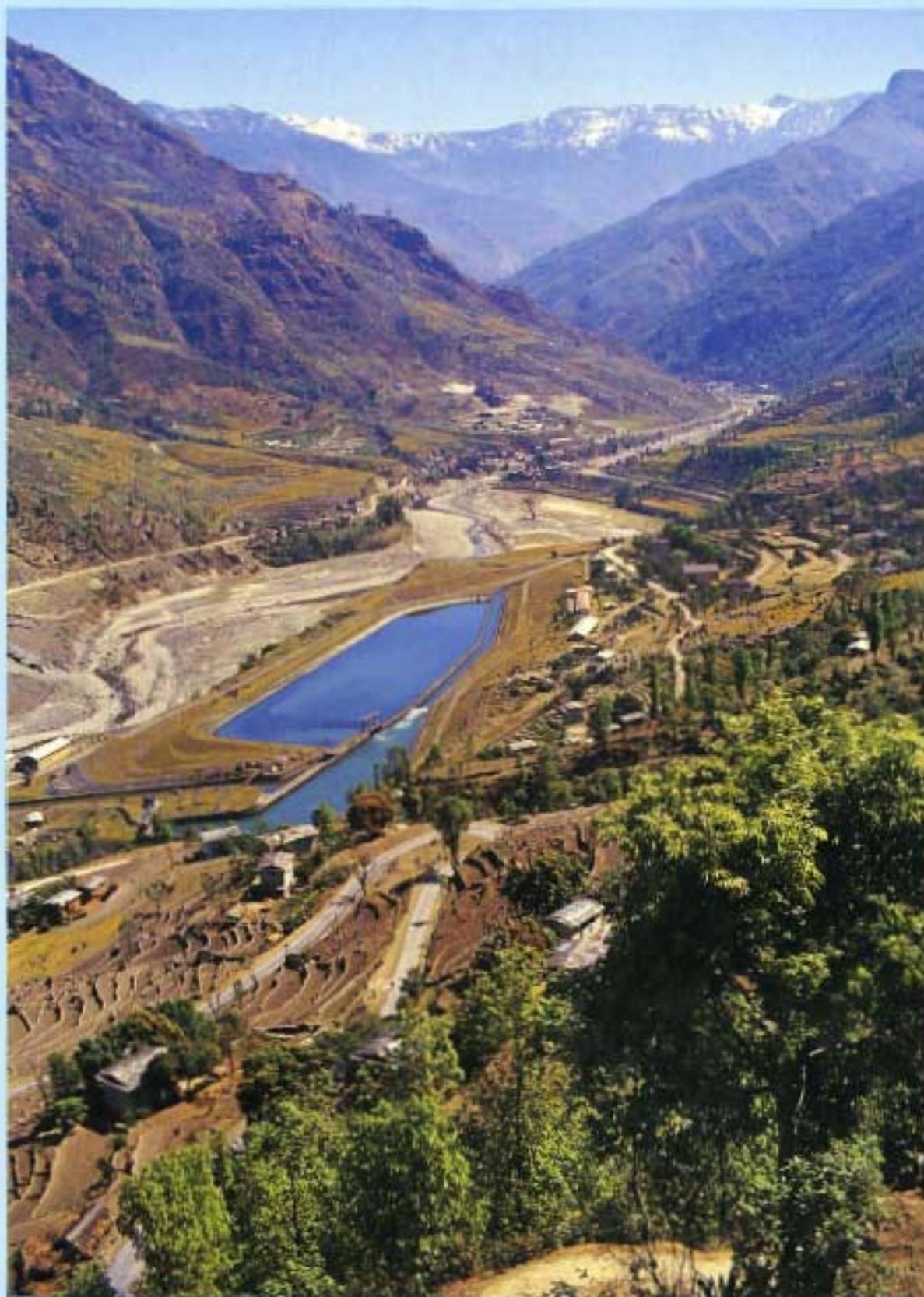


MOUNTAIN RISK ENGINEERING HANDBOOK

APPLICATIONS: Part II



Principal Editors
B. Deoja, M. Dhital, B. Thapa, A. Wagner

Cover Photographs : B. Deoja

Front : Damages to a mountain road
along a river.

