embuell.

# Soil Dynamics

## Tien Hsing Wu

Professor of Civil Engineering Ohio State University

ALLYN & BACON, INC. Boston, Mass.

MEI YA PUBLICATIONS, INC. Taipei, Taiwan COPYRIGHT © 1971 BY Allyn & Bacon, Inc.

Copyright 1971, in Taiwan, Republic of China by Allyn & Bacon, Inc. Assigned Republic of China Copyright No.

C. SOLAR STORE

All Rights Reserved. This book, or parts thereof, may not be reproduced in any form without permission of the publisher.

#### FOR SALE IN TAIWAN ONLY; NOT FOR EXPORT

First printing......July, 1971

Reprinted by MEI YA PUBLICATIONS, INC. P. O. Box 22555 Taipei, Taiwan The Republic of China

## Contents

Preface ix

Notations xi

1

#### Stress and Strain 1

- Fundamental Relationships 1.1
- 1.2 Elasticity 4
- 1.3 Viscoelasticity 7
- 1.4 Plasticity 10

#### 2

#### **Dynamic Soil Properties** 13

- 2.1 Effective Stress Principal 13 STRAIN RATE EFFECT 15
- 15 Strain-Rate Effect on Pore-Pressure Behavior 2.2 15

1

۷

- 2.3 Strain-Rate Effect on Stress-Strain Relationship
- 2.4 Strain-Rate Effect on Shear Strength . 17 REPEATED LOADING AND VIBRATION 20
- 2.5 Loading Conditions 20
- 2.6 Stress-Strain Relationship 21
- 2.7 Fatigue Failure 22
- 2.8 Soil Compaction by Vibration 26

#### CONTENTS

3

#### Wave Propagation in Soils 33

- PRINCIPLES OF WAVE PROPAGATION 33
- 3.1 Elastic Waves in a Bar 33
- 3.2 Elastic Waves in Three Dimensions 39
- 3.3 Rayleigh Waves 42
- 3.4 Viscoelastic Waves in a Bar 44
- 3.5 Plastic Waves in a Bar 46 WAVE PROPAGATION IN SOILS
- 3.6 One-Dimensional Waves 51
- 3.7 Low-Amplitude Waves in Bars 53
- 3.8 High-Amplitude Waves in Bars 57

#### 4

### Reflection and Refraction of Waves 63

- 4.1 Measurement of Direct Wave 63
- 4.2 Reflection at Free Surface 66
- 4.3 Reflection and Refraction at Interface 68
- 4.4 Refracted and Reflected Waves in Layered Media 70

50

- 4.5 Refraction Method 72
- 4.6 Reflection Method 76

#### 5

#### Stress Waves Due to Blast Loading 83

- 5.1 Air-Blast Phenomenon 83
- 5.2 Air-Induced Ground Motion 86
- 5.3 One-Dimensional Stress Wave, Superseismic Case 90
- 5.4 Empirical Attenuation Factor 96
- 5.5 Evaluation of Soil Properties 102
- 5.6 Direct Transmitted Ground Shock 106

#### 6

### Vibration of Soils 111

SYSTEMS OF LUMPED PARAMETERS 111

- 6.1 Systems with One Degree of Freedom 112
- 6.2 Systems with Two or More Degrees of Freedom 117
- 6.3 Hysteretic Damping 123 VIBRATION OF SOIL COLUMNS 125
- 6.4 Undamped Vibration 126
- 6.5 Damped Vibration 128
- 6.6 Soil Vibration Experiments 132

#### CONTENTS

- 6.7 Vibration Properties of Soils 136
- 6.8 Packings of Elastic Spheres 139

#### 7

#### Foundation Vibrations 143

VIBRATION OF ELASTIC HALF SPACE 143

- 7.1 Vertical Oscillations 143
- 7.2 Horizontal Translation, Rocking and Torsion 155
- 7.3 Oscillator Tests 159

Representation by Lumped Parameter Systems 162

- 7.4 General Relationships 162
- 7.5 Analysis of Foundation Vibrations by Lumped Parameter Systems 166 DESIGN CONSIDERATIONS 171
- 7.6 Design Requirements 172
- 7.7 Characteristics of Dynamic Loads 173
- 7.8 Choice of Lumped Parameters 175
- 7.9 Settlement Under Vibration 179
- 7.10 Vibration of the Free Surface 179
- 7.11 Transient Vibrations 180

#### 8

#### Dynamic Bearing Capacity and Penetration 195

- 8.1 Penetration into Soil Medium 195
- 8.2 Dynamic Bearing Capacity 197
- 8.3 Impact 205

#### 9

#### Earthquake Problems 219

- 9.1 Earthquake Phenomenon 219 EARTHQUAKE INDUCED MOTIONS 223
- 9.2 Aperiodic Motion 223
- 9.3 Ground Vibration 228
- 9.4 Ground Effects on Building Vibration 232
- 9.5 Vibration of Embankments 238
- DESIGN CONSIDERATIONS 243
- 9.6 General Principles 243
- 9.7 Ground Deformations 244
- 9.8 Earth Dam Design 245

#### Bibliography 255

Index 269