ROCKFALL HAZARDS PROTECTION

Introduction

Rockfall occurs when a rock fragment becomes detached from a slope and propels to the ground below. The rockfall is generally initiated by an event such as heavy or prolonged rainfall, vibrations or disturbance during construction, erosion of surrounding soil / rock, freeze-thaw processes, chemical degradation or weathering, root growth, or root leverage from high winds on trees. Once unhinged from the slope, the rock will bounce, slide, or roll down the slope until coming to rest. If infrastructure, such as a roadway exists within the path of the projectile, significant risks to both the roadway and to the public can occur.

Factors that affect the path of the projectile include:

- Slope Geometry – steep and high slopes will yield projectiles with rapid velocities. In addition small irregularities along the slope, such as knobs or minor benches, will help to "launch" the rock away from the slope. Alternatively, larger benches can hinder the path of the rock and reduce the energy and velocity of the projectile.

- Slope Composition – the falling rock can be retarded to some extent during contact with the slope, depending on the nature of the rock / soil that make up the impact surfaces. Clean faces of hard unweathered rock hinder the movement of the falling or rolling rock much less but more bouncing than soil, gravel, and extremely weathered rocks.

- Other factors, such as the size and shape of boulders, or whether or not the rock breaks into pieces are less significant to the path of the projectile.

RISK LEVEL

Alberta Transportation uses a frequency-severity matrix to assign a *Risk Level* to geohazard sites. A *Probability Factor* (*PF*) of between 1 and 20 and a *Consequence Factor* of between 1 and 10 are assigned to the site. The Risk Level is then calculated as follows:

Risk Level = *Probability Factor* x *Consequence Factor*

Where the *Probability Factor* is based on:

1- Inactive, very low probability of fall occurrence.
3- Inactive, low probability of fall occurrence.
5- Inactive, moderate probability of fall occurrence.
7- Inactive, high probability of fall occurrence (e.g. seasonal, following freeze/thaw cycles and/or a fall has occurred in the historic past.
9- Active, falls occur after exceptional weather (e.g. the melting of greater than average snow accumulations or exceptionally intense precipitation); fall frequency is in the order of once a decade.
11- Active, one or two falls occur each year triggered by annually recurring weather conditions.
13- Active, several falls occur each year and/or the frequency of falls is increasing in comparison to equivalent time periods in previous years.
15- Active, many falls occur each year and/or the area producing rock falls is expanding. Ongoing or persistent rock falls during specific times of the year.
20- Active, a large volume of rock is surrounded by open cracks. Toppling or sliding of the displacing mass is accelerating. Sites where rapid movement of a large fall are possible.

And *Consequence Factor* is based on:

1- Rock fall contained by ditch if cleaned as required maintaining capacity.
2- Rock fall onto roadway removable by maintenance crews by hand or with shovels; Road closure not required; minor damage to the road surface that can be repaired during scheduled patching and sealing of the road; minor to no damage to vehicles being struck by falling rocks or striking rocks deposited onto road.
3- Rock fall onto road that could damage a vehicle (e.g. flat tire, dent body of vehicle); rocks bounce or roll onto the road surface but likely not with a trajectory that would pass through the windows of windshield of a passing vehicle.
4- Individual rocks or the total volume of rocks deposited on the road large enough to: 1) damage vehicles or cause accidents if struck by traffic or damage vehicles and injure occupants if they strike a moving vehicle; or 2) cause partial closure of the road or require a detour lane prior to cleanup. Damage to the road surface may require temporary repair in order to re-open road.
6- Individual rocks or the total volume of rocks deposited on the road large enough to: 1) damage / destroy vehicles and severely injure occupants if struck by traffic or damage / destroy vehicles and severely injure / kill occupants if they strike a moving vehicle; 2) cause complete closure of the road, with a rough detour / diversion possible within hours to days; or 3) require days to weeks required to restore the road to normal service. Possibly significant damage to the road surface that requires immediate repair.
8- Same as weighting 6, but with several days required to develop a rough detour / diversion around the rockfall site.
10 Individual rocks or the total volume of rocks deposited on the road large enough to: 1) damage / destroy vehicles and severely injure occupants if struck by traffic; 2) bury vehicles if they strike a moving vehicle; 3) cause complete closure of the road, with a temporary, rough detour or diversion possible in days to weeks; or 3) require complete reconstruction or rerouting of the road after the rockfall.

REMEDIAL MEASURES

Based on the risk value applied to the slope in question, several remedial options can be undertaken to reduce the likelihood of a rockfall hazard impacting the roadway or the public. In general, the remedial measures can be categorized as either active or passive remedial measures.

Active remediation methods are employed to restrain the projectiles from becoming unhinged in the first place. These measures require detailed geotechnical information, and are generally more expensive than passive measures. When implemented, however, the risk of a rockfall hazard is significantly reduced. Active remediation methods include the use of rock scaling, rock bolts, wire draped or anchored mesh (rockfall netting), and shotcrete.

Depending on the risk level of the slope and the geotechnical information available, active remedial measures may not be deemed necessary or cost effective. As such, it is possible to use passive measures to constrain the rockfall hazards, which are implemented to restrain a rockfall from impacting nearby public or infrastructure. Passive remediation measures include berms; rock traps (ditches, barriers, catch fences, or mesh draping), and rock sheds.

A probabilistic geotechnical analysis should accompany any project to determine the size, amount, and probable velocities of the rockfall, and consideration should be given to maintenance, availability of materials, ditch capacity, adjacent traffic volumes, distance from traveled lane, impact severity, constructability, environmental (parks) requirements, when determining the best possible remedial measure.

BEST MANAGEMENT PRACTICES (BMPS) FOR ROCKFALL CONTROL

BMPs for rockfall control are various measures that have been proven to work on past construction sites when they were properly planned and constructed. These measures reduce potential for rockfalls to impact adjacent roadways by removing the potential projectiles, stabilizing the slope face, or providing barriers to catch the falling rocks. As discussed above, there are generally two types of rockfall control BMPs that can be. They are as follows:

- Active remedial measures which restrain or reduce the likelihood of rockfall initiation; and
- Passive remedial measures which serve to constrain or control the rockfall once it has become dislodged from the slope.

Experience is an integral component in the successful selection of the appropriate BMP(s) and the design and implementation of an overall erosion and sediment control plan. It is the designer's responsibility to ensure that BMPs are appropriate for site conditions.