INSTALLATION OF FLEXIBLE SNOW NET STRUCTURES ALONG I-90 SNOQUALMIE PASS WASHINGTON

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ABSTRACT: HI-TECH Rockfall Construction is currently constructing the largest avalanche barrier project ever undertaken in the U.S. These nets range from 3 meters in height up to 4 meters in order to control avalanches along I-90 in Washington State. In all HI-TECH will install 1229 meters of snow nets. The project consists of 322 meters 4.0/3.5 nets, 278 meters of 3.5/3.2 nets and 651 meters of 3.0/3.2 nets. These nets are installed at 4 different locations along the highway corridor. The major requirement for the contract provided explicitly for the snow nets designed in full accordance with the Swiss Guidelines for snow supporting structures and approved by the WSL. The design team included Kane Geo-Tech, Maccaferri, HI-TECH Rockfall and Dr. Ing. Roberto Castalidini, consultant from Italy.

The major challenges for construction of the flexible snow nets were the very rough and uneven terrain and the lack of access to where the nets were to be constructed and adverse drilling conditions. The snow nets required very high anchor loads due to the abnormal snow pressures and heavy snow density of 400 kg/m2 that we see at this location. With the use of specialized drill rigs and a helicopter HI-TECH's highly skilled employees were able to overcome the challenges and construct the flexible snow nets on budget and on time.

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INTRODUCTION

The installation of flexible snow supporting structures along a major transportation corridor at Snoqualmie Pass, Washington U.S.A. was undertaken by HI-TECH Rockfall Construction Inc. The project consisted of several different heights and capacities of the snow supporting structures in an area of very uneven terrain with difficult access in four different locations. The specifications called out for the contractor to submit an approved layout and design and all snow supporting structures were required to be snow nets approved by WSL. Maccaferri Inc.-USA was contracted to supply the required snow supporting structure materials and Dr. Ing. Roberto Castaldini was contracted to oversee the design and layout of the systems.

BACKGROUND

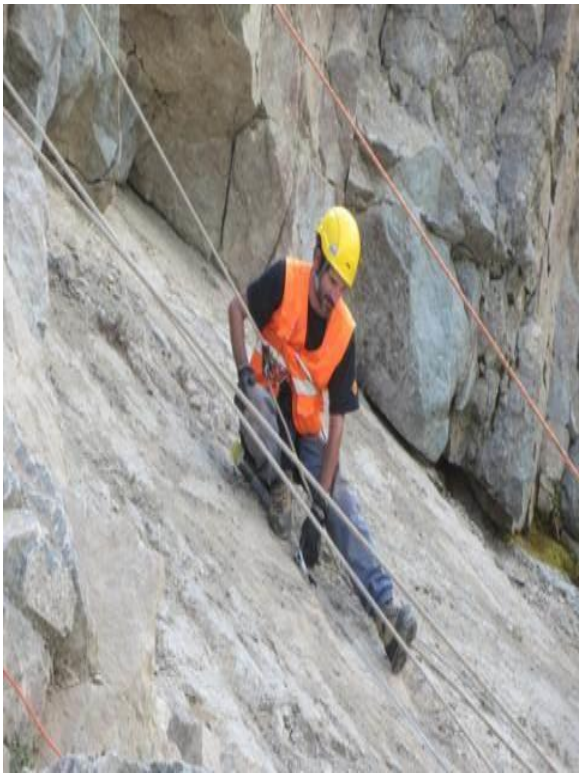
Interstate 90 in Washington State is the east to west lifeline and continues across the U.S. from coast to coast. The average daily traffic through this corridor is 30,000 vehicles per day with an increase to 58,000 on the week-ends. The highway has been closed off and on many times in past years due to avalanches covering the highway. The Washington State Department of Transportation has provided avalanche control in this corridor over the years using explosives. During times when active avalanche control was ongoing it required that the highway be closed for hours at a time. In 2007 WSDOT began a study to determine if the use of snow supporting structures could be used to control the avalanches and allow for the highway to remain open continuously during the winter months without interruption to traffic flows. The low altitude at the pass of 3022 feet allows for winter rains which when combined with the normal snowfalls provides for extremely heavy snow densities at the site. Average snowfalls at this site in the last five years have been 419 inches annually. A second study and final report was completed in 2010 and it was determined that the use of flexible snow nets was a viable option for this site. The project was put to bid in 2011 by WSDOT and consisted of 1229 meters of 2.5m. 3m, and 3.5m flexible snow nets. Final design and layout was to be submitted for approval to WSDOT by the contractor.

