

Other volumes in the
Series on Rock and Soil Mechanics

W. Reisner, M. v. Eisenhart Rothe:
Bins and Bunkers for Handling Bulk Materials
– Practical Design and Techniques –
1971

W. Dreyer:
The Science of Rock Mechanics
Part I: Strength Properties of Rocks
1972

T. H. Hanna:
Foundation Instrumentation
1973

C. E. Gregory:
Explosives for North American Engineers
1973

M. & A. Reimbert:
Retaining Walls Vol. I
– Anchorages and Sheet Piling –
1974

Vutukuri, Lama, Saluja:
Handbook on Mechanical Properties
of Rocks Vol. I
1974

Editor-in-Chief
Professor Dr. H. Wöhlbier

Series on Rock and Soil Mechanics
Vol. 2 (1974/76) No. 2

RETAINING WALLS

Volume II

Study of Passive Resistance in Foundation Structures

by

Marcel L. Reimbert
Consulting Engineer

and

Andrew M. Reimbert
Consulting Engineer

Member, Committee „SILOS“ of the American Concrete Institute

First Edition
1976

TRANS TECH PUBLICATIONS

Distributed
in the USA and Canada by
TRANS TECH PUBLICATIONS
411 Long Beach Pkwy.
Bay Village, Ohio 44140
USA

and worldwide by
TRANS TECH S. A.
CH-4711 Aedermannsdorf
Switzerland

Copyright © 1976 by
Trans Tech Publications
Clausthal, Germany

Translated by C. V. Amerongen, M. Sc., M.I.C.E.
for OLYMPIA TRANSLATION SERVICE, London

International Standard Book Number
ISBN 0-87849-013-2

Library of Congress Catalog Card Number
LCC 74-77789

Printed in Germany

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

1. Preface

Volume I, entitled "Retaining Walls, Anchorages and Sheet Piling", showed how the values of the **maximum thrust** and of the **minimum passive resistance** exerted upon, or developed by, retaining walls in general could be calculated.

These optimum values correspond to the "at rest" state of equilibrium of the soil, this being **the only state compatible with proper stability of retaining structures**.

Nevertheless, in special cases where such structures undergo displacements whereby they push back the retained soil upon itself, it used to be known merely that the magnitude of the passive resistance reaction developed by that soil would increase rapidly and considerably, though the relationship between the displacements and the stresses resulting therefrom had never been clearly established.

The extremely accurate experiments reported in Volume II have revealed the **deformation relationship** for a granular material under loading whereby it develops **translatory passive resistance** or **rotational passive resistance**. This deformation is defined by a **linear function of the passive resistance coefficient** in the elasto-plastic stage of equilibrium of the material.

The special problem presented by the equilibrium of soil developing passive resistance is therefore unambiguously solved, for it is henceforth possible to know the displacements that a retaining structure would undergo, depending on the value of the passive resistance coefficient corresponding to the equilibrium of the retained material tending to be pushed back upon itself by forces of determinate magnitude.

The information yielded by the researches reported in this book is thus directly applicable to the design of retaining walls, sheet piling, diaphragm walls, etc.

The information presented in this book embodies the results of our personal and unbiased efforts. It necessitated upwards of a thousand experiments of various kinds, performed with equipment designed entirely by ourselves and without any financial assistance from outside sources.

Nevertheless, despite the effort and expense involved, we carried out a properly planned experimental program that enabled us to ascertain and interpret the passive resistance phenomena in a most exhaustive manner.

Thus we have devoted, separate chapters to the effect of scale in models, to dilatancy, to the effect of displacement of the retaining wall in its own plane, to the surface condition of the wall, etc.

As regards this last-mentioned point, we knowingly confined ourselves to what was apparently a small displacement as soon as it was found to be sufficient to reveal that the surface condition of the wall was of no influence on the passive resistance at rest, while at the same time confirming the validity of the linear relationship between the deformations and the forces which has been proposed by us with regard to the phenomena of passive resistance.

This preliminary notice will thus have served to inform our readers of the scope and conditions of the present treatise which carries these researches to their proper conclusion in providing the interpretation of the phenomena of translatory and of rotational passive resistance.

