

A rockslide in October 2009 closed Interstate 40 in North Carolina for nearly six months.

Photo: North Carolina DOT

ROCKFALL

CHARACTERIZATION AND CONTROL

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Rockfall: *Characterization and Control*, a five-year effort of a Transportation Research Board (TRB) task force, examines all aspects of rockfall characterization, analysis, and mitigation. Authored by a dozen internationally recognized rockfall experts, the book's 18 chapters address the state of knowledge about rockfall, the available procedures for rockfall investigation, and the regulatory and economic climates affecting rockfall investigations and corrective actions.

The 650-plus page book was directed by the same editorial team that produced TRB Special Report 247, *Landslides: Analysis and Mitigation*, published to acclaim in 1996 and still in demand. *Rockfall: Characterization and Control* provides critically important information about methods of analyzing rockfall phenomena and about selecting rockfall mitigation options that have emerged in the years since the publication of Special Report 247.

Hazards and Countermeasures

In the past decade or so, rockfall has gained recognition as a significant socioeconomic issue—rockfalls have had destructive effects on transportation infrastructure and operations worldwide. With growing populations and an associated increase in the demands for energy, mining, forestry, agricultural products, and recreational activities, communities and civil infrastructure have expanded into marginal lands; in many of these areas, evaluations of the potential rockfall hazards and appropriate countermeasures are difficult. In addition, many transportation agencies are experiencing increased costs for maintenance and operations, as rock exposures constructed 30 to 40 years ago are degrading, posing rockfall hazards and triggering rockfall events.

The economic and public-safety consequences of rockfall-induced traffic disruptions, accidents, and injuries have spurred improvements in procedures



PHOTO: COLORADO DOT

Large rockfall blocks severely damaged a bridge deck on Interstate 70 in Glenwood Canyon, Colorado, closing the highway for four days and leading to extended travel restrictions.

for rockfall evaluation and mitigation and the adoption of new technologies for the evaluation and quantification of rockfall hazards and for protections from rockfalls. Information about these technologies, however, has not been widely available; the new TRB volume remedies a critical lack.

Topic Areas

The 18 chapters of *Rockfall: Characterization and Control* address four main topics. The first two topics comprise 60 percent of the book and describe rockfall hazard and the methods of rockfall analysis and investigation. The last two topical sections present information about mitigation options.

1. Recognition of Rockfall Hazard (five chapters) provides an overview of rockfall phenomena, including an historical overview, rockfall definitions and research, and examples of significant rockfall events. A summary of rockfall failure types and mechanisms is followed by a chapter describing the Rockfall Hazard Rating System (RHRS), developed in Oregon and supported by the Federal Highway Administration since 1990.

More than 25 transportation agencies in North America, as well as many jurisdictions throughout the world, have adopted the RHRS. Several agencies have modified the system to reflect specific topographic, climatic, or geological characteristics or to expand the evaluation of mitigation alternatives and of the economic impacts of rockfall events.

Typical field setup of terrestrial LiDAR unit scanning a rock slope along a road in Catalan Province, Spain; umbrella keeps scanner cool and makes digital display easier to read.



An additional chapter provides details about eight systems that have made working adjustments to the original RHRS. The concluding chapter of the first section offers an in-depth discussion of alternative approaches to the assessment, evaluation, and quantification of rockfall hazards and risks and to the selection of rockfall mitigation measures.

2. Fundamentals of Rockfall Analysis and Investigation (five chapters) defines the rockfall investigation process and its organization, with an emphasis on gathering the appropriate descriptive data during field investigations. New technologies are presented for measuring and monitoring rockfalls, including systems that apply photogrammetry, LiDAR, radar, and Geographic Positioning System-based surveying. The fundamentals of Newtonian mechanics and their use in describing motions of falling, bouncing, and rolling rock blocks are reviewed.

