Evaluation of Hybrid Rockfall Barrier/Drape System Initial Report Experimental Features

January 2011

Report 2011- 1
Reporting on Work Plan 2008-1

State of Vermont
Agency of Transportation
Materials and Research Section

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Date: 3/17/2011

1. Report No. 2011-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Evaluation of Hybrid Rockfall Barrier/Drape System Intiial Report**		5. Report Date January, 2011
		6. Performing Organization Code
7. Author(s) Thomas D. Eliassen, P.G.		8. Performing Organization Report No. 2011- 1
9. Performing Organization Name and Address Vermont Agency of Transportation Materials and Research Section 1 National Life Drive Montpelier, VT 05633		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration Division Office Federal Building Montpelier, VT 05602		13. Type of Report and Period Covered Initial (4/2010-1/2011)
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

An evaluation of the constructability and performance of a hybrid rockfall barrier/drape fence (system) was conducted. An outline of the components making up the system, the sequence and methods for installation and observations of the performance of the system is presented. It appears that the hybrid system is performing as designed with no detrimental impacts to the system having been observed to date. A rating of very good was assigned for performance. Monitoring the effectiveness and maintenance of the system will continue as future rockfall occurs and the system ages.

17. Key Words	18. Distribution Statement
Rockfall, Rockfall Fence, Rockfall Attenuator, Hybrid Rockfall Barrier Drape System	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. Pages	22. Price
Unclassified	Unclassified	9	

TABLE OF CONTENTS

1.0 INTRODUCTION

This experimental features report presents an evaluation of the construction and performance of a hybrid rockfall barrier/drape fence which was installed in the fall of 2009 on a rock slope at I-91 southbound, mile marker 89.50 in Fairlee, Vermont (VTrans Hartford/Newbury IM 091-2(72) project). Rockfall fences have been in use since the 1980s in the United States. VTrans had installed a medium duty rockfall fence in 1996 alongside US-5 in the town of Fairlee, Vermont. Advancements in fence design have led to a "hybrid" design that can be used in applications where falling rock is allowed to impact a fence and attenuate rockfall forces. This is accomplished by attaching a "tail" to a traditional rockfall fence that allows rock to exit the system at low velocities and ideally finish it's trajectory in the catchment ditch at the base of a slope. Figure 1 shows the hybrid system as installed.

Figure 1 Photograph of Hybrid Barrier/Drape Installation, I-91, Fairlee, Vermont.

The hybrid rockfall barrier/drape fence (referred to as the "system" for the remainder of this report) was designed to provide rockfall protection should rocks travel down the slope towards the roadway. Rockfall fence systems are designed and manufactured by a small handful of firms and as a result, these systems tend to be proprietary. The evaluation of the effectiveness of a system is dependent upon rockfall occurrences that essentially cannot be predicted with accuracy. Therefore, it was determined to prepare an initial report with the information gathered to date and, if when necessary, additional reports as future rockfalls occur and the system ages.

2.0 BACKGROUND

The rock slope where this hybrid system was installed is approximately 750 feet long by about 150 feet in height. Parts of the slope had been cut at 4V:1H when the roadway was constructed (about 1971) and parts of the slope are natural. In the area of the hybrid system installation (northern portion of the slope), the slope consists of a 45° tallus incline from the roadway to about 100 feet up-slope. Near vertical cliffs are present in the upper 50 feet of the slope. The rock type here is phyllite with inter-bedded meta-limestone. The foliation of the rock is quite contorted and has resulted in numerous large rockfalls in this area.

In 1997, as part of design studies for rockfall mitigation along a portion of I-91 (VTrans project - Hartford/Newbury IM 091-2(72)), the geotechnical consultant performing those studies (Golder Associates) observed individual rocks in the median area opposite the subject rock cut. It was apparent that rockfalls were occurring from the high bluffs (120-feet above the roadway) at mile marker 85.50 and developed enough velocity that they ended up rolling across the roadway. Golder recommended scaling of loose rock on this slope and the installation of a rockfall catchment fence within the northern part of the slope.

