such as Vibgyor, USP, Amanda, Golden Bells, Firewall Media, Mercury, Trinity, Laxmi appearing in this work are trademarks and intellectual property owned by or licensed to Laxmi Publications, its subsidiaries or affiliates. Notwithstanding this disclaimer, all other names and marks mentioned in this work are the trade names, trademarks or service marks of their respective owners.

Branches

Bengaluru	080-26 75 69 30	
Chennai	044-24 34 47 26,	24 35 95 07
Cochin	0484-237 70 04,	405 13 03
Guwahati	0361-254 36 69,	251 38 81
Hyderabad	040-27 55 53 83,	27 55 53 93
Jalandhar	0181-222 12 72	
Kolkata	033-22 27 43 84	
Lucknow	0522-220 99 16	
Mumbai	022-24 91 54 15,	24 92 78 69
Ranchi	0651-220 44 64	

PUBLISHED IN INDIA BY

Laxmi Publications (P) Ltd.
(An ISO 9001:2008 Company)
113, GOLDEN HOUSE, DARYAGANJ,
NEW DELHI - 110002, INDIA
Telephone : 91-11-4353 2500, 4353 2501
Fax : 91-11-2325 2572, 4353 2528
www.laxmipublications.com info@laxmipublications.com

C—
Printed at:

Preface

PREFACE TO THE SECOND EDITION

Soil Engineering, soil mechanics or geotechnique is one of the youngest disciplines of civil engineering involving the study of soil, its behaviour and application as an engineering material. The term 'Soil Engineering' is currently used to cover a much wider scope implying that it is a practical science rather than a purely fundamental or mathematical one. Good soil engineering embodies the use of the best practices in exploration, testing, design and construction control, in addition to the basic idealised theories.

The field of Soil Mechanics is very vast. The civil engineer has many diverse and important encounters with soil. Apart from testing and classification of various types of soils in order to know its physical properties, the knowledge of soil mechanics is particularly helpful in the designs of foundations, rigid and flexible pavements, underground and earth retaining structures, embankments, and excavations, and earth dams.

This textbook is intended to present the currently accepted theories, design principles and practices of soil mechanics and foundation engineering. The assumptions and limitations used in developing a theory or a method are pointed out and sufficient number of examples and practice problems are included to illustrate the application of basic principles of practical problems. The text provides sufficient material, ranging from the simple to very complex, for the undergraduate and postgraduate courses in the subject of soil engineering in the engineering colleges, universities and professional examinations in India. The book should also prove a useful design aid for the practising engineer and a convenient reference source.

The book has been sub-divided into eight parts : (1) Elementary Properties, (2) Soil Hydraulics, (3) Elasticity Applied to Soils, (4) Compressibility, (5) Strength and Stability, (6) Foundation Engineering, (7) Pavement Design and (8) Miscellaneous Problems. More advanced topics have been indicated by an asterisk which may be omitted in the first reading or at the undergraduate level. In addition, *twenty-one* more common laboratory experiments have been included to illustrate the practice of soil testing. The test procedures conform to the latest Indian Standards issued to date. Metric Units have been used in the text. The author is highly thankful to Dr. Alam Singh for his kind permission to reproduce the matter of the first edition of the book published in his collaboration. Account has been taken throughout of the suggestions offered by the many users of the book and grateful acknowledgement is made to them. Further suggestions will be greatly appreciated.

JODHPUR
1-9-73

B.C. PUNMIA

PREFACE TO THE THIRD EDITION

In the Third Edition, the subject-matter has been updated. In order to make the book more useful to the students appearing at the A.M.I.E. Examinations, questions from the examination papers of section B have been given in Appendix.

JODHPUR **B.C. PUNMIA**
1-9-75

PREFACE TO THE FOURTH EDITION

In the Fourth Edition of the book, the subject-matter has been thoroughly revised and enlarged to incorporate the latest developments. An article on 'dynamic analysis of block foundations' having six modes of vibrations has been added. The author is thankful to many readers of the book for useful suggestions.

JODHPUR **B.C. PUNMIA**
1-8-77

PREFACE TO THE FIFTH EDITION

In the Fifth Edition, the subject-matter has been revised, and an Appendix on SI units has been added at the end of the book.

JODHPUR **B.C. PUNMIA**
15-2-79

PREFACE TO THE SIXTH EDITION

In the Sixth Edition, the subject-matter has been revised and updated. Matter on under-reamed pile foundation has been added in Chapter 26.

