Blast Fragmentation Analysis - *Rhino3d[1] plugin*

User manual - Version 1.0

1 Introduction

Blast fragmentation Plugin is first set of functions available. It provides unique yet reliable approach to estimate fragmentation of blasted material in realistic blasting scenarios. It is based on relevant theoretical foundation that explains how blast induced fractures are formed and how their length can be calculated. It takes monolith rock and explosive properties as input and handles rock mass discontinuities by Discrete Fracture Network (DFN). Following parameters are taken as input:

- **Monolith rock**
  - Tensile strength
  - Poisson ratio
- **Drilling and explosive properties**
  - Hole radius
  - Charge radius
  - Detonation velocity
  - Charge density
  - Sequence of initiation
- **DFN**
- **Borehole pattern from previous row**

Well known fact in blasting is foundation of the model: "*Explosive charge will fragment only primary rock blocks that it passes through*" and therefore this plugin does exactly that, it analyses fragmentation of primary blocks that are intersected by each charge. This makes it possible to analyze fragmentation of blasting patterns with parallel and non-parallel boreholes such as ring blasting in underground mines which makes it unique. Results provide not only size distribution, but spatial position of each fragment so that oversized fragments can be located and blasting pattern adjusted accordingly.

Computation of each fragment is demanding process and that is why we utilize multithreaded computation in order to reduce time required for analysis.

Plugin works on latest service release of Rhino v6, and will be available on higher Rhino versions. This plugin is **free** of charge and comes **without any warranty**!

[1] Product of Robert McNeel & Associates.

2 Download and installation

First download plugin from HERE. Unpack compressed file and you will find 2 directories:

1. Install (where actual plugin is stored),
2. Resources (where example files are stored).

In order to use it Rhino service release must be ***6.34.21034.7001, 2/3/2021***, if this is not case please update to latest Rhino v6 service release.

Open Rhino and go *Tools -> Options -> Plug-ins* and click *Install* button. Then navigate to Install directory of uncompressed archive. Select **BFA.rhp** and you are done.

Resources directory contains three .3dm files are given; Simple.3dm where example for this manual is given, Ring_1.3dm and Ring_2.3dm with more specific examples for underground ring blasting.

3 Support

If you find any difficulties using this plugin, encounter bugs or you need help with more demanding models feel free to send us email to support@owl-fox.com and we will gladly help you.

4 Disclaimer

This code is under development and its performance, stability and results reliability can change over the time. We provide no warranty and you agree to use it on your own responsibility.

5 License

This plugin is property of Owl and Fox DOO, it is free to use and must not be decompiled or distributed commercially to third parties.

6 Available commands

BFA plugin consists of following commands typically executed in listed order:

1. primaryBlocks,
2. fragment,
3. analyze.

6.1 primaryBlocks

Command *primaryBlocks* is the first command in execution sequence and is used to define primary rock blocks based on Discrete Fracture Network (DFN). Importance of primary block analysis is explained with more detail in Chapter **Error! Reference source not found.**.

Definition of primary blocks is done by splitting of the main rock block being blasted. Splitting process is based on bisection principle where single block is split in two blocks by single fracture. All fractures are firstly sorted by size (area) in descending order and then splitting is performed. First (also largest) fracture splits main block in two while every next fracture splits one or multiple blocks depending on the execution mode. There are two execution modes:

1. Mode 0 – default mode where single fracture splits only block in which its centroid is located,
2. Mode 1 – fracture splits all blocks intersected by infinite fracture with same dip/dip direction.

Input:

- DFN layer name – layer containing DFN,
- Blocks layer name – layer containing main block,
- Execution Mode.

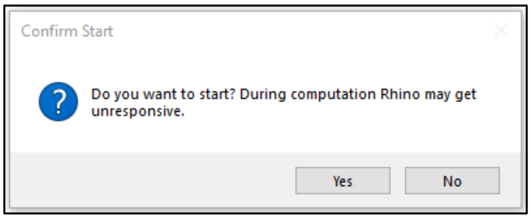
Output:

Set of primary rock blocks as solids.

6.2 fragment

This is the main command that will perform fragment computation. After executing command in Rhino command line user is asked to enter and confirm input parameters of explosive and rock by hitting *Enter*.

If parameters entry is correct user is then asked to confirm start of fragment computation (Figure 1). Message about Rhino unresponsiveness will be displayed as well.


