

Duplicating CRSP Results using RocFall

Introduction

Two of the most common rock fall analysis programs are:

- CRSP (Colorado Rock-Fall Simulation Program, Colorado School of Mines)
- RocFall (by Rocscience)

Often people have both programs and wish to compare results between the two, so a common question is “How do I set up a RocFall analysis so that it gives similar results to CRSP?” RocFall has numerous options for how to handle the variability in the rock fall parameters, such as slope geometry, rock geometry, and coefficients of restitution. Many of these options apply different assumptions to those made by CRSP.

As of version 4.052, RocFall now has a much improved import feature for CRSP files. This document describes the new CRSP import option, and how the various input parameters are converted. Results from two examples are then presented.

It is important to note that due to the probabilistic approach used by both programs, and some differences in the underlying algorithms, it is impossible to get exactly the same results. Rocscience does not have access to the CRSP code.

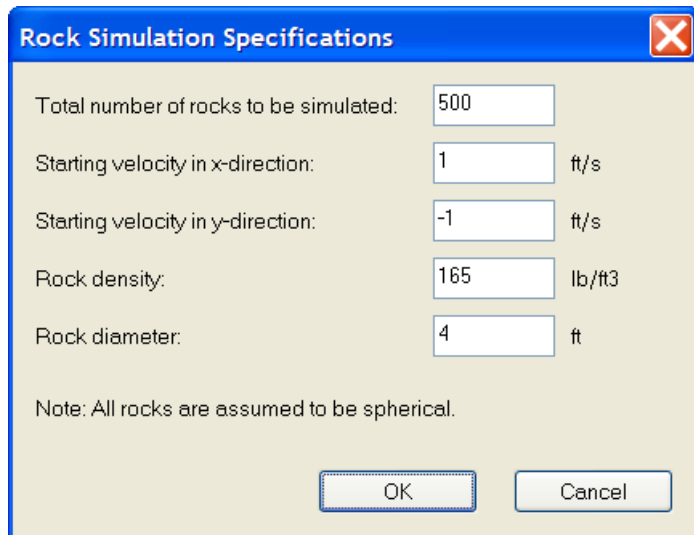
Importing CRSP files into RocFall

First check the version number of your RocFall software by selecting About RocFall... in the Help menu. If you are using a version of RocFall prior to version 4.052, you need to update your software. Use the automatic update feature in the Help menu of RocFall to update your software.

RocFall version 4.052 and later has a greatly improved Import feature for CRSP files. RocFall will now automatically set all relevant options to best simulate the assumptions made by a CRSP analysis. If you now simply read a CRSP file and press Compute, the results should be similar to those from CRSP.

To import a CRSP file into RocFall:

1. Select File > Import > Import CRSP
2. Open the desired CRSP file (.dat file extension).
3. RocFall will ask you for the number of rocks, initial velocities, rock mass, and rock diameter (see below), because these parameters are not stored in a CRSP file. Enter the values that you used when doing the CRSP analysis.



Rock Simulation Specifications

Total number of rocks to be simulated: 500

Starting velocity in x-direction: 1 ft/s

Starting velocity in y-direction: -1 ft/s

Rock density: 165 lb/ft³

Rock diameter: 4 ft

Note: All rocks are assumed to be spherical.

OK Cancel

4. Select OK and the CRSP model will be imported into RocFall.

For details regarding the import of CRSP parameters into RocFall, and the various assumptions which are involved, see the next section.

RocFall Options Required to Duplicate CRSP Results

When you import a CRSP file into RocFall (version 4.052 or later), the model input parameters are automatically converted as described below. If you wish to manually re-create CRSP results in RocFall, you can use the following procedure.

1. In the RocFall Project Settings dialog (see below), enter the rock density used in the CRSP analysis.
2. For Friction Angle, use either the “Set friction angle to zero” option, or use a friction angle from the material editor but define each slope segment as having a very small friction angle. When importing a CRSP file, each slope segment is given a friction angle of 1 degree. The reason for this is that the internal stability of the RocFall computation algorithm is better with a small friction angle versus zero friction. CRSP does not consider the sliding mechanism – rocks roll down the slope, usually as spheres.
3. In the RocFall Project Settings dialog, make sure the “Consider angular velocity” checkbox is on. CRSP always considers angular velocity. When computing angular velocity in RocFall, the moment of inertia of the rock is always assumed to be that of a sphere. In CRSP you can choose between a sphere, cylinder or disc. To compare with RocFall, you must use the default spherical shape in CRSP.
4. In the RocFall Project Settings dialog, make sure the “Scale Rn by Velocity” checkbox is on and the K factor is 30 ft/s for US imperial units or 9.144 m/s for metric units. CRSP always scales Rn by velocity.

