From concept to reality, combining a rockfall barrier with a retaining wall to protect railway tracks

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ABSTRACT

At a railyard in Hamilton, Ontario a slope needed to be cut and a retaining wall installed as part of the capacity improvement program. In addition to stabilizing the cut slope above the location of the proposed retaining wall a rockfall source area was identified. The hazard of rocks falling down the slope and over the retaining wall was very real. Canadian National Railway (CN) approached Geobrugg and inquired if there was any experience in combining rockfall protection with retaining walls. Geobrugg responded with conceptual level options to combine the retaining wall and a flexible rockfall barrier.

A consultant performed a rockfall evaluation and determined a site specific rockfall energy and bounce height. With this Geobrugg provided the anticipated system forces on the posts that would occur during the design impact. The 'H'-piles used in the soilder beam and lagging retaining wall were then dimensioned above the top of the wall grade to accommodate the rockfall barrier system.

The retaining wall was constructed and a rockfall net system was provided and attached to the extended 'H'-Piles. In areas where the retaining wall was no longer required, a traditional rigid post rockfall protection system was installed.

RÉSUMÉ

Dans le cadre d'une augmentation de capacité dans une gare de triage à Hamilton, en Ontario, la coupe d'une pente ainsi que l'installation d'un mur de soutènement était nécessaire. En plus de ces travaux planifiés, une source d'éboulement en amont a été identifiée. Le risque de chutes de blocs et le dépassement de ces blocs par-dessus le mur de soutènement était très réel. CN s'est enquis près de Geobrugg à la recherche d'expérience pour ce genre de situation. Des options au niveau conceptuel pour combiner le mur de soutènement et une barrière flexible contre les chutes de pierres ont été proposées.

Une énergie pour l'éboulement et des hauteurs de rebond ont été déterminées et Geobrugg fut en mesure de fournir, pour les poteaux, des estimations de force lors d'impacts de conception. Les poutres en H destinées à être utilisées pour le mur de soutènement ont été dimensionnés plus long que le mur même, afin d'accommoder le système de barrière flexible pare-pierre.

Le mur de soutènement a été construit et un système de filets contre les chutes de pierres a été fourni et fixé aux poutres en H. Dans les zones où le mur de soutènement n'était plus nécessaire, un système traditionnel de protection contre les chutes de pierres a été installé sur 50 mètres supplémentaires à l'aide de poteaux rigides autonomes.

1 INTRODUCTION

Canadian National Railway (CN) recently completed construction of a second mainline between approximately MP 36.9 and 39.4 Oakville Subdivision in Canada. As part of this project, a 420m long retaining wall with a specialized rockfall fence along the toe of a steep embankment was constructed.

It was determined that the potential for rock slides extended beyond the limits of the newly constructed retaining wall following the initial construction and the retaining wall needed to be extended by an additional 50m to mitigate the risk of glacial till deposits breaking loose and travelling with significant force and energy onto the tracks beyond the area currently protected.

1.1 Integrating Rockfall Barriers into a Retaining Wall

CN Rail discussed with different parties about the requirement of determining a reliable solution that would mitigate the rockfall hazard as efficiently as possible.

Various ideas were put forward including rockfall berms, lock block walls, stand-alone rockfall barriers or integrating the rockfall barrier into a retaining wall that was anticipated to be installed at the site. A retaining wall utilizing cast-in-place concrete and 'H' pile design was already under consideration to increase the space available for the second mainline.