The next chapter discusses and compares approaches to the quantitative modeling and prediction of rockfall. These include empirical models based on field observations to establish hazard zones, computer-based approaches incorporating the empirical relationships, 2-D simulation models that provide data on energy and bounce height for the design of mitigation measures, and recently developed 3-D models that allow a full spatial evaluation of rockfall events. The final chapter of the section describes in detail how to conduct rockfall field tests.

3. Rockfall Mitigation (six chapters) begins with an overview of mitigation options, including engi-



PHOTO: CATRAMS

Earthen berm constructed from on-site materials is a low-cost and effective protection measure capable of withstanding moderate- to high-energy impacts.



Small rockfall debris pile on tracks near Lytton, British Columbia, caused a train derailment in January 2007.

WWW.ARIZONAVALS.COM/ICR-DETRAILMENT.HTML

neered versus nonengineered solutions, as well as discussions of criteria for selecting an option. The five chapters that follow examine the major mitigation options in detail: avoidance of rockfall areas, stabilization of rockfall, protections, flexible rockfall fences, and drapery systems.

4. Rockfall Maintenance and Management Programs (two chapters) explores the role of maintenance and monitoring systems and rockfall management programs. Appropriately designed maintenance or monitoring activities may significantly reduce the risk associated with rockfall and can improve public safety. Several state departments of transportation (DOTs), notably Washington and Tennessee, have implemented rockfall management programs. The final chapter discusses the importance of rockfall management programs and their integration into broader asset management approaches to achieve significant cost savings.

The book also contains two appendices: the first includes stereographic projections for structural analysis; and the second provides an overview of the contents of the DVD accompanying the book.

Rockfall Videos

The DVD provides valuable supplemental information to the text. The disk contains 29 short video clips of rockfall field tests, illustrating rockfall impact energies and testing procedures, and four longer video presentations. The longer videos include the historic 1963 film of the rockfall testing procedures conducted in Washington State by pioneering researcher Arthur Ritchie; field tests conducted by Caltrans in 1990 to evaluate rockfall restraining nets; field tests conducted for Oregon DOT in conjunction with the 2001 rockfall catchment design guide; and rock-slope scaling techniques recorded by Colorado DOT.

In addition, the DVD holds digital copies of all the book illustrations, including color versions of most of the photographs and technical drawings.

Definitive Resource

Although the focus of *Rockfall: Characterization and Control* is on rockfall events along transportation facilities, most of the discussions and examples apply to any situation that requires rockfall characterization and control. The factors of geology, topography, and climate that interact to cause rockfalls are the same; the same methods apply for evaluating rockfall hazards; and the methods for preventing or correcting rockfall hazards—within economic limits—remain largely independent of nearby land uses. As a result, anyone involved in the evaluation of rockfall hazards will find this volume useful.

The text addresses a diverse audience, including

- ◆ Geologists and engineers responsible for rockfall investigations,
- ◆ Students in geoscience and geotechnical fields with an interest in rockfall, and
- ◆ Researchers who need a definitive source for rockfall investigation and mitigation procedures.

Many students and researchers seek comprehensive references to the literature and discussions of case studies, state-of-the-art techniques, and research directions. Accordingly, the authors have identified suitable literature citations and have provided discussions of recent developments.



Rockfall: Characterization and Control, 658

pages, plus DVD with video clips of rockfalls and field tests, can be ordered at www.TRB.org/Rockfall; hardcover edition (ISBN 978-0-309-22306-5), \$110; softcover edition, ISBN 978-0-309-22312-6, \$100; or contact TRBSales@nas.edu or visit TRB's online bookstore: <http://books.trbbookstore.org/>.

PHOTO: WASHINGTON STATE DOT



Use of movable rockfall barriers to provide protection for traffic when the roadway was reduced from four to two lanes following a large rockfall on Interstate 90 near Snoqualmie Pass in the Cascade Mountains, Washington. Barrier consists of a proprietary rockfall fence mounted to specially fabricated, interconnected steel plates that are easily secured to pavement and provide full design capacity for the fence to absorb rockfall impacts.