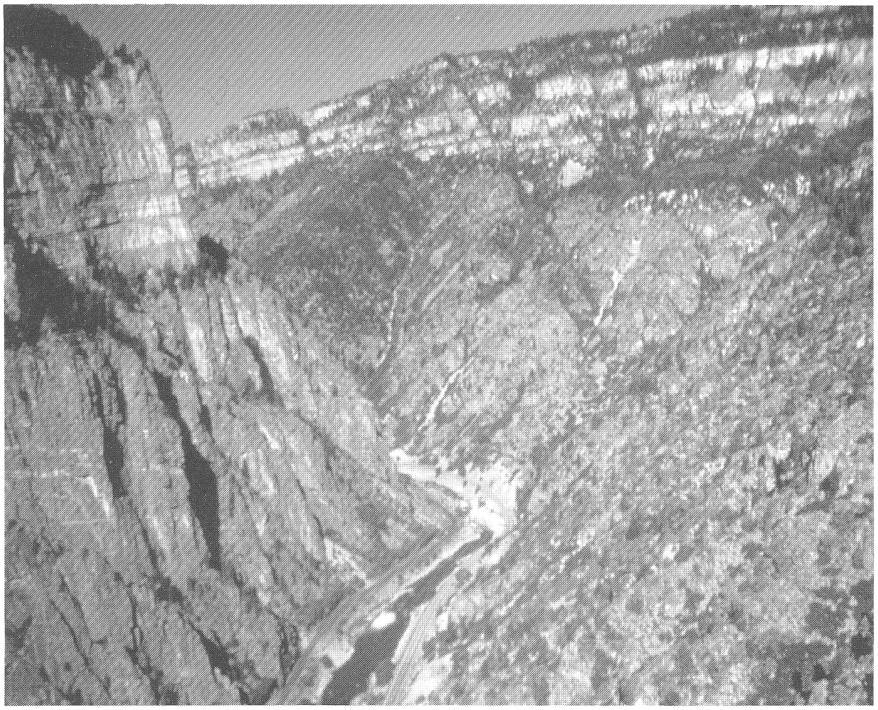
RESEARCH PAYS OFF

Colorado Rockfall Studies



CDOH

Glenwood Canyon Project.

Problem

Rockfalls are a constant danger to motorists and to highway facilities in mountainous terrain. Measures taken to minimize potentially catastrophic rockfalls have ranged from simply posting warning signs to constructing elaborate structural solutions. The effectiveness of these solutions varies. To improve remediation and preventive techniques for existing highways and for new highway construction, rockfall behavior must be better understood.

The construction of I-70 through Glenwood Canyon, Colorado, highlighted the problem and was ideal for conducting rockfall research. The 13 miles of I-70 under construction run through the bottom of a narrow river gorge, with walls of rock reaching at least 2,000 feet above the roadway.

Rocks falling from steep slopes, natural cliffs, or rock cuts can be free-falling, bouncing, or rolling, or can fall in some combination of these ways. The velocities and bounce heights of falling rock must be estimated to design effective protective measures. Geologists with the Colorado Department of Highways (CDOH) found that these estimates could be determined by computer simulations. CDOH, in cooperation with the Federal Highway Administration, provided funds to develop a simulation program. Field testing and calibration studies were part of the development process.

Solution

The Colorado Rockfall Simulation Program (CRSP), developed with the help of the Colorado School of Mines, can be used to predict rockfall bounce height and velocities. Input to CRSP includes data on slope profile, roughness of the slope, frictional and

elastic properties of slope materials, and the size, shape, and initial location of rocks. CRSP predicts the behavior of a rock at any point on the slope profile. Predictions include maximum and average bounce heights and velocities and maximum total kinetic energy.

CDOH conducted field tests on rockfall mitigation designs and collected data for verification and calibration of CRSP on a 300-foot high hillside near Rifle, Colorado. Some tests were videotaped as reference tools to modify and verify CRSP.

Application

CRSP is part of a comprehensive rockfall control program being used in the Glenwood Canyon project. Simulations determine the severity of the rockfall hazard and help develop criteria for designing mitigation measures. An unexpected benefit resulting from this powerful analytical tool included the development of three new, relatively low-cost rockfall mitigation devices.