Arniko Highway, Nepal, March 1991.

Back : A road blending with the
environment - Lamosangu-Jiri Road.



Mountain Risk Engineering Handbook - Part II
Applications

Principal Editors : **B. Deoja, M. Dhital, B. Thapa, A. Wagner**

Published by
International Centre for Integrated Mountain Development
Kathmandu, Nepal

Copyright © 1991

International Centre for Integrated Mountain Development

All rights reserved

Cover Photographs : B. Deoja
Front : Damages to a mountain road along a river.
Aniko Highway, Nepal, March 1991
Back : A road blending with the environment.
Lamosangu-Jiri Road, Nepal, March 1991.

Citation:

International Centre for Integrated Mountain Development, 1991.

Mountain Risk Engineering Handbook : Part II - Applications

G.P.O. Box 3226, Kathmandu, Nepal

Typesetting : ICIMOD Computer Centre

Please direct all enquiries and comments to:

International Centre for Integrated Mountain Development

G.P.O. Box 3226, Kathmandu, Nepal

Telephone: (977-1) 525313

Telex: 2439 ICIMOD NP

Fax: (977-1) 524509

Cable: ICIMOD, NEPAL

PREFACE

The progressive and effective development of mountain communities through an integrated approach is the principal perspective in ICIMOD's mandate. Infrastructural establishment, therefore, being one of the primary needs for development, has to be carried out, taking into consideration this integrated, holistic perspective. Notwithstanding, experiences indicate that integration of essential modern development technologies with effective and sustainable resource management has not received sufficient attention.

In the Hindu Kush-Himalayan (HKH) Region, failures and washouts of roads, irrigation canals, and power plants have resulted in considerable losses of life and property. In addition, the vulnerability of mountain ecosystems has been exacerbated by the techniques applied in establishing infrastructure. Development with conservation is, therefore, essential.

The impacts of artificial structures and human interventions on mountain slopes can only be understood adequately within the context of a broader-based knowledge and understanding of the inherent properties of the materials constituting the mountains themselves and the dynamics that influence the surface and sub-surface processes and environments. Traditional civil engineering education and practices are not adequate to fulfill this requirement.

Geology, the science of the earth, can help to provide the requisite understanding so that civil engineers will have a clear picture of what can be done to keep a structure in place throughout its expected life. This knowledge, however, is only useful to the engineer provided the time horizon, material, and process characterisation provided by geology are adequately scaled, quantitatively ascertained, and clearly presented to facilitate their direct input into civil engineering analysis and design.

The application of engineering-geological inputs is not new in the case of major projects such as dams, tunnels, and mines, but in the case of linear infrastructure, such as roads and canals, scant attention has been paid to engineering-geological inputs, especially in the developing countries. As the pressure of population increases in the mountains, there will be a need for more roads and canals throughout these areas. The additional impacts caused by their construction are bound to accelerate natural destabilization and processes caused by people will add to the forces of nature. This presents us with a choice, i.e., people as a positive force, friendly to nature, or as a negative force that is hostile to nature.

The devegetation and deforestation associated with infrastructural establishment have created an extremely important role for soil conservation, forestry, and ecology so that establishment of plantations and vegetation within the watershed areas that influence roads has become an integral part of normal engineering practice. Long-term, sustainable protection of mountain slopes influences infrastructural stability and, in this respect, plantations and vegetation are crucial because engineering solutions alone are neither cost-effective nor hospitable to mountain ecosystems.

Infrastructural development is no longer the domain of a single discipline, i.e., civil engineering, and mountain infrastructural engineering cannot be separated from a basic knowledge of the geology, environment, and other related disciplines. The Mountain Risk Engineering (MRE) Programme introduced by ICIMOD is a step forward in the process of the integration of various disciplines in order to induce the establishment of sustainable mountain infrastructural institutions.