3.0 DESIGN

Golder Associates evaluated the probability of rockfall in this area to reach the roadway and determined design parameters using rockfall software developed by the Colorado Department of Transportaition[1]. Based on the results of that analysis, Golder estimated that a rock fence fifteen feet in height and able to withstand 2,000 kilojoules (kJ) of force would be required. Golder originally recommended the installation of a traditional rockfall catchment fence to be placed in the ditch area. VTrans was concerned about placing a rockfall fence within the 30-foot clear zone the Agency strives to maintain. After further investigations by Golder and VTrans, it was determined that a hybrid rockfall barrier/drape system could be placed part way up the slope, thereby eliminating structures within the clear zone.

As design progressed, a number of alternatives for the design and location of the system were considered. The placement of the system would need to meet the following criteria:

- The height should be sufficient to catch any of the bouncing rock blocks which may occur,
- The lateral extent needs to be enough to catch rocks originating from several locations along the high portions of the slope,
- The "tail" length needs to be long enough to allow the dissipation of energy, yet allow rocks to pass beneath it and fall safely into the ditch,
- The system energy capacity should be such that rocks representing the maximum expected size that may fall would be effectively contained.

[1] *1998, Report on Rock Slope Hazard Assessment and Treatment Options, Vermont Interstate Safety, Hartford-Newbury IM IR 091-2(6) report by DuBois & King, Inc. and Golder Associates Inc.*

It was determined to place the system approximately 50 to 100 feet up-slope from the roadway. An aerial photograph showing an outline of the system on the slope and elevation contours is presented as Figure 2. Figures 3 and 4 shows the layout of the hybrid system and details of the system components.

Figure 2 Location of Hybrid System Superimposed on Slope.

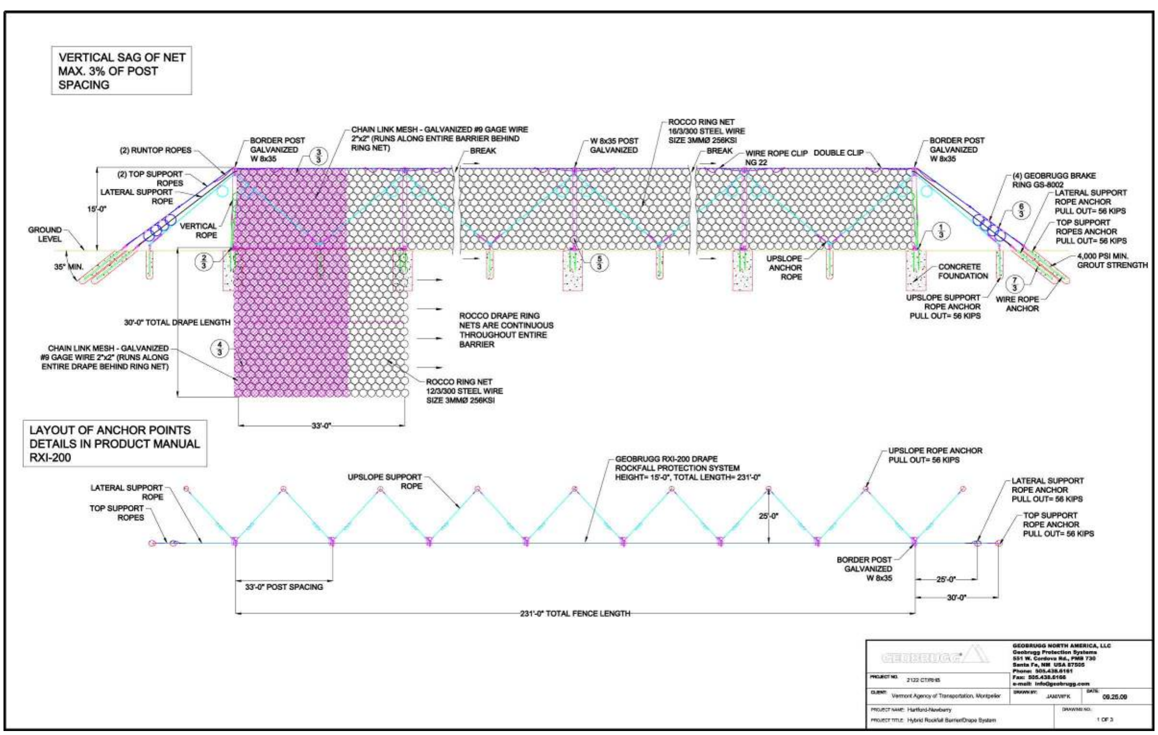

Figure 3 Plan Layout of Hybrid System.