Figure 1. View of area called slide curve

SNOW STRUCTURE DESIGN

Dr. Ing. Roberto Castaldini was forwarded all the preliminary design information completed by WSDOT for his review. During this process it was discovered that due to the heavy density value of 600 kg/mc listed in the 2010 WSDOT final design specifications. No WSL certified systems could be provided. For this reason at first Dr. Ing. Castaldini proposed to proceed to a calculation of the structures ofr the specific case. This would have taken time and maybe a higher cost and meant not to use standard snow nets. WSDOT reviewed the data gathered and determined the snow density listed in the 2010 report was in error and amended the density to 400kg for design purposes. The project was full of challenges to provide an adequate and accurate design, these challenges included very steep and smooth slope surfaces,

Figure 2. Dr. Castaldini laying out steep smooth surface



very high glide and creep velocities, intense and heavy snowfalls, difficult subsurface conditions and the fact that this was the first project of its type in the U.S. and was to protect a major transportation corridor. The snow nets approved by the WSL were calculated in full accordance with the Swiss Guidelines assuming a typical snow density of the Alps that is 270 -300 kg/mc. With a snow density of 400 kg/mc the loads on the structure are higher. For this reason it was necessary to upsize all of the original snow nets listed in the contract by WSDOT Providing for structures characterized by larger Dk value from 2.5m to 3m, 3m to 3.5m and 3.5m to 4m and in glide factor or N value from 2.5 to 3.2 which allowed for the snow nets to have a higher Sn value and therefore meet the criteria required for snow retention and using WSL certified structures. Other adjustments necessary due to the heavy snow density, depth and very steep terrain were to shorten the distance between the lines or L value and add artificial slope roughening at many of the locations to reduce the glide factor. After many meetings, site visits and months of correspondence HI-TECH was finally able to submit a design that met all the criteria listed in the bidding documents. This design was subsequently approved by WSDOT allowing for the materials to be ordered so the construction phase could be scheduled.

To use stronger (i.e. models with higher Dk and higher N) standard snow supporting structures in a context different from that of the Alps the designer has to be very careful!

To check Dk, N and S'N, S'Q was necessary but not sufficient

The acting loads on snow nets change not only in modulus but also in the direction, due to the fact that the snow net will be partially filled in back.

It is always necessary to calculate the acting loads on the partially back filled structure and to compare them with those which the standard structure can do

FLEXIBLE SNOW NET MATERIALS

Maccaferri USA was chosen to supply all of the materials for the flexible snow nets. As there are no manufacturing facilities in the U.S.A. for these structures they had to be manufactured in Italy and then shipped to the U.S. The coordination of this portion of the project was very critical. The order consisted of 4.0/3.2, 3.5/3.2 and 3.0/3.2 flexible snow supporting structures. All of these systems use different sizes of anchors cables, foundation bars, posts, bracing ropes and associated hardware. In order to assure construction activities could begin

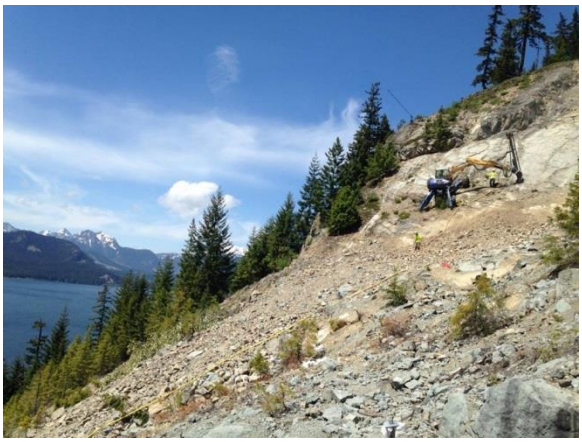
quickly all of the anchors and foundation bars were shipped first followed by the remaining snow net materials. It was critical to tag and label all of these materials separately in order to keep track of the many different sizes being shipped. Also the packaging of the materials was important so as to not mix different materials from different sized structures in the same shipping container for ease of sorting.

ANCHOR DESIGN AND CONSTRUCTION

The anchors for the project required HI-TECH to contract with an U.S. based geo-tech engineer to determine drilling depths and hole diameters to achieve the required pull-out strength. The project specifications called out sacrificial anchors to be installed in all the different ground conditions that would be encountered to prove the bond strength of the anchor design. Kane Geo-Tech of Stockton, CA, U.S.A. based on their vast experience in designing and testing of ground anchors for rockfall mitigation and debris flow practices. With the different capacities and sizes of the flexible structures on the project there were 18 different anchor capacities overall. Some of the challenges of the design were the fact that WSDOT was requiring all the anchors to be tested to 2 times the design load to assure that the anchors would not fail. It was determined that the materials supplied for the flexible structures could not with stand that type of testing and failure of the wire rope cables would occur as the loads needed to be pulled during the testing far exceeded the breaking strength of the material. After many meetings and discussions it was determined that HI-TECH could upsize the material for the sacrificial tests to prove the bond strength between the grout and ground conditions, however the testing criteria would remain at 2 times the design load. More meetings and discussions were required for the production anchors and the testing criteria got reduced from 2 times to 1.6 times and then finally to 1.35 times design load. The Owner required 100% of all the anchors installed to be tested this included every production anchor. Having to deal with the very steep and uneven terrain required specialized drilling equipment. The hole diameters ranged from 50mm to 100mm and the depths from1.7 meters to 4.5 meters into solid rock. HI-TECH brought in wagon drills and Spyder backhoes with specialized drills mounted on the arm to drill all of the holes. These machines have the capability to be winched and crawl around in steep and uneven terrain while still having the ability to level themselves and productively drill in those conditions.