This handbook is a synthesis of selected practical experiences and up-to-date literature, and its objective is to provide a working basis for training institutions and practising engineers and geologists involved in the development of infrastructure in mountainous areas, in general, and in the mountainous areas of developing countries, in particular.

The question arises, in the case of developing countries with low per capita income, of the additional costs incurred by MRE approaches. How much room is realistically available in fragile mountain terrains for site selection? how compatible is the concern for resource conservation over the long term with the immediate needs of a subsistence economy? and so on.

A comprehensive response to all of these concerns is outside the scope of this Handbook. Nevertheless, experience has shown that there is ample room for the minimisation of hazards and that the cost of rehabilitating failed infrastructures will easily offset the one or two per cent of additional expenditure needed for proper investigation and analysis. In addition, the benefits accruing from soil loss reduction and reduction in the loss of productive land, caused by hazards incurred by infrastructures designed within a narrow framework, are additional bonuses.

This handbook is a combination, of an earlier draft version and incorporates inputs and comments received from several resource persons and institutions, both in the Region itself and from other parts of the world. For this reason, and because of the limited time period permitted for its completion, the general spelling style has, by and large, had to follow the most common usage prevailing in the case of each term and word. Had we standardised to one of the principal dictionary styles (Websters or Oxford) the document would not have been completed within the time-frame required, given the facilities available. In short, the amount of material to be edited, and the degree of editing prohibited by this, is a fact regretted by the editor.

The complete MRE approach has been used to conduct a feasibility study for, and to design a road project in, Nepal. Obviously, there will be more inputs of this nature in future and the Handbook will need revision from time to time until Mountain Risk Engineering establishes itself as a discipline in its own right and until it is fully institutionalised within the infrastructural agencies of the developing mountain nations. In this respect, an Expert Group Meeting, International Consultative Meeting, Pilot Training, and individual visits from academicians, policy-makers, and donor agencies have served to indicate the sizeable degree of enthusiasm already existing as a result of the establishment of the Mountain Risk Engineering Project.

Thanks are due to all those who helped us to achieve this task; those who inspired ICIMOD and who became inspired by ICIMOD about Mountain Risk Engineering. The mountains, which remain seemingly silent, but nonetheless dynamic, will give more to mountain inhabitants than they will receive provided we handle them with care.

These mountains, seemingly silent but truly dynamic, have a lot to give to the people of the mountains as well as to the people of the plains provided we start to understand and appreciate them. MRE, thus, begins this process.

Birendra Deoja

MRE Project Coordinator

ACKNOWLEDGEMENTS

This handbook on Mountain Risk Engineering (MRE) is the product of the contributions of many people. I am grateful to all of them. In particular, I wish to record my deep appreciation and thanks to Dr. Colin Rosser, the Previous Director, for the initiation of Mountain Risk Engineering (MRE) work at ICIMOD, and Dr. E. F. Tacke, the current Director, for his encouragement and untiring support throughout the work on the completion of MRE Phase I and for initiating MRE Phase II which has resulted in the first full-scale publication of this Handbook.

The generous financial support of the Commission of the European Economic Community (EEC), for Phase I, and the Swiss Development Cooperation (SDC) and German Technical Assistance (GTZ), for Phase II, are gratefully acknowledged. This is indicative of their growing concern for the deteriorating mountain environment and the increasing impoverishment of its inhabitants.