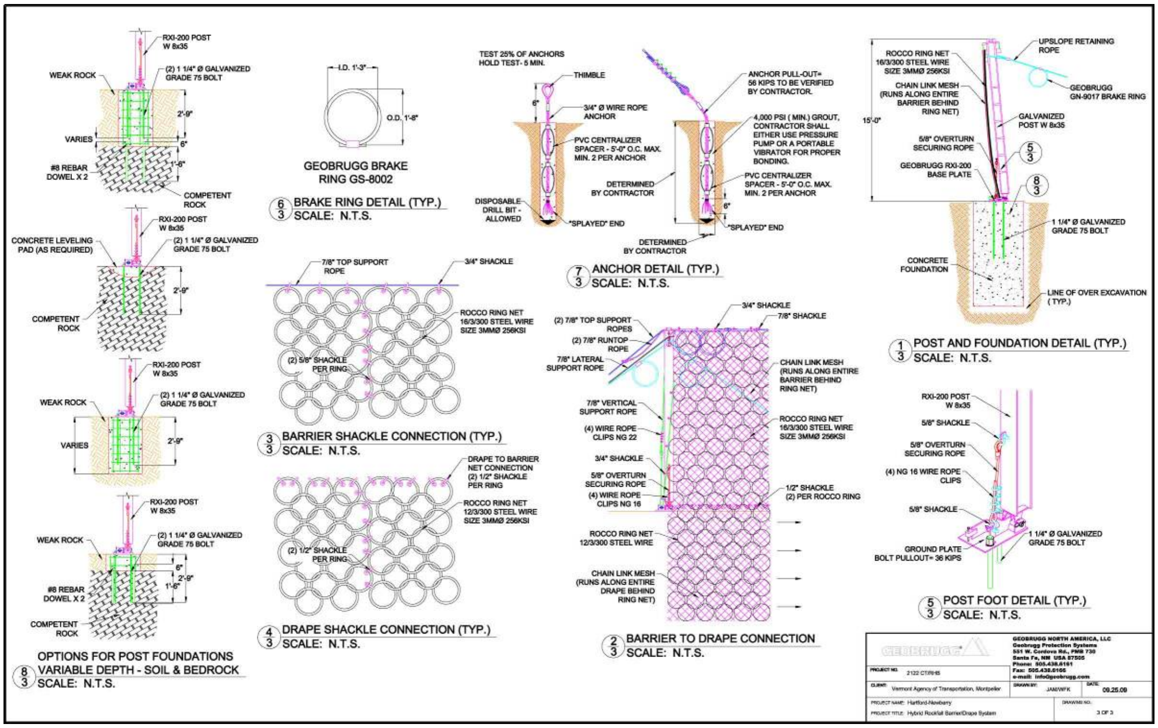

Figure 4 Detail Sheet showing Hybrid System Components.

The contractor for the VTrans Hartford/Newbury IM 091-2(72) project was J.A. McDonald Inc. of Lyndon Center, Vermont. Installation of the hybrid system was subcontracted and performed by Midwest Rockfall, Inc. of Henderson, Colorado. Based on criteria contained in the project special provisions, the contractor selected a hybrid system designed and manufactured by Geobrugg. The system consists of a 15 foot high RXI-200 Rockfall fence with a 30 foot long ring net drape. Components included HEB Type steel posts (hinged), steel base plates, support and retaining steel ropes, spiral rope anchors and breaking elements, steel shackles and poured concrete support foundations. The cost to the Agency for this system was $395.00 per linear foot of the fence portion of the system and $9.00 per square foot of drape. The fence measured 231 feet in length and the drape measured 9,440 square feet. This brought the total expenditure for the system to $176,205.00.

Hybrid rockfall systems are designed to catch falling rock while letting large rocks pass through (at reduced velocities) and accumulate at the toe of the slope. The steel posts and base plates provide a skeletal structure for the draping of netting. The steel ropes provide a means of attaching the netting and the breaking elements allow energy to dissipate without shocking the system. As an added support, steel ropes from the top of the posts are anchored into the slope uphill of the framework. The series of photos shows the fence components as delivered to the project site.

Figure 6 Ring Net Panels.

Figure 5 Support Cables, Breaking Elements and Rope Anchor Cables.

Figure 7 Steel Posts.