Figure 3. Wagon Drill

Figure 4. Spyder Drill



A portion of the shorter depth 2” holes were hand drilled by HI-TECH employees with the use of 30k hand held rock drills. To date 70% of the anchors are installed and grouted and we have had no test failures.

CONSTRUCTION OF THE FLEXIBLE STRUCTURES

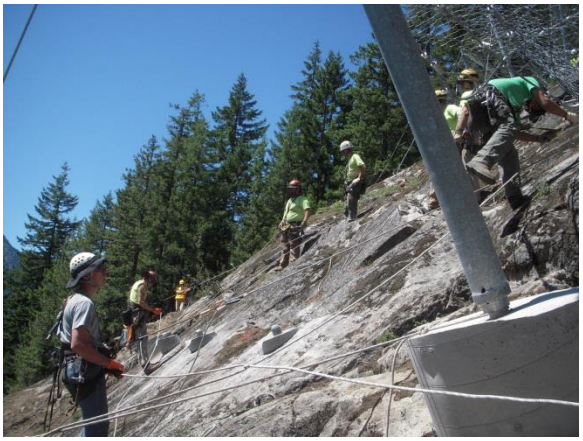
The uneven ground conditions required that many of the foundations were above ground piers. These foundations required engineering by a structural engineer to assure that they

would allow for the snow nets to function properly. These piers ranged from 30cm to 120cm above existing ground. The use of a helicopter was required to fly all the required materials for the foundations to specific points on the slope.

Figure 5. Pier footing being prepared

The concrete was mixed on the slope and poured into the forms. Water for mixing had to be pumped up the slope from as far away as 200 meters to temporary storage containers that were placed on the slope. Once the foundations were constructed the installation of the post and nets was the next step.

Figure 6. Completed pier footing



The snow net lines were laid in a level area approximately 11Km from the slope as this was the only area large enough to accommodate our needs. The lines were laid out in 2 and 3 post setups to be prepared to be lifted by the helicopter and placed up on the slope.

Figure 7. Materials ready for fly

Alberto Grimald from Maccaferri was onsite during this time to ensure that the system was being properly installed. HI-TECH had previously used helicopters to install rockfall draperies on over 100 projects in the past but had never installed flexible snow nets before. The installation went very smooth as we averaged 110 meters per day in place. This operation required 4 men at the yard area and 10 men up on the slope.

Figure 8 & 9. Helicopter installing post & nets

To date approximately 20% of the flexible structures are in place and complete and the remaining 80% will be complete by October 2015. HI-TECH is continuing construction of anchors and foundations at upper slide curve and should be complete with that portion this year. Lower slide curve is still awaiting final approval from the changes recommended by Dr. Castaldini in his site visit this year. This area had the most uneven terrain and loose rock on the slope and required grading to be done prior to lay-out. The initial grading is complete and we are beginning final grading for the lay-out this year.

Figure 10. Initial grading of lower slide curve

CONCLUSION

The design and construction of flexible snow supporting structures is a very precise, detailed and complicated undertaking. The construction of flexible snow supporting structures is typically done in areas with little or no access with normal equipment. While HI-TECH has over 20 years of experience in constructing rockfall barriers and working in areas with little or no access we found that constructing the flexible snow supporting structures was very challenging. They are quite different from rockfall barriers as the tolerance levels for the anchors and foundations are much more stringent. The project during the construction phase has gone smoothly. Most of the challenges have been in the design and layout of the systems. It is very important that when designing these structures that the design team reach out to the experts in this field. This project being the first of its kind in the U.S.A. could have benefited from having more accurate data in the preliminary stages of the design and involving more experienced experts in the field to come up with a more accurate and precise design in the bidding stages. The project budget from original bid date has increased by over 125% as all of the systems had to be upsized, all of the lines had to be spaced closer together increasing the linear footage of structures to be built and artificial slope roughening was added. These changes have cost the owner approximately $4,000,000.00 USD above the original bid price.

ACKNOWLEDGEMENTS

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