JODHPUR **B.C. PUNMIA**
1-10-80

PREFACE TO THE EIGHTH EDITION

In the Eighth Edition, many new articles have been added and the subject-matter has been revised and updated.

JODHPUR **B.C.PUNMIA**
25-4-83

PREFACE TO THE NINTH EDITION

In the Ninth Edition, few new articles have been added. Notable amongst these are : bored compaction piles, field set-ups for plate load test, field set-up for pile load test and pneumatic caissions. The subject-matter has been revised and updated.

JODHPUR **B.C. PUNMIA**
24-10-84

PREFACE TO THE TENTH EDITION

In this edition, few misprints of the previous edition have been removed and the subject-matter has been updated.

JODHPUR **B.C. PUNMIA**
15-2-87

PREFACE TO THE ELEVENTH EDITION

In the Eleventh Edition, the book has been thoroughly revised and enlarged, using SI units. Care has been taken to distinguish between 'mass' and 'weight' and between 'density' and 'unit weight' and separate symbols have been assigned to these quantities to avoid confusion. Density (ρ), based on laboratory measurements has been expressed in the units of g/cm^3 (or kg/m^3) while the unit weight (γ) has been expressed in kN/m^3. The value of gravitational constant g has been taken as 981 cm/s^2. Thus, the density of water (ρ_w) has been taken as 1 g/cm^3 (or 1000 kg/m^3) while its unit weight has been taken as 9.81 kN/m^3.

A chapter on 'Advanced Measuring Instruments' has been added at the end. A large number of photographic plates, illustrating various testing equipment used in 'Soil Testing Laboratory' have been added. The authors are thankful to M/s Associated Instruments Manufactures, India (AIMIL), Delhi and M/s HEICO Instruments, Delhi for supplying photographs and illustrative catalogues of the instruments/ equipment manufactured by them.

It is hoped that this revised and updated edition will be useful to the students and practicing engineers. Further suggestions will be gratefully accepted.

JODHPUR **B.C. PUNMIA**
1-7-88 **A.K. JAIN**

PREFACE TO THE TWELFTH EDITION

In the Twelfth Edition, subject matter has been revised and enlarged. Chapter 24 on Bearing Capacity and chapter 25 on Shallow Foundations have been rewritten and many new articles and new examples have been added.

JODHPUR **B.C. PUNMIA**
1-12-90 **A.K. JAIN**

PREFACE TO THE THIRTEENTH EDITION

In the Thirteenth Edition of the book, the subject matter has been thoroughly revised and updated. Many new articles and solved examples have been added. The entire book has been typeset using laser printer. The authors are thankful to Shri Mool Singh Gahlot and Shri Prem Singh Sankhla for the fine laser typesetting done by them.

JODHPUR
14th Nov. 1994

B.C. PUNMIA
ASHOK K. JAIN
ARUN K. JAIN

PREFACE TO THE SIXTEENTH EDITION

In the Sixteenth Edition, the subject matter has been thoroughly revised and updated, and rearranged. In each chapter, many new articles have been added. All the diagrams have been redrawn using computer graphics and the book has been computer type-set in a bigger format, keeping in pace with the modem trend. At the end of each chapter, problems appearing at various central competitive examinations (such as Civil Services, Engineering Services and Gate) have been solved. In addition to these, a new chapter on 'Geotextiles' have been added at the end of the book.

It is hoped, this thoroughly revised and updated edition will be useful to the students, teachers and practicing engineers. Further suggestions will be gratefully acknowledged. The authors are thankful to Shri R.K. Gupta of Laxmi Publications (P) Ltd. for good printing and excellent get-up of the book and that too in a record short time.

JODHPUR
1st March 2005

B.C. FUNMIA
ASHOK K. JAIN
ARUN K. JAIN

Contents

PART I
ELEMENTARY PROPERTIES

1. INTRODUCTION **3–8**

1.1 Soil and Soil Engineering 3
1.2 History of Development of Soil Mechanics 4
1.3 Field of Soil Mechanics 6
1.4 SI Units 7

2. PRELIMINARY DEFINITIONS AND RELATIONSHIPS **9–38**

2.1 Soil as a Three Phase System 9
2.2 Water Content, Density and Unit Weights 10
2.3 Specific Gravity 12
2.4 Voids Ratio, Porosity and Degree of Saturation 13
2.5 Density Index and Relative Compaction 15
2.6 Functional Relationships 17
Solved Examples 21
2.7 Packing of Uniform Spheres 28
2.8 Examples from Competitive Examinations 30
Problems 37