Confirm Start

Do you want to start? During computation Rhino may get unresponsive.

Figure 1 Fragment start confirmation

Fragment computation is demanding task and is implemented with multithreading for major and complex tasks that are thread safe. All available cores will be used. Have in mind that it is not currently possible to break from fragment computation in order to avoid drop in performance. Progress can be tracked in bottom right corner where processed percentage of model is shown.

After computation is finished all fragments will be available in layer “Blocks” and their size distribution can be analyzed by calling “analyze” command. Computation time of the model will be saved in log file in same directory with main .3dm file.

6.3 analyze

This command will provide insight in obtained results by creating “*results.csv*” file in the model directory. File will contain volume and size of each fragment that can be used for further purposes. Size of the fragments is measured in meters and represent the diameter of the bounding sphere around certain fragment.

7 Model preparation example

Model preparation is simple and relies on Rhino's capabilities. First step is to prepare layers where necessary objects are placed. Complete analysis requires following layers:

- Boreholes (layer where main explosive charge are located)
- Previous (layer where previous explosive charges are located; Optional if user wants to include blast induced fractures in analysis),
- Blocks (layer where solid block to be fragmented is located),
- DFN (layer containing Discrete Fracture Network).

Currently it is required that direction of blasting is aligned with Y axis, that means normal vector of blasted face corresponds to Y axis. Due to this requirement, it is necessary to adjust DFN dip direction to account rotation of the blasted face.

By making ***Blocks*** layer current we are adding solid block that is to be fragmented by using ***Box*** command from Rhino. We are creating 21.6m long, 2.4m wide and 10m high block.