Alexis Wagner of ITECO International, Switzerland, Dr. Mahesh Banskota, Chief Programme Coordinator, Mr. Surendra Shrestha, the Chief Administrator, and Dr. M. Abdullah, the former Head of the Mountain Infrastructure and Technology Division of ICIMOD, assisted in the development of the project proposal and also helped in many ways in the completion of this work. Similarly, N.D. Sharma, Director General of the Department of Roads, HMG, Nepal provided his enthusiastic support and guidance. There were also several institutions that have been supportive throughout the whole period and a few of these are: The Department of Roads, HMG, Nepal; ITECO International, Switzerland; The University of Roorkee, India; The Transport and Road Research Laboratory (TRRL), U.K.; The Public Works' Department, Bhutan; The Ministry of Communication, NWFP, Pakistan; The Chinese Academy of Sciences, Beijing; Tribhuvan University, Kirtipur, Kathmandu; The Department of Mines and Geology, HMG, Nepal; and ITECO-Nepal, Kathmandu.

Professor H. Einstein of the Massachusetts Institute of Technology (MIT), U.S.A., Dr. Robert Schuster, USGS, Professor Tien Wu of Ohio University, and Dr. G. C. Nayak of the University of Roorkee, deserve unlimited thanks for devoting so much of their time and attention to provide valuable comments on the draft of the Manual and for attending the Consultative Meeting in February 1990. Also Dr. Donald H. Gray provided invaluable comments on biotechnical stabilizations.

Cliff Lawrance of TRRL, U.K., and Jane Clark and John Howell of Roughton and Partners, U.K., provided their valuable inputs in the field of geomorphology and biotechnical stabilizations.

The Handbook would never have been completed, within the short period of time given, without the untiring efforts of its team of contributors, Dr. R. Anbalagan, Dr. Dominique Chapellier, Dr. M. Dhital, Tom Heah, K.C. Manandhar, Dr. Tej Partap, Urs Schaffner, Dr. Bhawani Singh, Bhaskar Thapa, and Alexis Wagner.

Uday Tegi, Usha Tamang, Sudas Sharma, Purna Rana, and Rajendra Shah have put in an unlimited number of hours in order to type several versions of the manuscript. They have been supportive, patient, and tireless throughout this whole endeavour.

Greta Rana, the editor of ICIMOD, undertook the task of editing this voluminous manuscript in such a short period of time and made our task easier in preparing this manuscript which is now lucid and readable. Archana Karki, assistant editor, ICIMOD, was of invaluable assistance during the compilation of different sections.

The figures for the handbook have been painstakingly prepared by three excellent draughtsmen, Bipin Ghimire, P.B. Shakya, and S. B. Phainju, and the initial entering of the topic index was carried out by Sujit Thapa and Sarit Rana.

There are many others who have given their support both within and outside ICIMOD and, although they have not been listed here because of paucity of space, they are gratefully and duly acknowledged. Finally, we are grateful to all those authors whose generous contributions have made it possible to bring out this Handbook on Mountain Risk Engineering.

Birendra Deoja

MRE Project Coordinator

CONTRIBUTORS

- | | |
|-------------------|--|
| Dr. R. Anbalagan | Lecturer in Geology, Department of Earth Sciences, University of Roorkee, Roorkee, U.P. India.
(Chapter 24) |
| B. B. Deoja | Project Coordinator, Mountain Risk Engineering Project, International Centre for Integrated Mountain Development (ICIMOD), Jawalakhel, Nepal.
(Chapters 21, 22, 23, 24, 25, and 26) |
| Dr. M. Dhital | Lecturer, Central Department of Geology, Tribhuvan University, Kirtipur, Nepal.
(Chapters 22 and 23) |
| K. C. Manandhar | Consulting Engineer, Sub-Structural Consult, Kathmandu, Nepal.
(Chapter 24) |
| Dr. Bhawani Singh | Professor of Rock Mechanics, Department of Civil Engineering, University of Roorkee, U.P., India.
(Chapter 24) |
| A. Wagner | Consulting Engineering-Geologist, ITECO International, Afoltern a/A Switzerland.
(Chapters 22, 23, and Annex 1) |

FOREWORD

Infrastructural development in the Hindu Kush-Himalayan Region is a formidable task with considerable problems caused by washouts and failures resulting from landslides, erosion, and gullyng. Such problems are, to a significant extent, triggered by faulty planning and designing of mountain infrastructure which also have ramifications on their construction and maintenance. These problems are compounded by mass movements caused by natural processes, deforestation, and other human interventions. They constitute a huge challenge for the building and maintenance of sound physical infrastructure. Therefore, there is an urgent need to develop guidelines for the construction of infrastructure that is ecologically stable and economically viable. It is in this context that the mountain risk engineering programme was started in January 1988 with financial support from the European Economic Community (EEC).