3. DETERMINATION OF INDEX PROPERTIES **39–116**

3.1 General 39
3.2 Water Content 39
3.3 Specific Gravity 43
Solved Examples 45
3.4 Particle Size Distribution 46
3.5 Sieve Analysis 46
3.6 Sedimentation Analysis: Theory 48
3.7 Pipette Method 52
3.8 Hydrometer Method 54
3.9 Particle Size Distribution Curve 58
3.10 Consistency of Soils 60

3.11 Determination of Liquid and Plastic Limits 62
3.12 Shrinkage Limit 66
3.13 Determination of In-situ Density, Voids Ratio and Density Index 75
3.14 Activity of Clays 78
3.15 Sensitivity of Clays 79
3.16 Thixotropy of Clays 79
3.17 Collapsible Soils 80
3.18 Average Diameter of a Group of Particles 82
3.19 Specific Surface 83
3.20 Examples from Competitive Examinations 86
3.21 Laboratory Experiments 90
Problems 115

4. CLASSIFICATION OF SOILS 117–138
4.1 General 117
4.2 Particle Size Classification 117
4.3 Textural Classification 118
4.4 Highway Research Board (HRB) Classification 119
4.5 Unified Soil Classification System (USCS) 121
4.6 Indian Standard Classification System, (ISCS) (IS : 1498–1970) 126
Solved Examples 131
4.7 Examples from Competitive Examinations 138

5. SOIL STRUCTURE AND CLAY MINERALOGY 139–150
5.1 Soil Structure 139
5.2 Solid Particles in Soils 140
5.3 Atomic and Molecular Bonds 140
5.4 Interparticle Forces in a Soil Mass 144
5.5 Single Grained Structure 145
5.6 Honeycomb Structure 146
5.7 Flocculent and Dispersed Structures 146
5.8 Structure of Composite Soils 147
5.9 Clay Minerals 148

PART II
SOIL HYDRAULICS

6. SOIL WATER: EFFECTIVE AND NEUTRAL STRESSES 153–183
6.1 Modes of Occurrence of Water in Soil 153
6.2 Adsorbed Water 155
6.3 Capillary Water 156
6.4 Capillary Tension, Capillary Potential and Soil Suction 159

6.5 Capillary Phenomenon in Soils : Capillary Zones 162
6.6 Shrinkage and Swelling of Soils 163
6.7 Slaking of Clay 164
6.8 Bulking of Sand 164
6.9 Frost Action 165
Solved Examples 167
6.10 Stress Conditions in Soil: Effective and Neutral Pressures 169
6.11 Capillary Siphoning 174
6.12 Examples from Competitive Examinations 175
Problems 183

7. PERMEABILITY 184–212
7.1 Introduction 184
7.2 Darcy's Law 184
7.3 Discharge Velocity and Seepage Velocity 186
7.4 Validity of Darcy's Law 186
7.5 Poiseuille's Law of Flow Through Capillary Tube* 187
7.6 Factors Affecting Permeability 190
7.7 Coefficient of Absolute Permeability 193
7.8 Determination of Coefficient of Permeability 193
7.9 Constant Head Permeability Test 195
7.10 Falling Head Permeability Test 196
7.11 The Jodhpur Permeameter 197
Solved Examples 198
7.12 The Capillarity-Permeability Test 201
7.13 Permeability of Stratified Soil Deposits 203
7.14 Examples from Competitive Examinations 206
7.15 Laboratory Experiments 209
Problems 212

8. WELL HYDRAULICS 213–232
8.1 Introduction 213
8.2 Some Definitions 213
8.3 Steady Radial Flow to a Well : Dupuit's Theory 215
8.4 Field Determination of k and T : Pumping Out Tests 218
Solved Examples 220
8.5 Pumping in Tests 222
8.6 Interference Among Wells 223
8.7 Fully Penetrating Artesian Gravity Well 224
8.8 Partially Penetrating Artesian Well 224

8.9 Spherical Flow in a Well* 225
8.10 Flow Towards Open Well : Recuperation Test 226
8.11 Examples from Competitive Examinations 230
Problems 232

9. SEEPAGE ANALYSIS 233–259
9.1 Head, Gradient and Potential 233
9.2 Seepage Pressure 234
9.3 Upward Flow : Quick Condition 235
Solved Examples 236
9.4 Two Dimensional Flow : Laplace Equation 240
9.5 Graphical Method of Flow Net Construction 243
9.6 Flow Net by Electrical Analogy 244
9.7 Applications of Flow Net 245
9.8 Seepage Through Anisotropic Soil 247
9.9 Deflection of Flow Lines at Interface of Dissimilar Soils 249
9.10 Phreatic Line of an Earth Dam 249
9.11 Phreatic Line in an Earth Dam with no Filter 251
9.12 Examples from Competitive Examinations 255
Problems 259

