## ROCK MECHANICS DESIGN IN MINING AND TUNNELING

## Z.T.BIENIAWSKI

Professor of Mineral Engineering and Director Mining and Mineral Resources Research Institute The Pennsylvania State University



A.A.BALKEMA / ROTTERDAM / BOSTON / 1984



## Contents

PREFACE	v
1 INTRODUCTION	1
Rock mechanics applications	1
Sources of information	3
References	4
AUT - STORM CONTRACTOR	
2 HISTORICAL PERSPECTIVE	5
Ancient mining and tunneling	5
Middle Ages	8
Modern times	10
References	22
3 THE DESIGN PROCESS IN ENGINEERING	25
Design stages	27
Ethics and professionalism in design	29
References	30
4 DESIGN APPROACHES FOR EXCAVATIONS IN ROCK	33
Design methods in mining and civil engineering	34
Contracting and project management	45
References	51
5 INPUT PARAMETERS FOR DESIGN	55
Geological site characterization	56
Ground stresses	69
Strength and deformability of rock masses	71
Integral approach to site characterization of rock masses	85
Summary of parameters for input data collection	86
References	92

6 EMPIRICAL METHODS OF DESIGN	97
Classification systems in rock engineering	97
Terzaghi's rock load classification	101
Lauffer-Pacher classification	104
Deere's Rock Quality Designation	104
RSR (Rock Structure Rating) concept	105
Geomechanics Classification (RMR system)	112
Q-system	121
Guide to classification procedures	126
Recent developments	128
References	132
7 OBSERVATIONAL METHODS OF DESIGN	137
Rock monitoring techniques	137
The New Austrian Tunneling Method	152
The convergence-confinement method	154
References	155
8 ANALYTICAL METHODS OF DESIGN	159
Numerical modeling	160
Physical modeling	164
Failure criteria	168
Validation of analytical modeling	174
References	180
References	100
9 INTEGRATED DESIGNS	183
The Strata Control System for German coal mining (System zür	
Gebirgsbeherrschung)	183
Design of mine pillars	187
Comparisons of pillar strength formulae	205
Integrated design procedure	209
References	214
10 GUIDED DESIGN	217
General considerations for support design	218
Roof support design in civil engineering tunneling	219
Roof support design in hard rock (metal) mining	233
Roof support design in coal mining	250
References	267
Legislands of the demokratical control of the demokratical	1420
AUTHOR INDEX	269
SUBJECT INDEX	271
discretion in the supplier of	HARL