The first device involved the construction of attenuators, using tires or other durable materials, suspended from heavy cables that are anchored across narrow draws or chutes. Rolling and bounding rocks strike the attenuator, and significant decreases in velocity and kinetic energy result. A designer can use CRSP to select attenuator lengths and optimum locations on a slope to prevent the rocks from reaching a critical structure or feature. The average cost of materials and installation of three attenuators, each about 120-feet long, was $200 per linear foot, for a total cost of $72,000.

The second device is a two-sided geosynthetic or gabion wall, which provides a vertical impact barrier to oncoming rocks. These space-efficient impact barriers, with a cross-sectional width of between 5 and 8 feet, have been successfully field tested and plans to install them are under consideration. A preliminary estimate of material and installation costs is $150 per linear foot. This cost is relatively low considering the massive energies these barriers can absorb.

Both the attenuators and the barriers can survive encounters with very large rocks. The cost of materials and installation for other currently available proprietary devices, which can absorb large energies, vary from $200 to $600 per linear foot, according to a recent bid history from the New Mexico Department of Transportation.

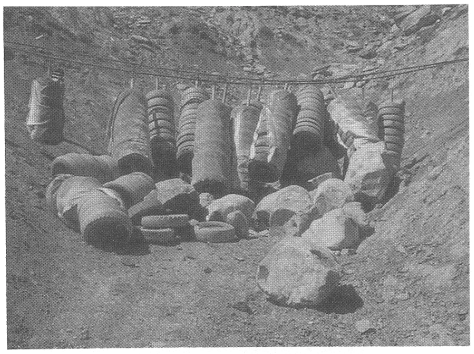
In many areas most rocks causing problems have a diameter of 2 feet or less. These rocks are capable of generating typical kinetic energies of up to 40,000 foot-pounds as compared with 100,000 foot-pounds or more generated by larger rocks. CDOH has developed and is patenting a low-cost fence that is capable of mitigating rockfalls involving these smaller rocks, the Colorado Flex-Post Rockfall Fence. A 600-linear-foot fence has been installed by CDOH; the cost of materials and installation was $65 per linear foot for a total cost of $39,000. CDOH has plans for constructing segments totaling more than a mile of the Colorado Flex-Post Rockfall Fence in Glenwood Canyon and will use these fences on other mountain highways in the future.

Benefits

CRSP can analyze rockfalls and aid in the design of rockfall mitigation measures. The three new, relatively low-cost devices have already produced savings and have the potential for producing even more savings. Use of mitigation measures developed with CRSP has enhanced the safety of motorists and the integrity of highway facilities in Colorado. CRSP has also proven critical to communications among geologists, managers, owners, landscapers, and others--a function that may prove most beneficial of all.

For more information, contact Robert K. Barrett, Senior Engineering Geologist, Colorado Department of Highways, P.O. Box 2107, Grand Junction, Colorado 81502 (telephone 303-248-7231).

Suggestions for "Research Pays Off" topics are welcome. Contact Crawford F. Jencks, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 (telephone 202-334-2379).



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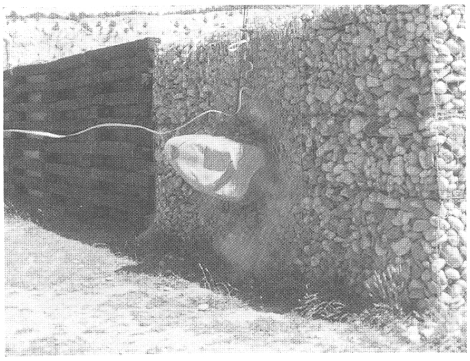

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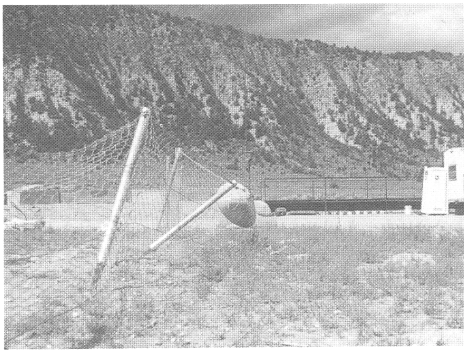

CDOH

(c)

Rockfall mitigation devices (a) attenuation device constructed of tires and suspended from cables. (b) testing of gabion wall. (c) Colorado Flex-Post Rockfall Fence.