10. SEEPAGE BELOW HYDRAULIC STRUCTURES 260–277
10.1 Introduction 260
10.2 Piping : Exit Gradient 261
10.3 Khosla's Theory 261
10.4 Composite Profiles : Schwarz-Christoffel Transformation 263
10.5 Pavlovsky's Method : Finite Depth Problems 272

11. DRAINAGE AND DEWATERING 278–288
11.1 Introduction 278
11.2 Ditches and Sumps 278
11.3 Well Point System 279
11.4 Shallow Well System 280
11.5 Deep Well Drainage 280
11.6 Vacuum Method: Forced Flow 281
11.7 Electro-Osmosis Method 282
11.8 Seepage Analysis 283
11.9 Protective Filters 287

PART III
ELASTICITY APPLIED TO SOILS

12. ELEMENTS OF ELASTICITY **291–306**

12.1 State of Stress at a Point 291
12.2 Equilibrium Equations 292
12.3 Equilibrium Equations for Saturated Soil Body 294
12.4 Strain Components : Strain Tensor 296
12.5 Compatibility Equations 297
12.6 Boundary Condition Equations 298
12.7 Generalised Hooke's Law : Homogeneity and Isotropy 299
12.8 Typical Values of Modulus of Elasticity and Poisson's Ratio 300
12.9 Two Dimensional Problems 300
12.10 Compatibility Equation in Two Dimensional Case 301
12.11 Stress Function 303
12.12 Equilibrium Equations in Polar Co-ordinates 304
12.13 Compatibility Equations and Stress Function in Polar Co-ordinates 305
12.14 Cylindrical Co-ordinates 306

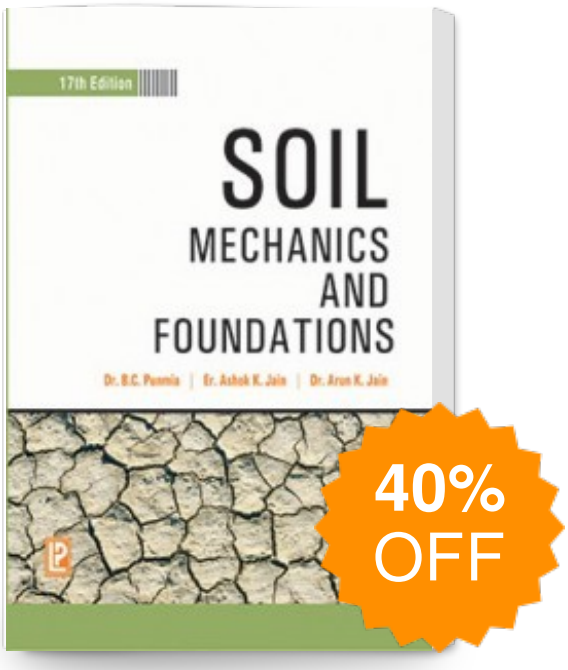
13. STRESS DISTRIBUTION : I **307–338**

13.1 Introduction : Stresses Due to Self Weight 307
13.2 Concentrated Force : Boussinesq Equations 308
13.3 Pressure Distribution Diagrams 312
Solved Examples 315
13.4 Vertical Pressure Under a Uniformly Loaded Circular Area 317
13.5 Vertical Pressure Due to a Line Load 319
13.6 Vertical Pressure Under Strip Load 320
13.7 Vertical Pressure Under a Uniformly Loaded Rectangular Area 321
13.8 Equivalent Point Load Method 325
13.9 Newmark's Influence Chart 326
13.10 Westergaard's Analysis 329
13.11 Contact Pressure 336
13.12 Examples from Competitive Examinations 337
Problems 338

14. STRESS DISTRIBUTION : II* **339–352**

14.1 Vertical Line Load 339
14.2 Horizontal Line Load 341
14.3 Uniform Vertical Load Over a Strip 343
14.4 Concentrated Force: Boussinesq Problem 344

Soil Mechanics And Foundations



Publisher : Laxmi Publications ISBN : 9788170087915

Author : B C Punmia, Ashok Kumar Jain And Arun Kumar Jain

Type the URL : http://www.kopykitab.com/product/10483

Get this eBook