After a few 'napkin' conceptual sketches were made, the idea was realized that it would be possible to integrate a rockfall barrier from a manufacturer into a retaining wall designed by others. (Figure 1)

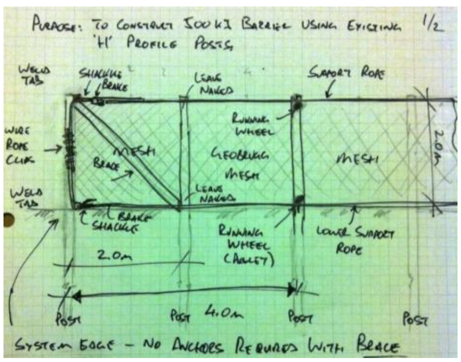

Figure 1. Simple 'proof of concept' sketch showing that it would be possible to attach a catch fence to a retaining wall simply extending 'H' Piles 2m above wall height

1.2 Benefits of integrating a barrier into a retaining wall

Geobrugg North America LLC. A supplier of tested and certified barriers proposed connecting their rockfall barrier system to be attached the 'H' piles embedded in the retaining wall. Rockfall barrier posts from the supplier would not be required, saving the client money. The benefit of this hybrid solution of a barrier attached to the retaining wall would be that a separate specialized drilling contractor would not need be mobilized, resulting on cost savings.

Also, it was suggested to utilize a rigid post design to reduce the need to drill upslope for anchoring support ropes. (Figure 2). Rigid post system require more installation time and materials which is a benefit, however the forces are larger compared to a hinge post system. A hinge or pin connection will reduce the moment at its base.

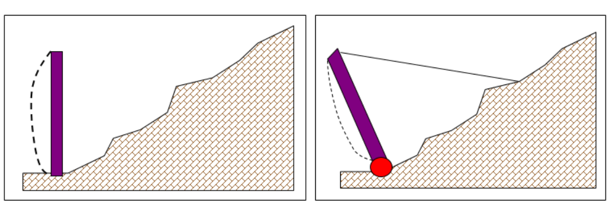

Figure 2. Rockfall barrier systems showing rigid post (left) and hinge post (right) application

Furthermore, the track would be made secure from rockfall sooner by incorporating the rockfall system with the retaining wall construction. This would enable the client to allow trains to stay safely at this section of track and potentially reduce construction time.

The proponent of the rockfall barrier suggested extending intermediate 'H' piles 2.0 metres higher than the top of the retaining wall to allow catchment of boulders up to 1.0 cubic metres. The resulting forces of a rockfall impact were supplied to structural engineers and they were tasked with dimensioning the appropriate 'H' pile absorb and transmit these forces into the ground.(Figure 3) These forces are a result of load sensors during full-scale rockfall barrier testing.

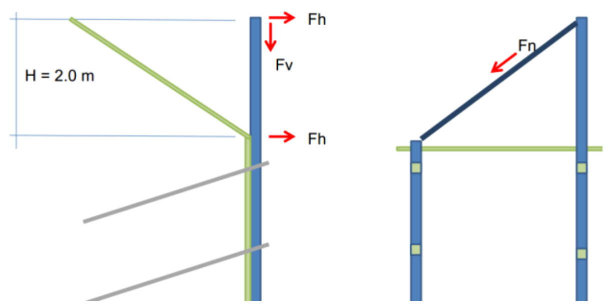

Figure 3. Basic forces on a barrier resulting from rockfall impacts.

1.3 Continuation of the Concept Into a Design

Geobrugg provided the impact forces and connection details for their rockfall barrier to CN Rail who then worked together with their structural design team to further dimension 'H' pile size and spacing. Various scenarios were discussed particularly how to transmit loads into the end posts of the systems where the load bearing ropes terminate.

This is a particularly important detail as the forces not only bend the outside posts outward from the impact, but also laterally pull the post toward each other within the system.