Paris,
January 1976

Marcel L. Reimbert
Andrew M. Reimbert

Contents

1. Preface	V
Contents	VII
2. Introduction	1
3. Granular Materials Used	2
3.1. Cereals	2
3.2. Sands	2
4. Deformations Associated with Passive Resistance	5
4.1. List of Symbols	5
4.2. Experimental Equipment	6
4.3. Configuration of the Granular Material in the Experiments	8
5. Experiments Relating to the Surface Conditions of the Diaphragm	10
5.1. Experiments Relating to Passive Resistance Due to Horizontal Translatory Movement of the Diaphragm	10
5.2. Experiments Relating to Passive Resistance Due to Translatory Movement of the Diaphragm along Ascending or Descending Inclined Planes	13
5.3. Remarks	14
6. Experiments Relating to Translatory Passive Resistance	18
6.1. Characteristic Stages of Deformation of a Granular Mass Developing Translatory Passive Resistance	18
6.2. Material with Horizontal Top Surface	21
6.3. Material with Top Surface Inclined at the Upper Angle of Repose ($+\alpha$)	32
6.4. Material with Top Surface Inclined at the Lower Angle of Repose ($-\alpha$)	37
6.5. Conclusions Relating to Material with Horizontal or Inclined Top Surface	42

7. Ultimate Passive Resistance Coefficients	46
8. Confirmation, by Tests Relating to Translatory Passive Resistance, of the Thrust Coefficients for Granular Material with Inclined Top Surface	47
8.1. Vertical Wall	47
8.2. Sloping Wall	48
8.3. Conclusions	58
9. Deformations Relating to the Adaptation and Elasto-Plastic Equilibrium Stages of Granular Material Developing Translatory Passive Resistance	59
9.1. Review of Results	59
9.2. Special Case: Test Sands other than Fine Sand	60
10. Effects of Vibration and Compaction on the Deformations of Granular Material Developing Passive Resistance	62
10.1. Vibrated Fine Sand	63
10.2. Closely Packed Sand	64
10.3. Compacted Fine Sand	64
10.4. Conclusions	70
11. Deformations in Granular Material Subjected to Surcharge	72
11.1. Introduction	72
11.2. Experiments Concerning Translatory Passive Resistance of Material with Horizontal Top Surface and Carrying a Surcharge	72
11.3. Experimental Procedure	73
11.4. Tests	74
12. Dilatancy of Granular Material Developing Translatory Passive Resistance	77
12.1. Definition	77
12.2. Experiments Relating to the Dilatancy of a Mass of Granular Material of Indefinite Extent	77
12.3. Experiments Relating to the Dilatancy of a Mass of Granular Material of Triangular Cross-section	78
12.4. Remark	79
12.5. Millet	80
12.6. Fine Sand	82

13. Investigation of the Minimum Dimensions of Models	84
13.1. Test Results	85
13.2. Deformations of Material Developing Translatory Passive Resistance Across the Width L	87
13.3. Note	89
13.4. Some Additional Comments.	90
13.5. Deformations of a Material Developing Passive Resistance: Effect of Height of the Material	91
 14. Practical Determination of Parameter λ in the Laboratory	 92
 15. Deformations Associated with Rotational Passive Resistance	 95
15.1. Introduction	95
15.2. Experiments Relating to the Rotational Passive Resistance of Material with Horizontal or Inclined Top Surface	96
 16. Deformations Associated with Toe Resistance	 108
16.1. Introduction	108
16.2. Tests with Fine Sand	109
16.3. Convergence of the Straight Lines Representing the Deformations of a Granular Material Developing Resistance	114
 17. Summary and Formulas.	 118
17.1. Introduction	118
17.2. Stages of Adaptation of the Material	118
17.3. Stage of Elasto-Plastic Equilibrium of the Material	119
17.4. Deformations of Vibrated Granular Material or of Closely Packed or Undisturbed Soil	121
17.5. Deformations of Compact Material	122
17.6. Deformations of a Cohesive Mass of Granular Material	122
17.7. Stage of Plastic Equilibrium of the Material	123
 18. Calculations for the Design of Sheet Pile Walls and Diaphragm Retaining Walls.	 124
18.1. Sheet Piling	124
18.2. Diaphragm Walls	141
 19. Program for Design by Electronic Computer	 149

20. Determining the Minimum Angle of Internal Friction of a Granular Material	150
20.1. Determination of the Minimum Angle of Internal Friction ϕ_0 of a Granular Material.	151
20.2. Experiments	152
20.3. Settlement of Granular Test Materials	167
20.4. Angles of Internal Friction of Wet Fine Sand	168
20.5. Practical Consequences for Retaining Wall Design	174
20.6. Comparison of the Results Obtained by the Friction Plate Method and the Triaxial Compression Apparatus.	174
20.7. Conclusions.	175
20.8. Important Final Remark	176
21. Appendix	177
Synopsis	211
Errata	211
References	212

2. Introduction

The experiments forming the subject of the present Volume II were carried out with the aid of procedures significantly different from those employed in the experimental work concerned with the measurement of thrust and passive resistance "at rest", as reported in Volume I.

The reader's attention is more particularly directed to the fact that the experiments relating to passive resistance with displacement of the retaining wall (as represented by a diaphragm in the investigations) provide rigorous confirmation of the previously proposed formulas for defining the state of equilibrium at rest of granular materials having a horizontal or an inclined top surface, with or without surcharge.

The information yielded by these researches as a whole thus thoroughly covers the whole range of the subject and provides a complete cross-check of all the formulas.