Project Settings

Rock setup

Number of rocks to throw: 500

Minimum velocity cut-off: 0.33 [ft/s]

Rock density: 165 [lb/ft3]

Friction angle

Use friction angle from material editor

Calculate friction angle from Pt

Set friction angle to zero (rolling)

Sampling Intervals

Number of horizontal locations to analyze: 50

Angular velocity of the rocks

Consider angular velocity

Coefficient of normal restitution (Rn) scaling

Scale Rn by Velocity $Rn(\text{scaled}) = Rn / (1 + (V_{\text{rock}}/K)^2)$ where K = 30 [ft/s]

Scale Rn by mass $Rn(\text{scaled}) = Rn / (1 + (M_{\text{rock}}/C)^2)$ where C = 1000 [lb]

Random-number generation

Random

Pseudo-random

Specify seed: 190274

Multi-seeder probability setup

Equal probability on any seeder

Probability depends on length of seeder

OK Cancel

5. After drawing your slope in RocFall, go to the Slope Editor in the Slope menu (see below). Make sure the standard deviation of all vertices is zero and that the “Use standard deviations when generating slope vertices” checkbox is off. CRSP does not allow for the variation in slope vertex location. In CRSP, variation in slope geometry is done through a

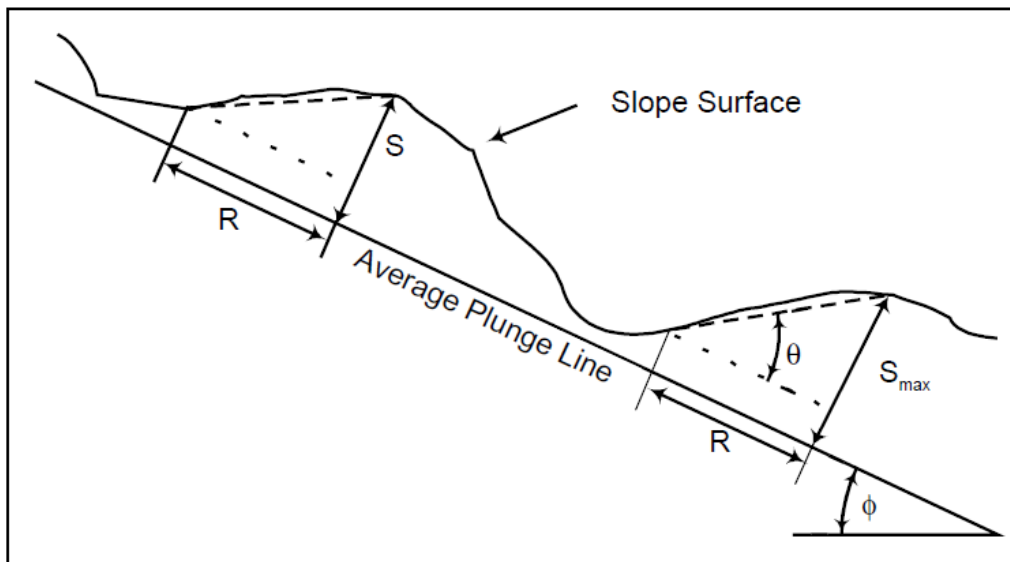
roughness parameter which varies the angle of the slope segment on contact with a rock. In RocFall, one can statistically vary the angle of the slope segment in the Material Editor dialog.

Vertex	X [ft]	std dev	Y [ft]	std dev	Material
1	0	0	320	0	
2	8	0	314	0	Cell 0001
3	18	0	304	0	Cell 0002
4	34	0	290	0	Cell 0003
5	66	0	258	0	Cell 0004
6	92	0	240	0	Cell 0005
7	120	0	214	0	Cell 0005
8	199	0	164	0	Cell 0007
9	260	0	140	0	Cell 0008

Use standard deviations when generating slope vertices Common std dev... Copy OK Cancel

- In the Material Editor (Slope menu), add new materials for regions of the slope that have different coefficients of restitution and/or different surface roughness. Surface roughness (S) in CRSP is defined as shown in the following figure:

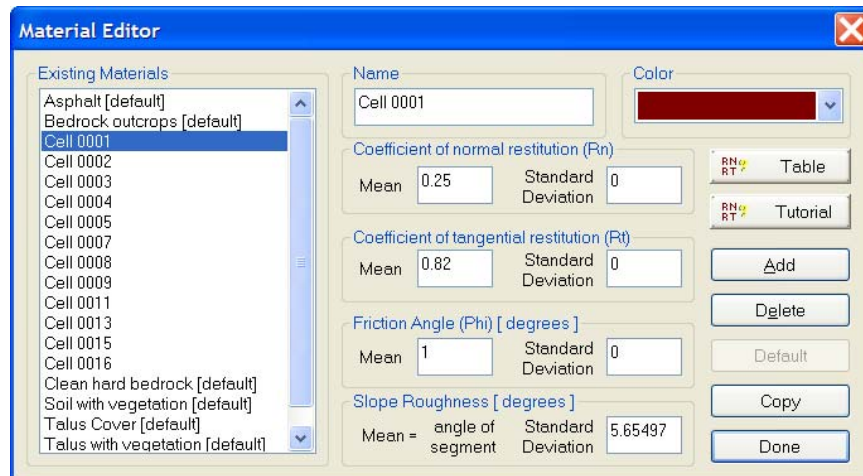
$$\theta_{\max} = \tan^{-1}\left(\frac{S}{R}\right) \quad (1)$$



Surface roughness (S) established as the perpendicular variation from an average plunge line (defined by slope angle ϕ) over a distance equal to the radius of the rock (R). Maximum slope variation (θ_{\max}) is defined by S and R (Pfeiffer, 1989; Pfeiffer et al., 1991; 1995).