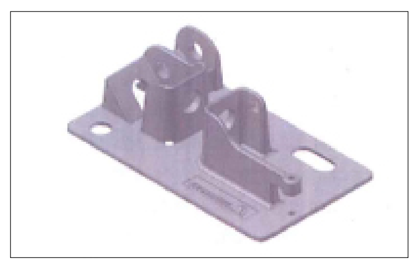

Figure 8 Steel Post Base Bracket.

Figure 9 Close-up of Breaking Element.

Figure 10 Close-up of the Top of Steel Post.

4.0 CONSTRUCTION

The system was constructed during the fall construction season of 2009. Initial plans were to scale loose rock above the planned location of the before installation of the system, however the contractor was concerned that scaled rock would travel across the roadway and pose a threat to the traveling public. The alternative was to detour all traffic from the Interstate in this area. VTrans opted to install the system prior to scaling the high areas of the slope. This served two purposes; 1) Scaling after system installation would allow the system to perform as intended and prevent rocks from reaching the roadway and 2) by scaling into the hybrid fence/drape, actual rockfall events could be observed and the effectiveness of the system could be assessed.

Construction was accomplished using a crane and rock slope mitigation technicians using rope access techniques. Work was initiated by first clearing a level area for the footprint of the fence portion of the system. Next, hand excavations through the overlying soil down to bedrock were conducted and galvanized steel rock anchors were drilled into the bedrock. Three foot diameter concrete foundations were poured over the protruding rock anchors. On top of these foundations, steel plates were installed that would accept the base of the steel HEB posts. After installing the posts, steel support ropes were threaded through the top of the posts and extended both laterally and horizontally to spiral rope anchors embedded into bedrock. A diagram showing the system is presented as Figure 9. Figure 10 shows details of the components of the hybrid system.

Chain link netting was attached to each ring panel on the ground and panels were lifted into place by the crane. Panels were secured to the support ropes and each 20-foot section was shackled together. After all of the panels were put into place, the system was tightened. The following series of photos shows the construction sequence.

Figure 11 Preparing Slope for Hybrid System Footprint and Excavation for Steel Post Foundation Pads.

Figure 12 Connecting Chain-Link Mesh to Ring Nets.

Figure 14 Placing Steel Posts.

Figure 13 Lacing Support Wire Ropes.

Figure 15 Hoisting Panels onto Steel Posts and Steel Support Ropes.

5.0 PERFORMANCE

Testing of the hybrid system was performed in the spring of 2010. The contractor scaled the high portions (120-feet in height) of the slope while VTrans monitored any rock hits to the fence/netting. A number of large rocks impacted the fence/drape. Some of these rocks measured approximately 4-feet in length by about 2-feet in thickness and width. All of these rocks were retained underneath the drape portion of the system. Ideally, the rocks should tumble out from beneath the drape and fall uneventfully in the catchment ditch. The contractor was able to remove these accumulated rocks by reaching up with an excavator and lifting the lower end of the drape while scooping out the rocks. Figure 16 shows the accumulation of these rocks. Video recordings (though of poor quality) were taken during some of these rockfall events. Interestingly, one of the video shows a tractor trailer traveling down the Interstate at the same moment a large rock block was scaled. This large rock block was contained by the drape portion of the system and it became apparent that had the fence not been there, that rock would have easily made the roadway into the path of the truck.

Figure 16 Rock Accumulated in the "Tail" Portion of Hybrid System.

The fence/netting remained intact with no distortions to the ring nets or distortions or tears to the chain link netting. A few small rocks impacted the posts and support ropes however this resulted in no damage to either element.

7.0 SUMMARY AND CONCLUSIONS

An evaluation of the constructability and performance of a hybrid rockfall barrier/drape fence (system) was conducted on a newly installed system on Interstate 91 in Fairlee, Vermont. This was the first such installation in Vermont. This report outlines the components of the system and the sequence and methods for installation. Also discussed were observations made during testing where rocks were scaled high-up above the system and allowed to be intercepted by the fence/drape.

Based on observations during scaling, it appears that the hybrid system is performing as designed. After a number of large rocks were intercepted by the system, there appeared to be no detrimental impacts to any of the components. We rate the performance of the system as very good. We recommended monitoring the effectiveness and maintenance of the system as future rockfall occurs and the system ages on an annual basis.

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