Evaluation of Pocket-type Rock Net by Full Scale Tests

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Summary

This research involved conducting tests to confirm the performance of the energy absorbers, as well as full-scale tests of the pocket-type rockfall protection nets ("pocket-type rock net" below), and evaluating pocket-type rock nets equipped with energy absorbers. The results demonstrated that pocket-type rock nets equipped with energy absorbers are able to absorb an increased amount of energy, and reduce the force acting on the wire cables and anchors connected to the energy absorbers.

Keywords: rockfall; rockfall protection net; pocket type rock net; energy absorbers; full scale test.

1. Introduction

Rockfall protection fences and pocket-type rock nets are economical and easy to construct because they use lightweight materials, such as nets. On the other hand, they can only handle 50-200 kJ of energy resulting from rockfall, which restricts the locations where they can be used. If their ability to handle more energy could be increased, they could be used in more locations. This research involved conducting performance tests of energy absorbers, and drop-weight impact tests using a full-scale model—of which there few examples in Japan—with the objective of evaluating the performance of pocket-type rock nets equipped with energy absorbers.

2. Full-scale testing of pockt-type rock net

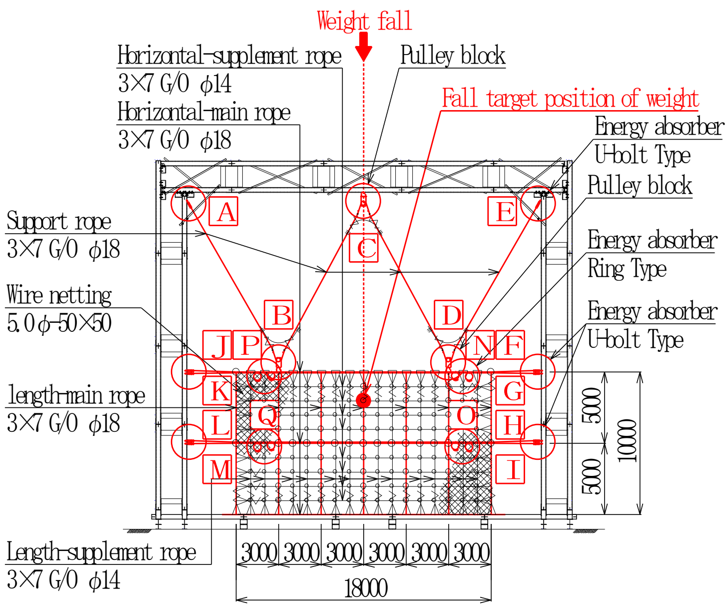

Fig. 1: Front elevation of sample pocket-type rock net

2.1 Testing procedure for pocket-type rock net

Figure 1 shows a front view of the pocket-type rock net in the full-scale test. The shape and dimensions of the test piece used in the test were as follows: The height of the net was 10 meters, the width of the net was 18 meters, and the distance between locations B and C (the locations of struts in actual structures) was 12 meters. The basic structure involved setting up pulleys in locations B, C and D and counterweights to smoothly move the support cable during rockfall impact, in a way that the overall structure disperses and absorbs the force of impact of the rockfall. For the energy absorbers, either u-bolt type or ring type devices were installed in locations B, C

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and D. In order to confirm the difference between using and not using energy absorbers, we conducted the tests using a standard structure without energy absorbers installed, and a high-energy-absorption structure with energy absorbers installed. A total of six tests were conducted with the energy absorbers installed and not installed by varying the impact energy of the weights. The items measured were drop-weight acceleration, the tension of the horizontal cables and support cables, the distance that the wire cable slipped when the energy absorbers were installed, the deformation of the test piece, and the displacement of the test piece.

2.2 Test results and discussion

Table 1: Test programs and observations of sample rockfall protection nets

Test No.	Type of Structure	Type of Energy absorber	Drop weight M [kg]	Fall height H [m]	Collision energy E_w [kJ]	Maximum acceleration of weight α_{max} [m/s^2]	Collision speed Theory ($\sqrt{2gH}$) V_t [m/s]	Collision speed Test ($\iint \alpha dtdt$) V_a [m/s]	Max. tension of wire cable Tmax [kN] (Position)
1	Standard type	Uninstallation	1700	6.0	100.0	97.5	10.84	11.69	112.1 (I)
2				8.0	133.4	100.1	12.52	12.98	152.4 (I)
3	High-energy absorption type	Ring type	2500	7.0	171.6	32.0	11.71	12.81	44.6 (I)
4				10.0	245.2	53.1	14.00	14.49	53.0 (I)
5		Ring type & U-bolt type		15.0	367.7	----	17.15	----	59.9 (D)
6				20.0	490.3	69.7	19.80	19.56	58.9 (D)

Table 2a: Cable slippage in energy absorber (ref. Figure 1)

Test No.	Slippage of wire cable [mm] at Energy absorber (Ring type of N-1 to Q-2)									Slippage of wire cable [mm] at Energy absorber :(U-bolt type of A to M)										
	N-1	N-2	O-1	O-2	P-1	P-2	Q-1	Q-2	Σ_R	A	E	F	G	H	I	J	K	L	M	Σ_U
3	105	110	100	80	470	460	320	350	1995	-	-	-	-	-	-	-	-	-	-	-
4	195	210	200	210	830	815	890	730	4080	-	-	-	-	-	-	-	-	-	-	-
5	340	170	220	220	85	185	905	710	2835	0	1180	0	0	0	0	940	810	0	0	2930
6	400	360	340	330	210	250	540	340	2770	0	0	0	0	0	0	1120	1080	195	450	2845

Table 2b: Absorbed energy by energy absorbers

Test No.	Absorbed energy E_f [kJ]		
	$\Sigma_R \times 28.0$*	$\Sigma_U \times 30.0$*	E_f (E_f/E_w*)
3	55.9	-	55.9 (32.6%)
4	114.2	-	114.2 (46.6%)
5	79.4	87.9	167.3 (45.5%)
6	77.6	85.4	163.0 (33.2%)

28.0* and 30.0*: Average tension estimated in pre-test
E_w* : Collision energy shown in Table 1

An overview of the test results for all of the tests is shown in Table 1. Tests No. 1 and No. 2 were standard tests with no energy absorbers installed, and tests No. 3 and on were tests of the high-energy-absorption structure with energy absorbers installed. Table 2a shows the distance the wire cable slipped and Table and 2b shows the energy absorbed by the energy absorbers, which was calculated by multiplying the distance the wire cable slipped by the mean tension of the energy absorbers.

3. Conclusions

1) By using energy absorbers in the pocket-type rock net it was possible to reduce the tension acting on the cables, mitigating the impact on the frame. As a result, when used in an actual structure, the forces acting on wire cables and cables fitted with anchors can be reduced, and stability and economy can be improved. **2)** Within the range of impact energy conveyed in the tests, the tension in wire cables in cases in which energy absorbers were installed was 60 kN or less, and it had almost no correlation with the size of the impact energy of the weight, but depends on the tension of the energy absorbing device. **3)** Based on an analysis of high-speed camera images, the whole structure absorbed about 40-50% of the impact energy. In the tests, the residual energy was zero when the drop-weight hit the ground, but energy of rockfall in actual structures is absorbed due to friction with the wire netting and slope as the rockfall is guided downward. **4)** It appears possible to account for the energy absorption of the horizontal supplementary cables in the theoretical calculations using the differences between the results of analyzing the high-speed camera images and the results of the theoretical calculations.