There are many ways to transmit these forces. Sometimes the outside lateral post are braced with a compression member. (Figure 4) Other times the posts are secured by a tension member or post support rope. A third option is to stiffen the outside lateral post. This was the choice made for the CN site. (Figure 5)

Figure 4. Rigid end post of a Geobrugg rockfall barrier braced by a compression member

Figure 5. Robust 'H' pile stiffened to prevent buckling during impacts. Additional lateral post ropes also were utilized

1.4 Figuring out the details

Discussions and design work continued between CN Rail, their structural engineering consultant and Geobrugg where it was realized to integrate into the retaining wall design. (Figure 5)

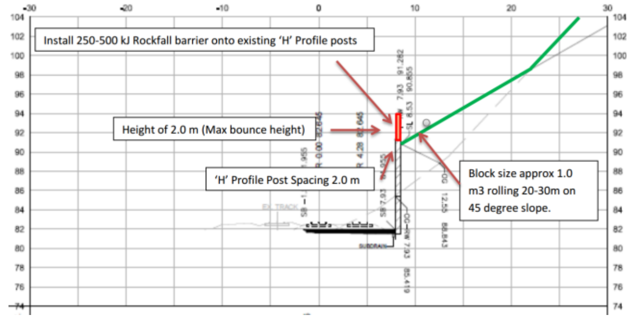

Figure 5. Rockfall barrier system components were integrated into the Owner's drawings

2 REALISATION – CONCEPT ADVANTAGES

Initially the dialog between the Owner, rockfall barrier net supplier and structural engineer went smoothly and all were on board. The client did receive a retaining wall integrated with a rockfall barrier. (Figure 6)

A separate drilling company was not required mobilize to install a stand-alone barrier. Time was not lost due to waiting for a separate rockfall barrier to be installed.

The overall solution appears clean and simple and will function as intended. (Figure 7)

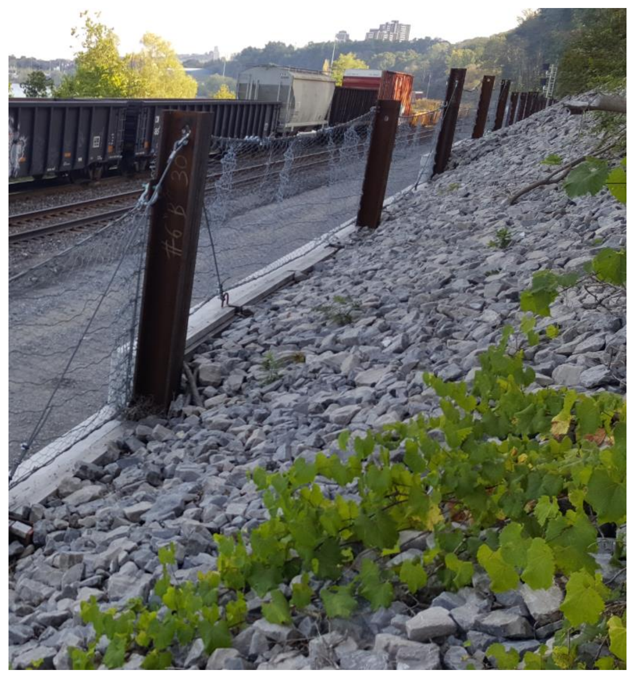

Figure 6. Completed Hybrid 'H' pile and concrete retaining wall view upslope of the barrier

Figure 7. Completed Hybrid 'H' pile and concrete retaining wall view downslope of the barrier

3 REALISATION - DISADVANTAGES

While the hybrid retaining wall and rockfall barrier combination proved to be a reasonable and effective solution, there are further efficiencies that could be achieved to keep the installation costs down.

3.1 Structural Engineering Costs

The goal was to save the client money and time by not utilizing a specialized drilling company to install the stand-alone rockfall barrier above the proposed retaining concrete wall. A substantial amount of time and money were spent on structural engineers as they determined how to combine rockfall barrier supplier impact loads and details into the retaining wall structure.

3.2 Structural Materials Costs

The 'H' piles chosen where very robust and costly as they needed to be stiff enough to not bend during an impact. If the 'H' piles were to bend during an impact, damage could happen to the retaining wall in areas not normally effected by falling rocks.

Furthermore, all the 'H' piles were the same specification and located close together which increased the materials cost. Typically proprietary stand-alone rockfall barriers have spacings that vary between 8-12m and using proven efficient posts which save on installation time and material cost.