The first draft manual on Training in Mountain Risk Engineering was tested during a nine week pilot training programme from February-April 1989. Twenty participants, mainly engineers and geologists from Bhutan, China, Nepal, and Pakistan, participated in the training sessions. Subsequently the manual was revised and put into folder form for convenient distribution. The preparation of the manual was undertaken by ICIMOD staff in close collaboration with short-term professional inputs from Europe and the Regional countries.

The manual was sent to international experts in this field for their comments. This was followed by the organisation of an International Consultative Meeting on Mountain Risk Engineering in February 1990 in Kathmandu. Some 40 experts, representing government agencies, consultants, donor agencies, and university professors, participated and commented on the content and utility of the manual. There was a general consensus that the MRE Manual was an extremely useful document in the context of providing guidance for sound infrastructural development and that its wider application is urgently needed. It has already been used by the Department of Roads and several foreign consultants in Nepal. As a follow up to the recommendation of the Consultative Meeting, the Swiss Development Cooperation (SDC) and the German Technical Cooperation Agency (GTZ) were approached for funding for the preparation of this Handbook for wider dissemination and for the organisation of an eight week training programme in Kathmandu on Mountain Risk Engineering; and this they have generously supported.

This Handbook is being produced in two parts and will provide useful reference materials to field engineers engaged in building ecologically and economically sound infrastructure in the mountains. It can also provide useful course material for students who are being trained as civil engineers and geologists.

Finally, Mr. Birendra Deoja, Coordinator of this activity deserves special mention, along with his colleagues, who worked extremely hard to bring out this very useful Handbook on Mountain Risk Engineering.

Dr. E. F. Tacke

Director

TABLE OF CONTENTS

	Page
PREFACE	(i)
ACKNOWLEDGEMENTS	(iii)
FOREWORD	(v)
Chapter 21: INTRODUCTION TO PART II	558
21.1 BACKGROUND	558
21.2 ROAD TYPES	560
21.2.1 <i>Minor Roads</i>	560
21.2.2 <i>Medium Roads</i>	560
21.2.3 <i>Major Roads</i>	560
21.2.4 <i>High Standard Roads</i>	560
Chapter 22: PREFEASIBILITY ASSESSMENTS OF MOUNTAIN ROADS	561
22.1 MINOR ROADS	561
22.1.1 <i>Preliminary Survey of Road Alignment</i>	561
22.1.2 <i>Assessment of Quantities and Cost</i>	561
22.1.3 <i>Socioeconomic Assessments</i>	561
22.2 MEDIUM ROADS	563
22.2.1 <i>Background and Summary</i>	563
22.2.2 <i>Staging</i>	563
22.2.3 <i>Hazards and Risks</i>	565
22.2.4 <i>Traffic Levels</i>	578
22.2.5 <i>Geometric Standards</i>	578
22.2.6 <i>Design and Costing</i>	579
22.2.8 <i>Initial Environmental Examination (IEE)</i>	596
22.2.9 <i>Socioeconomic Assessments</i>	597
22.2.10 <i>Selection Process</i>	600
22.3 MAJOR ROADS	600
22.4 HIGH STANDARD ROADS	600
Chapter 23: FEASIBILITY ASSESSMENTS	603
23.1 MINOR ROADS	603
23.2 MEDIUM ROADS	603
23.3 FEASIBILITY STAGE HAZARD ASSESSMENT AND MAPPING	604
23.3.1 <i>Discussion, Literature Search, and Preparatory Work</i>	604
23.3.2 <i>Office Work Prior to Fieldwork</i>	604