In RocFall, you will need to compute the maximum slope variation (θ_{\max}) using the above equation 1 for each unique surface roughness as defined in CRSP. This requires the radius (R) of the rock assuming a spherical shape. For example, if in CRSP you define a slope segment to have a surface roughness of 0.4, and you defined the diameter of the rocks to be 4 feet (R=2ft), the maximum slope variation is 11.3 degrees ($\tan^{-1}(0.4/2)$).

RocFall asks for the standard deviation of Slope Roughness (see below). RocFall's slope roughness and CRSP's slope variation are similar. In CRSP you define the maximum slope variation. We think that CRSP then uniformly samples the slope angle with the upper limit being the maximum slope variation angle. In RocFall, you define the standard deviation of the slope roughness. RocFall assumes the actual slope angle at any point varies according to a normal distribution. To get similar results, set the standard deviation to be equal to half θ_{\max} . So if the maximum slope variation is 11.3 degrees, set the standard deviation of the slope roughness in RocFall to 5.65 degrees. The reasoning behind this is simple. In a normal distribution, 95 percent of all values fall within 2 standard deviations of the mean. So by setting the standard deviation equal to half the maximum slope variation, you are guaranteed that 95% of all sampled slope angles will fall in the range used by CRSP.



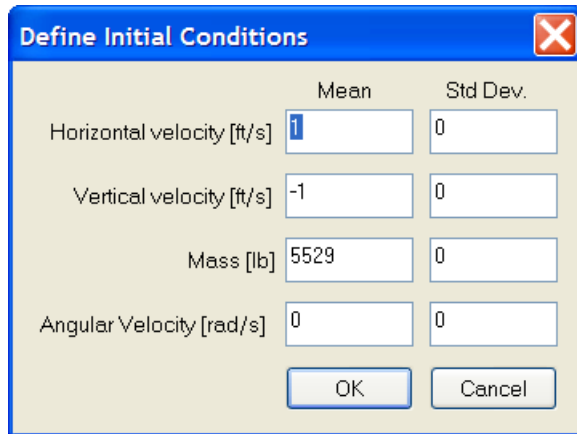
Also set the standard deviation of both the normal and tangential coefficient of restitution to zero. CRSP does not statistically modify these parameters. The variation in rock paths in CRSP comes solely from the slope variation. Set the friction angle to a small value, say 1 degree. CRSP assumes rocks bounce and roll so frictional sliding is not accounted for. We use 1 degree because the internal computation of rock paths is more stable with a small friction angle rather than zero friction angle.

7. After defining the slope geometry and material properties, the next step is usually to define a seeder. A seeder is the location from which rocks are thrown on to the slope. In CRSP, you define a rock shape, rock diameter and the density of rock. From these parameters, the mass of the rock is calculated. RocFall assumes spherical rocks, so define the mass (m) equal to:

$$m = 4/3 \pi R^3 \rho$$

where R is the radius of the spherical rock, $\pi = 3.1415$, and ρ is the density of the rock as defined in the Project Settings (see step 4 above). For example, if a rock is 4 ft in diameter with a unit weight of 165 lb/ft^3 then the mass is equal to 5529 lbs.

Set the standard deviation of all the parameters in the seeder initial conditions dialog (see below) to zero. CRSP does not impose statistical distribution on the initial velocities or mass of the rocks. The variation in rock paths in CRSP comes solely from the slope variation.



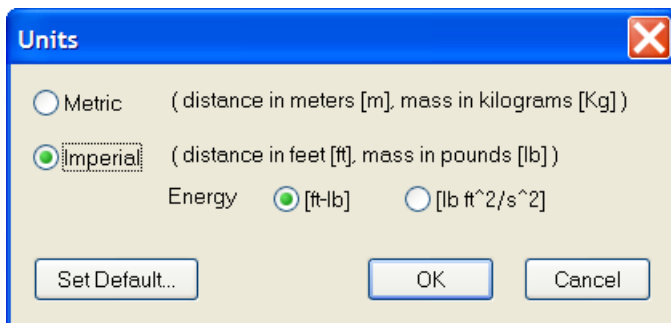
The 'Define Initial Conditions' dialog box contains the following fields:

	Mean	Std Dev.
Horizontal velocity [ft/s]	1	0
Vertical velocity [ft/s]	-1	0
Mass [lb]	5529	0
Angular Velocity [rad/s]	0	0

Buttons: OK, Cancel

US Imperial Energy Units

Versions of RocFall prior to version 4.052 output energy in $\text{lbm}\cdot\text{ft}^2/\text{s}^2$ units where lbm is pound mass. As of version 4.052, the user has the option to output energy in the more conventional units of $\text{ft}\cdot\text{lbf}$ where lbf is the more conventional pound force unit. CRSP uses the $\text{ft}\cdot\text{lbf}$ energy units. The conversion factor between the two sets of units is $1 \text{ lbm}\cdot\text{ft}^2/\text{s}^2 = 32.174 \text{ ft}\cdot\text{lbf}$. The new units dialog in RocFall (see below) allows you to select between the two energy units. Files written prior to version 4.052 will display energy results in the original $\text{lbm}\cdot\text{ft}^2/\text{s}^2$ unit system.