3.3 Construction Costs

As the general contractor was not familiar with the rockfall protection systems, they bid risk into their bid and there were significant change orders as well. A specialized rockfall barrier drilling and install company understands these flexible hazard mitigation systems well will keep installed prices lower based on their experience.

3.4 Communication

After the initial idea was tabled by Geobrugg, minimal communication was made between the structural engineer, rockfall materials supplier and the general contractor. The original proponent was not notified of the progress of the project and only found out that a rockfall protection system supplied by others was in fact installed by the contractor. The contractor did not make contact with the original rockfall barrier supplier who came up with the design.

The end result is acceptable from a rockfall mitigation perspective and will function as intended albeit a more costly project than originally anticipated.

4. STAND-ALONE BARRIER EXTENSION

As progress continued on the track widening, it was apparent that the combination retaining wall and rockfall barrier should be longer. As the elevation of the slope north of the retaining wall dipped, a tall retaining wall was no longer required and simple pre-cast concrete barriers were installed. They were placed to prevent soil from raveling onto to the new tracks. (Figure 8)

Figure 8. Precast 'L' shaped concrete buttresses used to prevent soil from raveling on to the track expansion

However, there was also a chance of boulder all from the glacial till deposits and rockfall from a conglomerate rock source area above the cut slope.

It was obvious that the precast concrete barriers were no match for any significant rockfall event. The rocks could simply roll over the wall in some locations, or worse, impact the precast buttresses causing concrete and rocks to land directly on the tracks or at worst damage a parked train.

Once again Geobrugg was tasked to come up with a solution design/supply/install that would help the client with fulfill the following requirements:

- The barrier extension must be 2.0m tall and certified for an impact energy of 500 kJ MEL
- An additional 50m in length was required
- The barrier must tie into the existing barrier and retaining wall installation
- The barrier must be adapted to fit into the existing terrain without regrading the slope

- No gaps between the systems or under the barrier were acceptable

4.1 Barrier Concept

After a site visit was performed, Geobrugg teamed up with David Wood and BAT Construction Ltd, Tit was not going to be impossible to fulfill the above mentioned requirements. Field measurements were made and a standard 50m long GBE-500A-R off-the-shelf system was specified with 10m spacings between posts.

Five post locations were chosen and with the sixth post being the last 'H' pile utilized from the earlier installation. (Figure 9 and 10)

Figure 9. New 500kJ rigid post rockfall extension concept attached to previously installed system viewed upslope

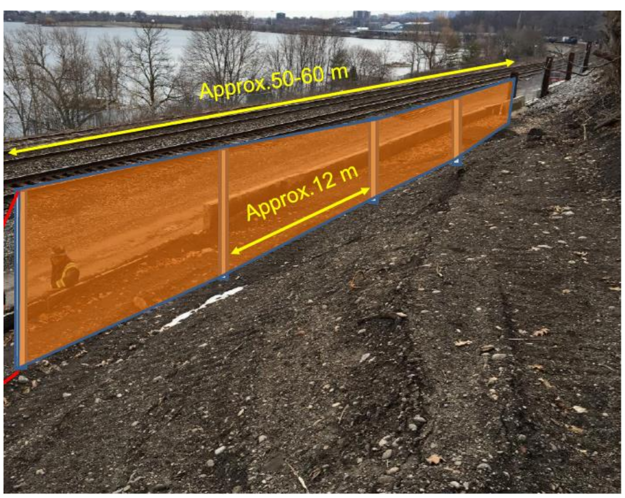

Figure 10. Proposed rockfall barrier extension viewed downslope

4.2 Construction Methodology

The 50m rockfall barrier was installed in just nine working days including mobilization and demobilization. A 30 inch hole was augered 4-5 feet down through soil to bedrock. Two 12 inch sonotubes were placed in the augured hole, backfilled and compacted. Eight inchtall formwork was used to create a concrete leveling pad around and to cap the augered holes. 3 inch diameter PVC sleeves were installed within the sonotubes to create a block-out to ease later drilling through to bedrock. Sonotubes and the 8 inch' concrete pad were installed into the looser embankment material to provide a pedestal style support for the soil anchors. (Figure 10)