	Page	
23.3.3	<i>Field Work Procedures for Engineering Geologists</i>	605
23.3.4	<i>Office Work After the Field</i>	612
23.3.5	<i>Background on Hazard Mapping</i>	618
23.3.6	<i>Digitized Rock Slope Hazard Mapping</i>	632
23.3.7	<i>Digitized Soil Slope Hazard Mapping (Method No 1)</i>	636
23.3.8	<i>Line Hazard Maps</i>	639
23.3.9	<i>The PC Software SHIVA for Rock and Soil Slope Hazard Mapping</i>	642
23.4	MAJOR AND HIGH VOLUME ROADS	642
23.5.4	<i>Feasibility Stage Assessments of Major and High Volume Roads</i>	642
23.5	ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR MEDIUM AND MAJOR ROADS	642
23.5.1	<i>Environmental Impact Assessment (EIA)</i>	643
23.5.2	<i>Resource Parameters and Influence Factors</i>	643
23.5.3	<i>Environmental Problems to and from Roads</i>	644
23.5.3	<i>Guidelines</i>	645
Chapter 24:	DETAILED SURVEY AND DESIGN	648
24.1	INTRODUCTION	648
24.1.1	<i>Detailed Survey</i>	649
24.2	HAZARDS AND RISKS	650
24.2.1	<i>General</i>	650
24.2.2	<i>Detailed Stage Engineering-Geological Studies</i>	650
24.3	ROAD FORMATION DESIGN	653
24.3.1	<i>Problems</i>	653
24.3.2	<i>Guidelines</i>	653
24.4	CUT SLOPE STABILITY AND DESIGN	654
24.4.1	<i>Problems</i>	654
24.5	DRAINAGE	670
24.5.1	<i>Problems</i>	670
24.5.2	<i>Guidelines</i>	671
24.6	RETAINING AND BREAST WALLS	690
24.6.1	<i>Problems</i>	690
24.6.2	<i>Guidelines</i>	696
24.6.3	<i>Semi-Empirical Design of Retaining Walls (Dry Backfill and No Earthquakes)</i>	714
24.6.3(a)	<i>Example of Retaining Wall Design Using Semi-empirical Method</i>	722
24.7	PAVEMENT DESIGN	727
24.7.1	<i>Problems</i>	727
24.7.2	<i>Guidelines</i>	728
24.8	BLASTING DESIGN	732
24.8.1	<i>Explosives</i>	732
24.8.2	<i>Blasting Techniques</i>	732
24.8.3	<i>Chemical Blasting</i>	733
24.9	LANDSLIDE STABILISATION	735
24.9.1	<i>General</i>	735
24.9.2	<i>Specifications for Landslide Drainage</i>	736

	Page
24.10 RIVER TRAINING	740
24.10.1 <i>Background</i>	740
24.10.2 <i>Problems</i>	755
24.10.3 <i>Guidelines</i>	756
Chapter 25: CONSTRUCTION	760
25.1 INTRODUCTION	760
25.2 PROBLEMS	760
25.2.1 <i>Project Cost Estimate</i>	760
25.2.2 <i>Construction Cost Estimate</i>	761
25.2.3 <i>Construction Time</i>	761
25.2.4 <i>Construction Planning, Administration, and Management</i>	761
25.2.5 <i>Environmental Considerations</i>	761
25.3 GUIDELINES	762
25.4 CONSTRUCTION CONTRACTING METHODS	763
25.4.1 <i>General Contract Method</i>	763
25.4.2 <i>Separate Contracts or Piece Work Contract Method</i>	763
25.4.3 <i>Design-Construct Method or Turnkey Method</i>	763
25.4.4 <i>Force Account Method</i>	763
25.4.5 <i>Professional Construction Management Method</i>	764
25.5 CONTRACT TYPES	764
25.5.1 <i>Unit Price Contract</i>	765
25.6 SPECIFICATIONS	765
25.6.1 <i>Design Specification</i>	766
25.6.2 <i>Performance Specification</i>	766
25.6.3 <i>Performance and Design Specification</i>	766
25.6.4 <i>Reference Specification</i>	766
25.6.5 <i>Standard Specification</i>	766
25.7 ENVIRONMENTALLY CONTROLLED CONSTRUCTION PRACTICES	767
25.7.1 <i>Construction Equipment</i>	767
25.7.2 <i>Side-Casting</i>	767
25.7.3 <i>Quarrying</i>	767
25.7.4 <i>Blasting</i>	767
25.7.5 <i>Construction Sequence</i>	768
25.7.6 <i>Use of Emulsion for Pavement Surface</i>	769
Chapter 26: MAINTENANCE	770
26.1 PROBLEMS	770
26.2 GUIDELINES	770
26.3 MAINTENANCE TYPES	771
26.3.1 <i>Routine Maintenance</i>	771
26.3.2 <i>Recurrent Maintenance</i>	771