The 'Units' dialog box contains the following options:

- Metric (distance in meters [m], mass in kilograms [Kg])
- Imperial (distance in feet [ft], mass in pounds [lb])

Energy options:

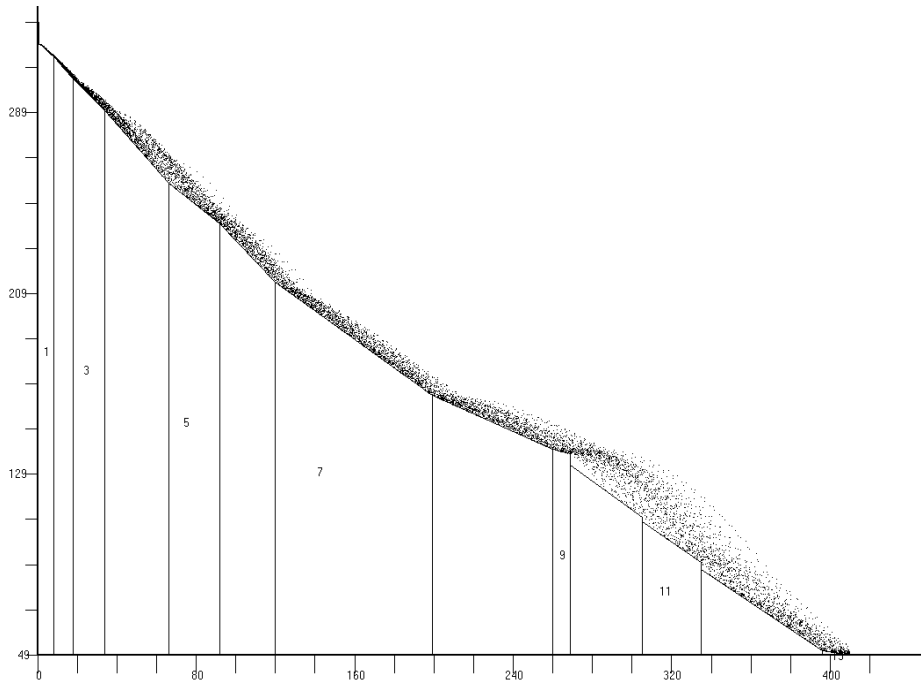
- [ft-lb]
- [lb ft²/s²]

Buttons: Set Default..., OK, Cancel

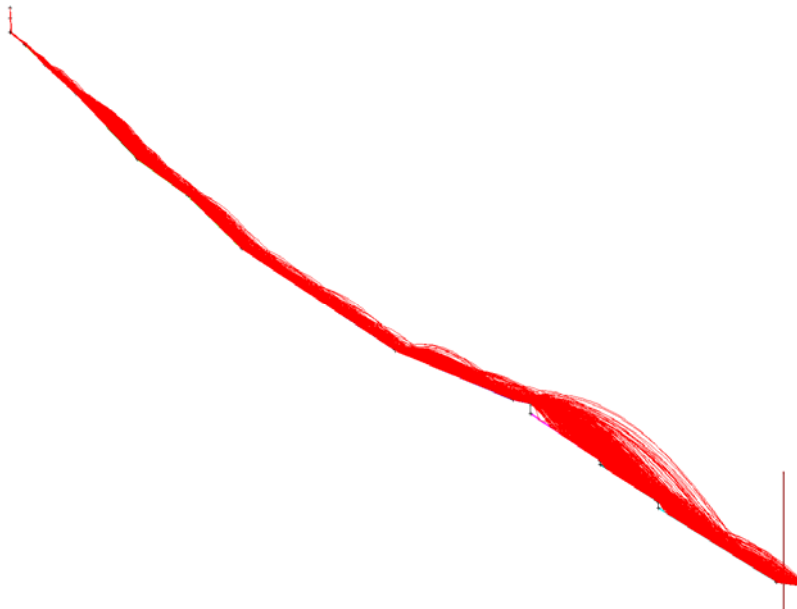
Rifle Example

The Rifle example comes with the CRSP software. The following compares the results from CRSP to the results from RocFall.