Figure 10. 12'' sonotubes, 8'' thick concrete pad and 3'' PVC sleeves

Posts locations were assured by using a template that fit snugly over the form work with holes cut into it that the PVC block outs extended through. The sonotubes and pad form work were filled with concrete, vibrated and troweled by using the form work jig to ensure that anchor placement was accurate. Hollow core self-drilling anchors were drilled through the PVC sleeves and drilled the prescribed embedment depth well past remaining soil and into bedrock in some cases. (Figure 11)


Figure 11. Concrete leveling pad with hollow core anchors visible prior to testing and installing rigid barrier posts

A clean installation was achieved by using string lines and levels. Additional vertical and shear support for the anchors was provided. All anchors were verification tested as required by the geotechnical engineer. (Figure 12)

Figure 12. Confirming pull-out resistance with jack stand

The grade between each post was graded to eliminate gullies or mounds in order to allow smooth anchor drilling and placing the posts. The anchor nuts and washer were used on the underside and topside of post base plate in order to achieve optimum compressive and tensile resistance. The overall installation of the posts and the nets went quickly and had a good overall appearance. (Figure 13) The transition area between the two systems went smoothly as contractor knew what was expected in order to prevent any gaps vertically or horizontally at the transition post. (Figure 14)

Figure 13. Rigid post barrier extension viewing downslope

Figure 14. Transition area where the previously installed system is connected to the 50m long new extension

5. CONCLUSION

This was a unique project in that an idea that was thought to be cost effective was made complicated and expensive due to third parties involvement. While the rockfall barrier proponent was able to come up with a simple solution that combined their net materials with an engineered retaining wall accommodating forces from a rockfall impact, third party structural engineers and the general contractor significantly increased construction cost simply by not being comfortable or experienced with utilizing the technology of proven, certified, reliable off-the-shelf rockfall protection systems.

Money and time could have been saved if there were clearer lines of communication between the Owner, rockfall barrier supplier and the installation contractor.

The initial result was a very expensive retaining wall with robust posts designed specifically for rockfall impacts. The retaining wall 'H' piles became massive as a result of having to be dimensioned for both rockfall impact forces and active earth pressures.

Moving forward, it would be advisable to weigh out the cost of materials and installation of a standard retaining wall with a separate rockfall catchfence compared to a specially designed retaining wall designed to also withstand rockfall impacts as well as active earth pressure behind the concrete wall.

Furthermore, the best cost savings for Owners of linear infrastructure, can be achieved when they turn their special projects over to a design-supply-install model where the bidder is responsible for the overall performance. Contractor, supplier and consultant should be work as a team on behalf of the Owner. Otherwise contractors and engineers will bid risk and come up with overly expensive designs and installations simply because they are working outside of their traditional skillset. They may even lack experience in special projects and their corporate tolerance for accepting any kind of risk is reflected in pricing.

Lastly, it is acceptable for suppliers of innovative technology to bring their solutions to the table realizing that they will make a profit by supplying proprietary proven systems yet save their client much money simply by the fact the wheel does not need to be reinvented. The contractor bid risk into the bid price and further initiated change orders because of lack of experience in all parties involved. Rockfall barrier material costs estimated by the supplier was only a small portion compared to costs of the overall project. Unfortunately, money saved in material costs were multiplied by high factors in the installation costs.

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Wyllie, D.C. and Norrish, N.I., 1996. Stabilization of rock slopes. In Landslides: Investigation and mitigation Transportation Research Board, National Academy Press, Washington, D.C. pp 474-504. *TRB Special Report 24*