	Page	
26.3.3	<i>Periodic Maintenance</i>	772
26.3.4	<i>Emergency/Urgent Maintenance</i>	772
26.3.5	<i>Rehabilitation/Reconstruction</i>	773
26.4	DISTRESSES IN FLEXIBLE PAVEMENTS	773
26.4.1	<i>Name of Distress: Alligator or Fatigue Cracking Description</i>	773
26.4.2	<i>Name of Distress: Bleeding</i>	774
26.4.3	<i>Name of Distress: Block Cracking</i>	774
26.4.4	<i>Name of Distress: Corrugation</i>	775
26.4.5	<i>Name of Distress: Depression</i>	776
26.4.6	<i>Name of Distress: Joint Reflection Cracking from PCC Slab</i>	776
26.4.7	<i>Name of Distress: Lane/Shoulder Drop-off or Heave</i>	777
26.4.8	<i>Name of Distress: Lane/Shoulder Joint Separation</i>	778
26.4.9	<i>Name of Distress: Longitudinal and Transverse Cracking (Non-PCC Slab Joint Reflective)</i>	778
26.4.10	<i>Name of Distress: Patch Deterioration</i>	779
26.4.11	<i>Name of Distress: Polished Aggregate</i>	780
26.4.12	<i>Name of Distress: Potholes</i>	780
26.4.13	<i>Name of Distress: Pumping and Water Bleeding</i>	781
26.4.14	<i>Name of Distress: Ravelling and Weathering</i>	781
26.4.15	<i>Name of Distress: Rutting</i>	782
26.4.16	<i>Name of Distress: Slippage Cracking</i>	782
26.4.17	<i>Name of Distress: Swell</i>	783
26.5	PAVEMENT EVALUATION AND RATING FOR PAVEMENT MANAGEMENT AND TENTATIVE DECISIONS ON PAVEMENT REHABILITATION	783
26.5.1	<i>Pavement Roughness</i>	784
26.5.2	<i>Pavement Condition Rating</i>	785
26.6	PAVEMENT EVALUATION FOR REHABILITATION DECISIONS	785
26.6.1	<i>Surface Deflection</i>	785
26.6.2	<i>Precautions for Interpretation of Pavement Deflection Data</i>	792
26.6.3	<i>Skid Resistance</i>	792
26.6.4	<i>Priority Ranking of Rehabilitation Alternatives</i>	793
26.7	PRIORITY RANKING FOR PAVEMENT MAINTENANCE BUDGETING AT NETWORK LEVEL	797
26.8	HILL ROAD MAINTENANCE MANAGEMENT SYSTEM	797
ANNEX 1		807
ANNEX 2		835
ANNEX 3		837
ANNEX 4		839
REFERENCES		841
INDEX		851

PART II

of the

MOUNTAIN RISK ENGINEERING HANDBOOK

dealing with

Applications