Rock Paths

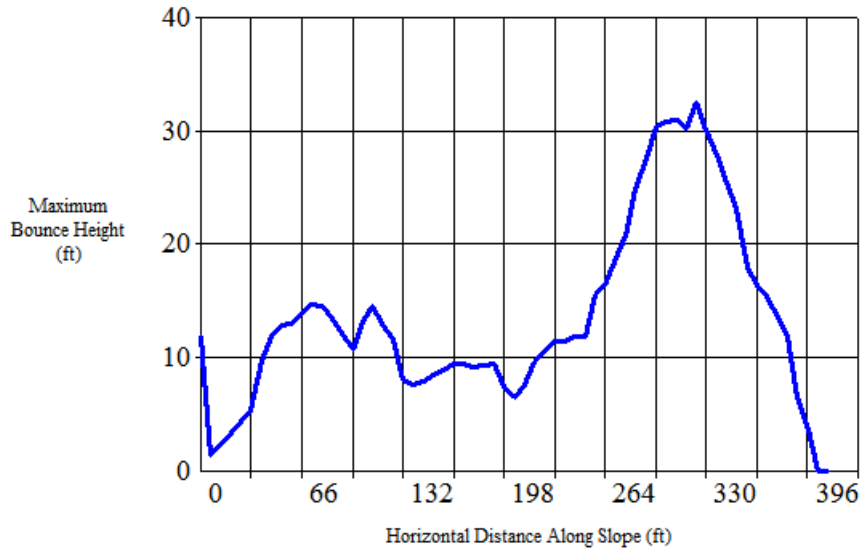


Rock Paths CRSP (Rifle example)



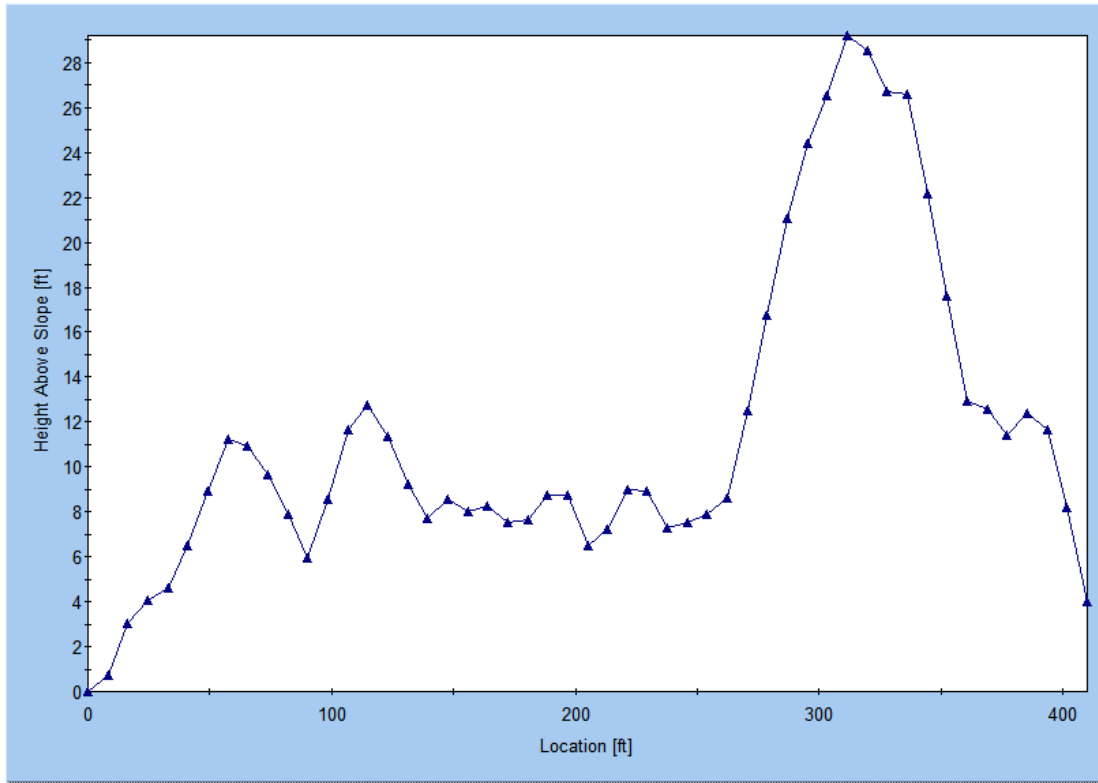
Rock Paths RocFall (Rifle example)

