This video provides an overview for those involved in the design of passive rockfall protection structures.


Welcome to this overview of the guidance document - Rockfall: Design Considerations for Passive Protection Structures. I will introduce each section of the guidance, so it may be useful to have a copy with you to refer to.

One point worth noting up front, is that the guidance is a detailed reference tool, but does not provide a prescriptive approach that must be followed for design. This overview is designed for geotechnical engineers and engineering geologists involved in the design of passive rockfall protection structures, and for regional and territorial authorities involved in consenting these.

The guidance is broken into 7 sections:
1. A brief subject introduction
2. An overview of the rockfall risk mitigation process, and site assessment
3. Rockfall mitigation
4. Design considerations for passive structures
5. Reporting outline
6. Other Design Considerations
7. Supporting references, examples and regulatory considerations

The guidance was developed in response to the Canterbury earthquakes, which resulted in widespread rockfall across the Port Hills of Christchurch. More than 100 homes were impacted. Some locations did have protection structures in place, however their performance was variable. Significant rockfall also followed the Kaikoura earthquake in 2016 and this further highlighted the need for this guidance.

In it, we describe passive rockfall protection structures (RPS). These are engineered structures built to capture, divert or slow falling rocks. They include:
- rockfall catch fences
- embankments or bunds
- attenuators
- rockfall sheds
- catch ditches.

These structures don’t prevent rocks from falling, but they can stop or slow their trajectory to protect buildings and infrastructure.

While risk assessment is not the purpose of this guidance, it’s worth understanding how this all fits together, so we’ll start here.

Risk assessment is one part of the entire Rockfall Risk Mitigation process shown in this chart. Risk assessment involves analysis of the rockfall hazard and consequences. It can be qualitative or quantitative.

The risk is assessed and evaluated against risk tolerance criteria. These criteria relate to the site, client circumstances and items exposed to the hazard.

Decisions to mitigate the risk can then be made and could include:
- avoidance of the hazard
- treatment of the source rock
- installation of monitoring systems and warning signage, or
- construction of rockfall protection structures.

There are a number of good references in the appendices that address risk.

The Swiss risk management process in Appendix C is recommended for study.

The Australian Geomechanics Society publication Landslide Risk Management concepts and guidelines is another useful reference that can be found online.

Section 3 provides an overview of a range of possible rockfall mitigation measures. These include
- avoidance
- stabilization
- protection
- non-engineered (or warning) measures.

Our guidance focuses on passive protection measures, but of course some sites may call for multiple measures to be deployed.

In terms of the types of protection structures we cover in the guidance, the approximate energy capacity levels in kilojoules for each are shown here.

The decision relating to both type and location of barrier will be informed by the nature of the site.

A preliminary step in the design process is the collection of information as part of the site assessment. This will include
- desktop studies and field investigations that are used to categorise the source rock
- the slope characteristics
- evidence of recent and historic rockfall.

Section 4 uses this flowchart to describe the design process for passive rockfall protection structures.

This involves the following steps:
- Selection of the design boulder
- Modelling of rockfall trajectories
- Selection of structure type and location
- The detailed design of selected structure type
- And consideration of other design factors

One of the most important inputs for the design is selecting the design block size.

Selection should be guided by the risk assessment, in conjunction with an evaluation of block sizes observed in both the source area and runout zone.

Where statistical methods are used to evaluate the block size, the design block (or boulder), is commonly in the order of the 95th percentile boulder size. This is based on recent European guidance.
Once the design block is selected, rockfall modelling is used to simulate falling rock trajectories and estimate velocity, energy and bounce height along selected slope profiles.

Both 2 and 3 dimensional rockfall modelling software is available. The choice is usually guided by the quality of available information and complexity of the slope topography.

Where 3D models are used, it’s common practice to use a 2D model to estimate boulder energies and bounce heights along critical trajectories identified in the 3D model.

These models are calibrated for both runout distance and bounce height against observed or inferred rockfall that has occurred at the site.

It’s important to keep the limitations of modelling in mind.

- rockfall is a “variable” process
- boulders can vary in size and shape
- they can break apart while falling
- falling trajectories can be affected by variations in slope shape, materials and geometry.

The next step is to consider the structure type, location and length. These should be considered in parallel, as the choice of location may affect the structure type and length.

An options study may be useful to compare multiple alternatives.

Other important factors to consider include:

- constructability and construction access
- maintenance
- health and safety
- land ownership.

The design of rockfall protection structures is a relatively new and evolving field.

Guidance and standards on the design of rockfall fences and embankments has recently been released in both Italy and Austria.

A summary of these approaches is included in Table 4.

We will now look more closely at the three main structures. Firstly - Flexible Barriers, or rockfall net fences, are usually proprietary systems developed and physically tested by manufacturers using approved testing systems. These structures typically have design energy ratings between 100 and 8500 kilojoules.

There are two approaches to designing these barriers:

- The Maximum Energy Level or MEL approach, means the fence is designed to sustain one impact from the design boulder after which it will need to be repaired or replaced.
- The Service Energy Level or SEL approach means the fence is designed to withstand two impacts of the design boulder with little to no repair required following the first impact. An SEL design is commonly used in areas where minimising maintenance is desirable.

In practice, using a design boulder with 1000 kilojoules of energy, the MEL approach would use a 1000 kilojoule fence to sustain one impact of the design boulder. The SEL design would use a 3000 kilojoule fence - noting that SEL is 3 times the capacity of the MEL approach. This higher capacity fence would still be functional after an impact of the design boulder.

Other aspects needing to be considered include:

- sizing of fence for bounce height
- downward deflection of fence in relation to the asset being protected
- anchorage and fence post foundations
- corrosion protection.

The next type are rigid deformable barriers - reinforced earthen embankments or bunds are the most commonly used type of these structures.

Unlike rockfall fences, these types of barriers do not have an energy rating. They are designed by estimating the penetration depth of the impacting block and by sizing the barrier based on an allowable deformation.

For these you need to consider:

- block energy and Bounce height
- construction materials, including facing
- global stability analysis (if built on a slope)
- upslope catch area configuration, and
- stormwater drainage through and around the structure.

Lastly, attenuators are flexible fence systems that dissipate the energy of falling rocks, rather than stop them. They may be used in conjunction with other barrier systems downslope.

At present, there are no published design approaches for attenuators. Their design is based on empirical methods developed from limited field testing and observation.

More detail is given in Table 6. Note however, because attenuators do not stop rocks, they are subjected to lower loads than a flexible barrier and may therefore be sized accordingly.

Last, but not least, a plan for regular inspection and maintenance is vital to the long-term performance of rockfall protection structures. A maintenance regime should
be included as part of the consent conditions. It is important to consider the long-term costs and challenges associated with inspection and maintenance, especially removal of fallen rock from structures.

More detail is provided in Table 8.

Section 5 of the guidance provides a summary of the information that should be included in design reports.

The final section, Other Design Considerations, includes factors that need to be addressed very early on in the process. These include legal and property ownership issues and health and safety.

The guidance is completed by a detailed set of appendices referenced in the main body.

Appendix A – provides a commentary on how the design of passive RPS structures fits with the regulatory context

Appendix B – includes worked examples of the design of a flexible RPS and an earthbund, and demonstrates how the guidance can be applied.

Lastly, Appendix C references the Switzerland Rockfall Risk Management Process which is one example of how a risk management process could be applied.

This concludes the presentation of the Guideline – Rockfall: Design Considerations for Passive Protection Structures.