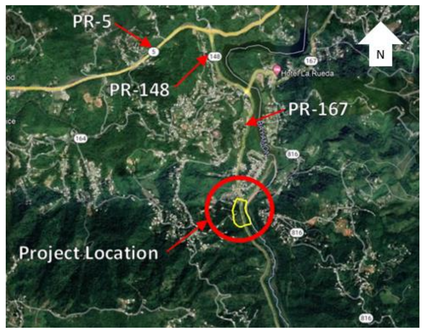
Analysis and Recommendation of Landslide and Road Damage on State Road PR-167, Km 7.2 Naranjito, PR

Author: Jonathan Molina Rosario
Advisor: Victor M. Uribe Florez, PhD
Civil Engineering, Environmental Engineering and Land Surveying Department

Abstract

The State Road PR-167 segment, where the project is located, is a primary state highway road bordering La Plata River, in the municipality of Naranjito, that serves as a connector between Naranjito and Comerío and represents the primary access to the second one to the metropolitan area. The steep rock slope, with frequent rock falls located on state highway PR-167 Km 7.2 in Naranjito was identified, and several road damages need to be addressed to ensure the stability of the slope condition and the safety of the road users. The proposed improvements include strategies and counter-measurements to repair and stabilize the rock slope. These counter measurements include repair works for the damages caused by the rockfall on the roadway and preventive works to reduce the possibility of future damages.



Location Map

Introduction

After Hurricane Maria, PRHTA have implemented countermeasures, that are neither permanent nor completely safe for road users, and its impact is affecting the operation of the road. For this reason, it is recommended that measures be implemented to improve the temporary alternative using competent materials existing in the geotechnical industry to resist the impact of rockfall.

Background

The alternatives considered in this project are:

- Rockfall protection using mesh system with ground anchors;
- Surface protection using shotcrete with ground anchors;
- Rock slope cut with draped mesh, concrete barriers, and chain-link fences.

Alternative 1: Rockfall Protection using mesh system with ground anchors

Ground anchors are one of the most common types of internal reinforcement. Ground anchors are threaded steel bars inserted into the rock via drilled holes and bonded to the rock mass by cement grout. Because the bond strength between the cement grout and the rock is less than the steel's maximum yielding stress, it significantly impacts the rock reinforcement's design load. Dowels are used on steep slopes in the same fashion as rock bolts, while shear pins are used on flatter slopes where bedding planes and discontinuities determine the slope angle and failure plane.

Wire Mesh Facing Over Rock Slope Example

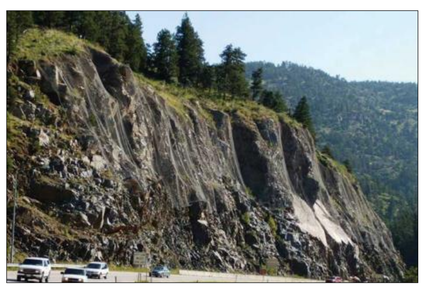
Alternative 2: Surface protection using shotcrete with ground anchors

The ground anchors technique used in this alternative is the same as in Rockfall Protection, using a mesh system with ground anchors except for the facing protection. To stabilize the slope facing, a facing of shotcrete is proposed to be installed as part of this alternative. The bearing plates of the ground anchors are supported on the initial facing. The final facing is constructed over the initial facing and provides structural continuity throughout the design life. The final facing may also include an aesthetic finish.

Shotcrete Facing Over Rock Slope Example

Alternative 3: Rock slope cut with draped mesh, concrete barriers and chain-link fences

This alternative consists in cutting the rock slope at an offset distance of approximately 4 meters from the edge of the road to create a safety buffer zone that serves as a deposit zone in case of any rockfall. This alternative is combined with a draped mesh system to allow rockfalls to be controlled and guided into the deposition zone. The safety buffer zone is delimitating using concrete barriers and chain-link fences to prevent the pass of the rocks to the traveled way.



Drape Mesh Over Rock Slope Example

Methodology

The following information explains the methodology used in this research. Through the data and information collection process, were made three (3) visits to the PR-167 Km 7.2. With the information provided by PRHTA and data initially obtained in the site visits, it was possible to propose three (3) different alternatives to that could qualify to solve rock fall problem and improve the operation the road.In addition, the data provided by the PRHTA was considered in the evaluations of the alternative. For each alternative, an investigation was carried out to analyze their advantages and disadvantages. After analyzing the alternatives and the data provides by PRHTA, a conclusion of results was reached, and the most viable alternative was selected.

Results and Discussion

Based on the considerations discussed on the Review of Literature and Methodology, the most feasible alternative, must be the one that repair the rock slope damages with:

- Shortest construction time
- Least disruption in traffic
- Less right of way impacts
- Less environmental impacts
- Less construction costs.

The preliminary cost was made using the historical cost of the past auction by the PRHTA. The preliminary cost of the entire project considering alternative 1, which consists of the installation of rockfall protection using a mesh system with ground anchors, is approximately $2,806,225.59.Alternative 2, which consists of the installation of rockfall protection using a shotcrete system with ground anchors, is approximately $3,114,853.00.Alternative 3, which consists of the rock slope cut with draped mesh, concrete barriers, and chain-link fences, is approximately $4,631,001.00.

Table 1 present the comparison of the results between the evaluated alternatives based on the criteria indicated above. For the comparison, points from 1 to 3 were assigned for each alternative based on the compliance with the criteria, were 3 is the best score and 1 is the lowest, for a total of 15 point considering the five items in the evaluation criteria.

Criteria	Alternative 1	Alternative 2	Alternative 3
Shortest construction time	3	3	1
Least disruption in traffic	1	1	1
Less right of way impacts	3	3	1
Less environmental impacts	3	3	1
Less construction cost	3	2	1
Total points	13	12	5

Evaluation Results Comparison Table

Conclusions

Based on the results, Alternative #1 (Rockfall Protection using mesh system with ground anchors) provides the most feasible alternative.

It is important to consider that Alternative 1 do not include the scope the consideration of a safety buffer zone to reduce the risk of rocks passing into the traveled way and increase the comfort perception of users. Alternative 3 consider a safety buffer zone between the road and the rock embankment, but this alternative was not selected because it obtained the lowest score of the three alternatives included in the evaluation. Also, for alternative 3 exists the risk of structural weakness during the implementation of the techniques for cutting the rock slope due to the high fracturing and hydrothermal alteration suffered by the rock withing the project area.

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