Bounce Height



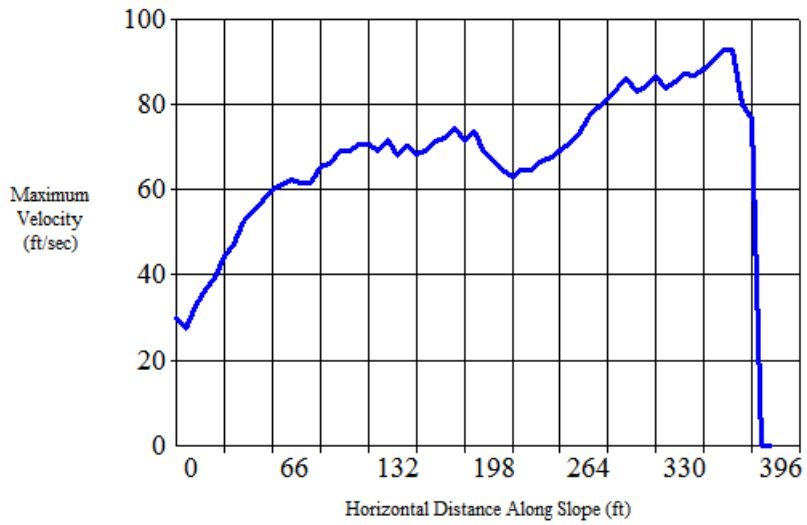
Bounce Height CRSP (Rifle example)

Bounce Height Envelope

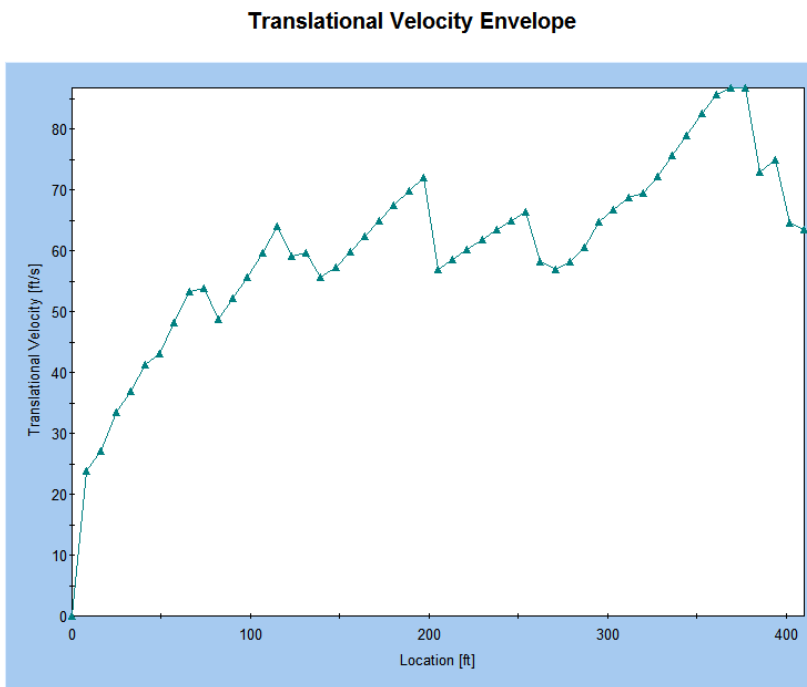


Bounce Height RocFall (Rifle example)

Maximum Velocity



Maximum Velocity CRSP (Rifle example)

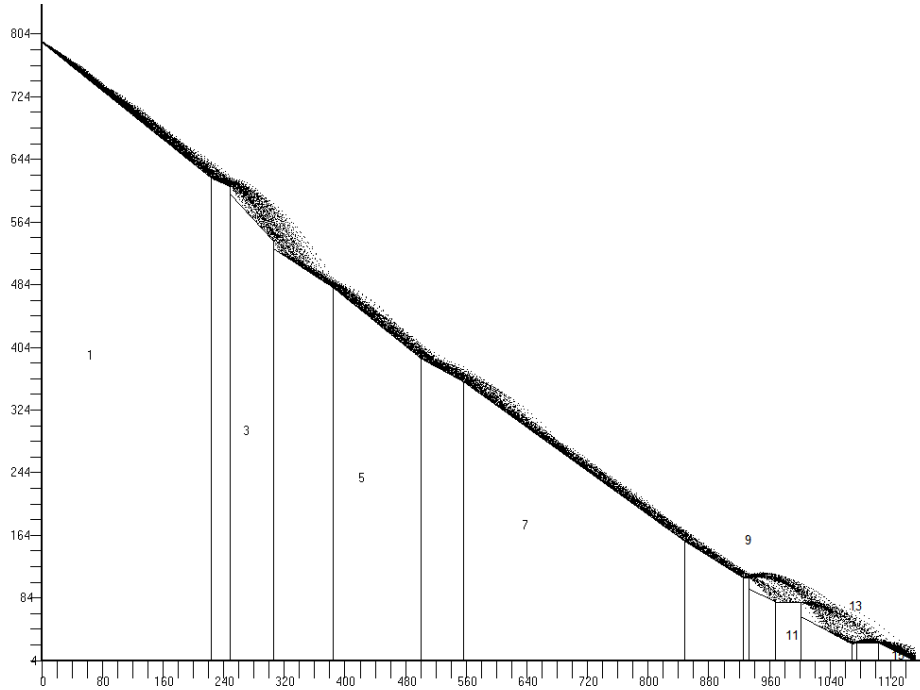


Maximum Velocity RocFall (Rifle example)

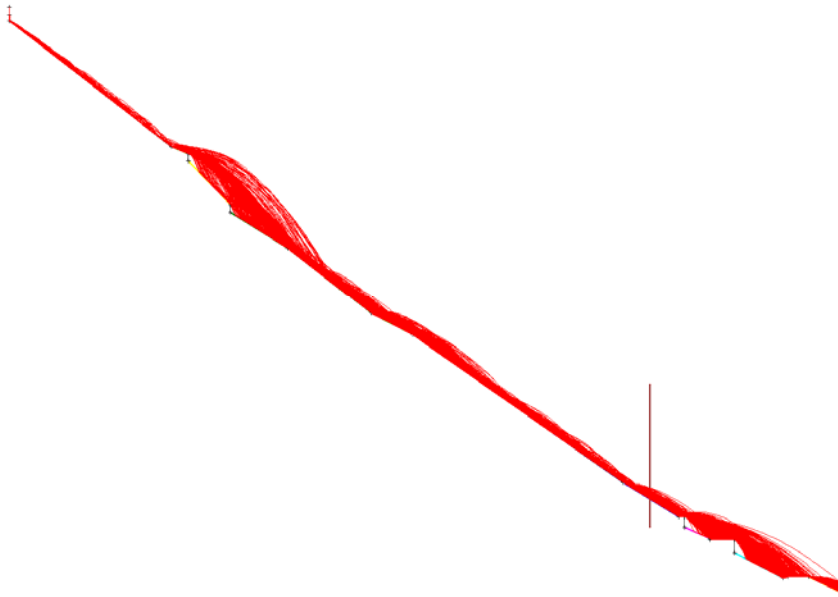
Glenwood Example

The Glenwood example comes with the CRSP software. The following compares the results from CRSP to the results from RocFall.

Rock Paths

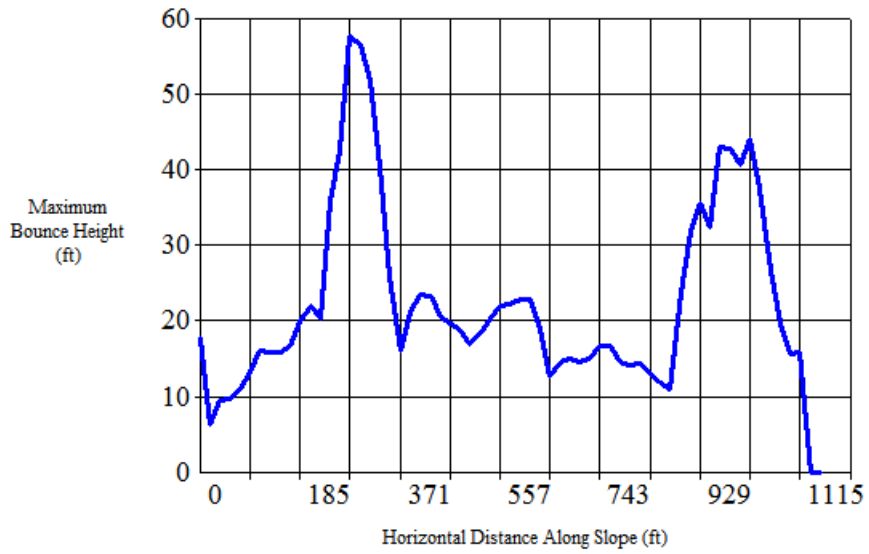


Rock Paths CRSP (Glenwood example)



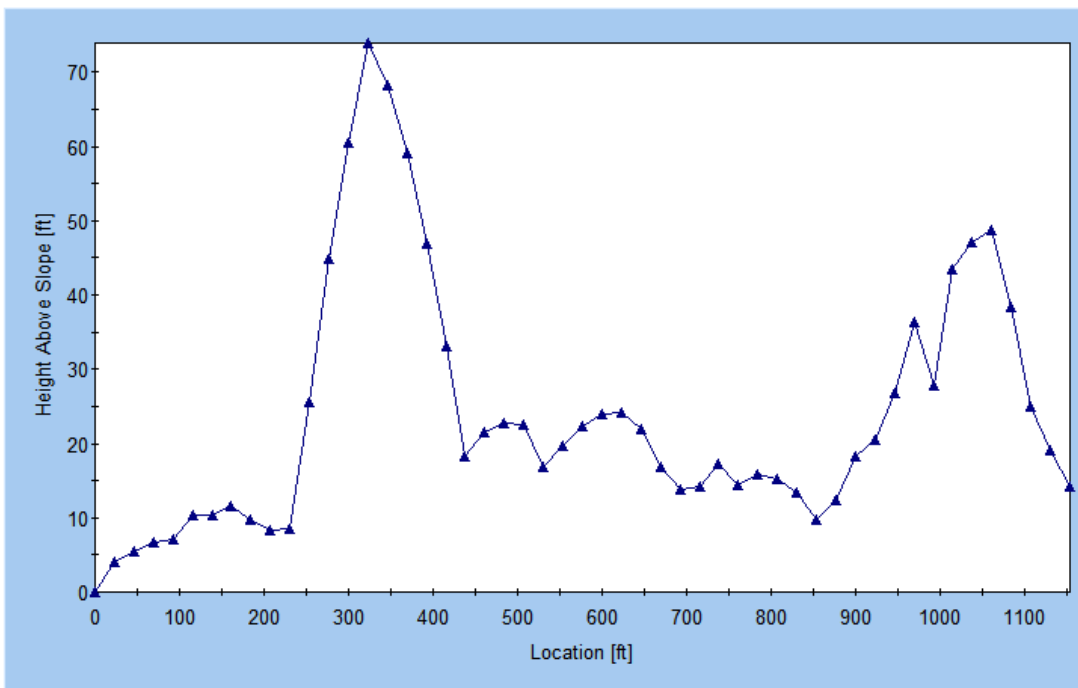
Rock Paths RocFall (Glenwood example)

Bounce Height



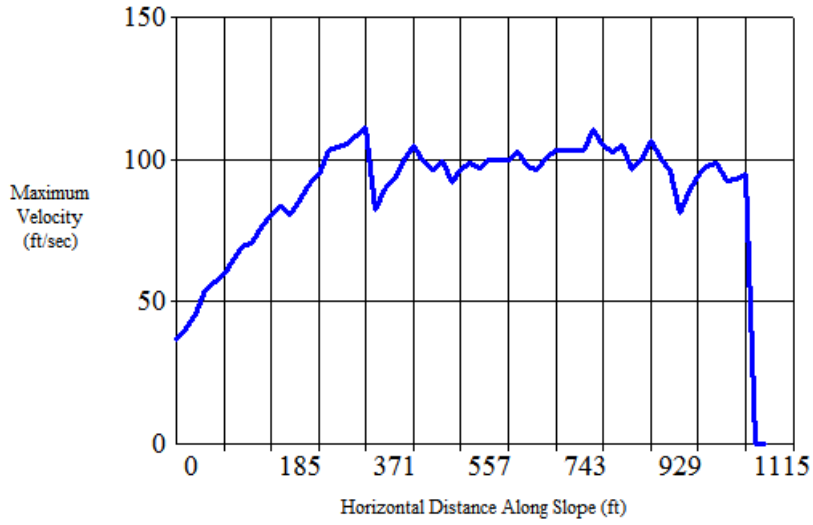
Bounce Height CRSP (Glenwood example)

Bounce Height Envelope



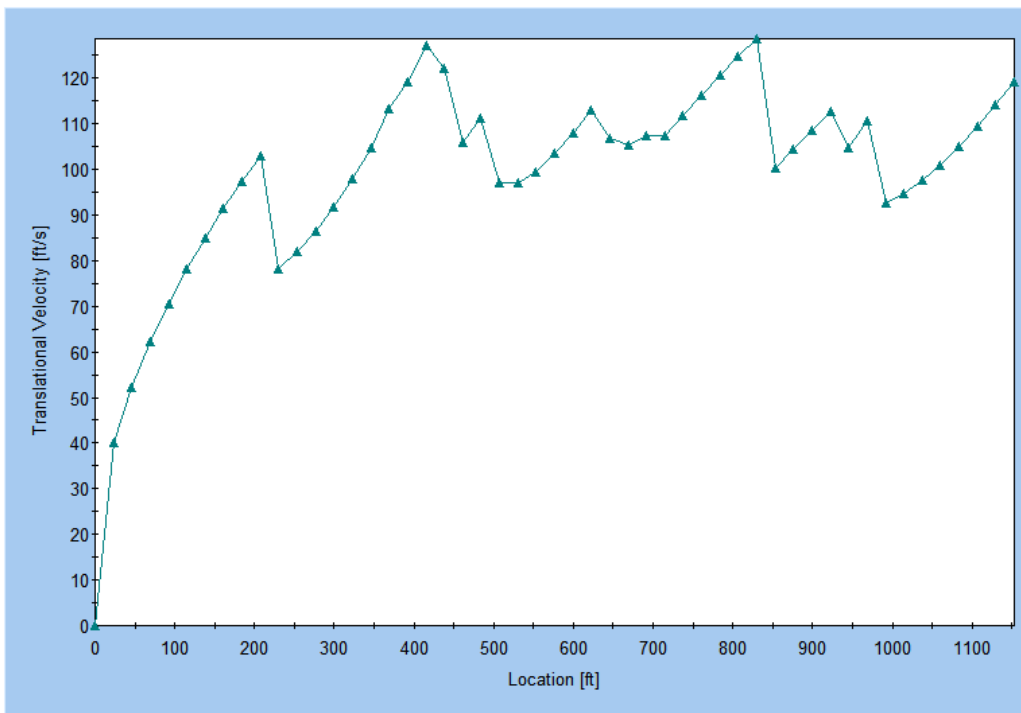
Bounce Height RocFall (Glenwood example)

Maximum Velocity



Maximum Velocity CRSP (Glenwood example)

Translational Velocity Envelope



Maximum Velocity RocFall (Glenwood example)