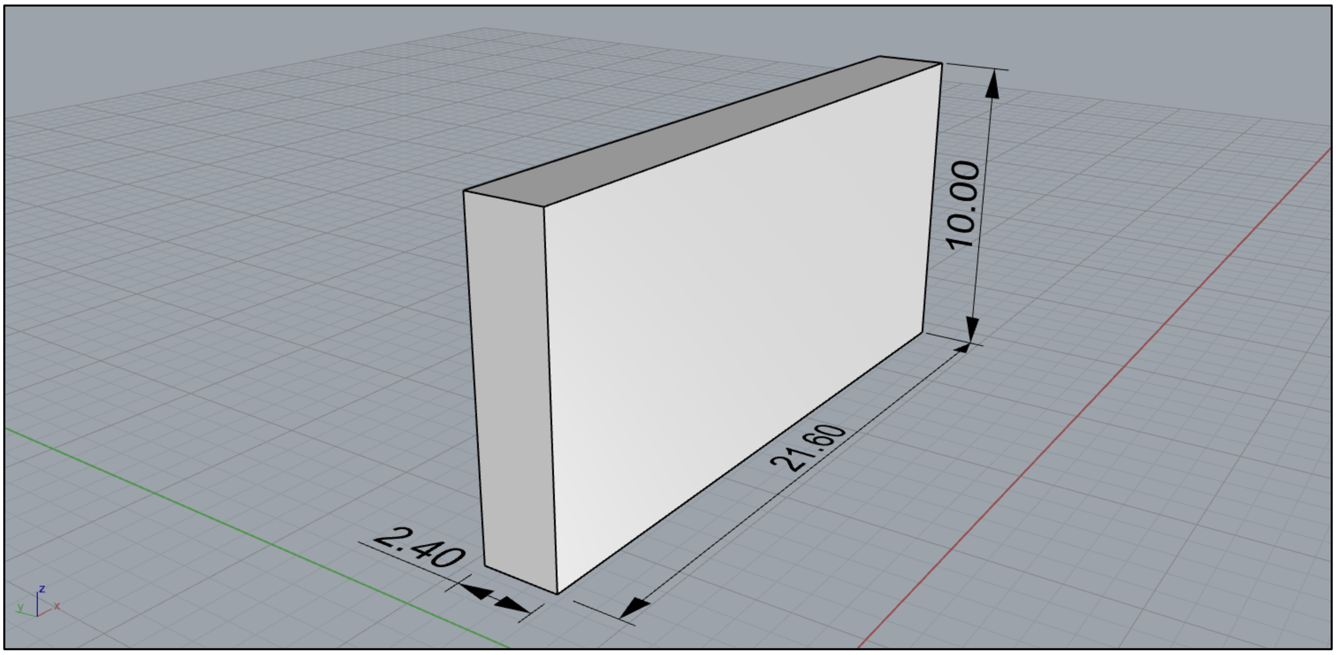
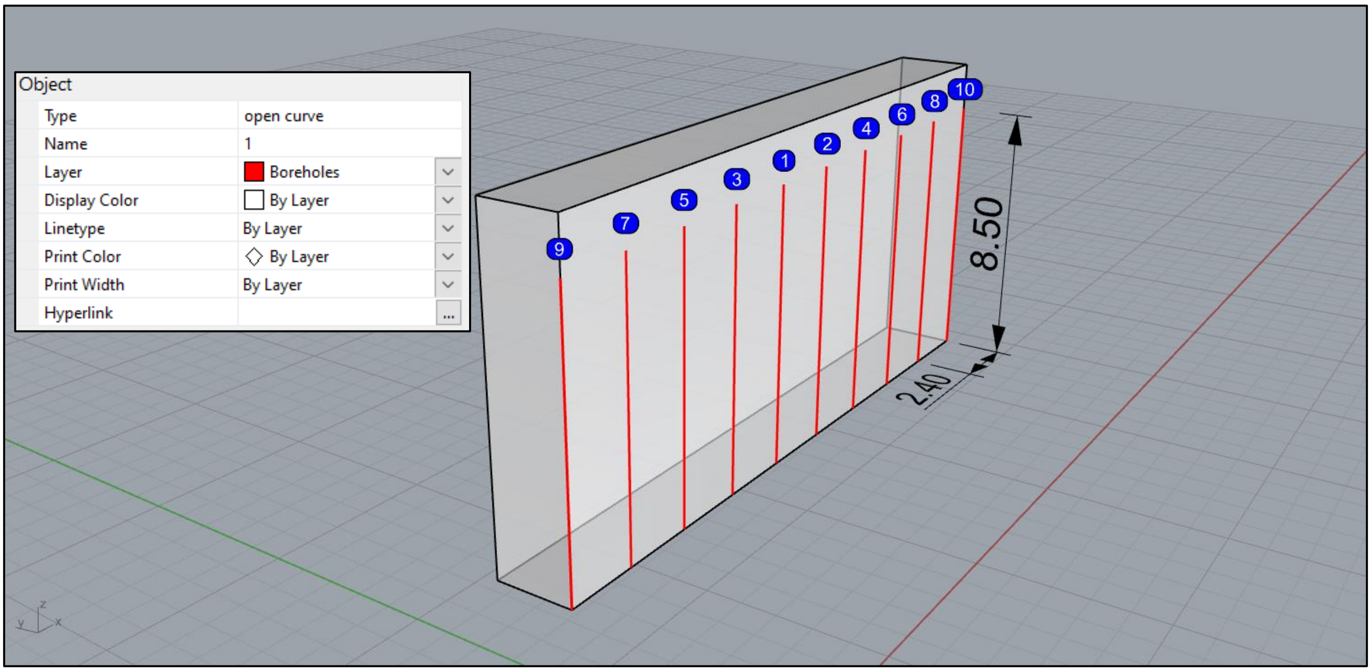


Figure 2 Solid block creation

Next, we are defining explosive charges by drawing vertical lines with 2.4m between them. In total we will draw 10 lines on ***Boreholes*** layer. Have in mind that these lines represent explosive charges and should be shorter for stemming length. ***Important*** step is defining sequence in which explosive charges are detonated. This is done by selecting single line representing explosive charge and entering number in ***Name*** field at Object properties tab in Rhino.



Object

Type	open curve
Name	1
Layer	🟥 Boreholes
Display Color	□ By Layer
Linetype	By Layer
Print Color	◇ By Layer
Print Width	By Layer
Hyperlink	

Figure 3 Explosive charge creation and sequencing of initiation

<u>Make sure that boreholes/lines lay exactly at boundary of solid block as showed in Figure 3.</u>

If you would like to incorporate fractures generated by blasting of previous row make right click on *Boreholes* layer in Layers tab and click on *Select objects*. Then, enter command in Rhino prompt *CopyToLayer* and select *Previous* layer from the list. Now we have exact copy of boreholes and we need to translate them to location of previous row. Right click on layer *Previous* and *SelectObjects* then enter *Move* in Rhino prompt and translate lines to opposite face of the solid block; translation vector is (0, 2.4, 0). At this moment we have new set of explosive charges that will be incorporated in analysis (Figure 4).

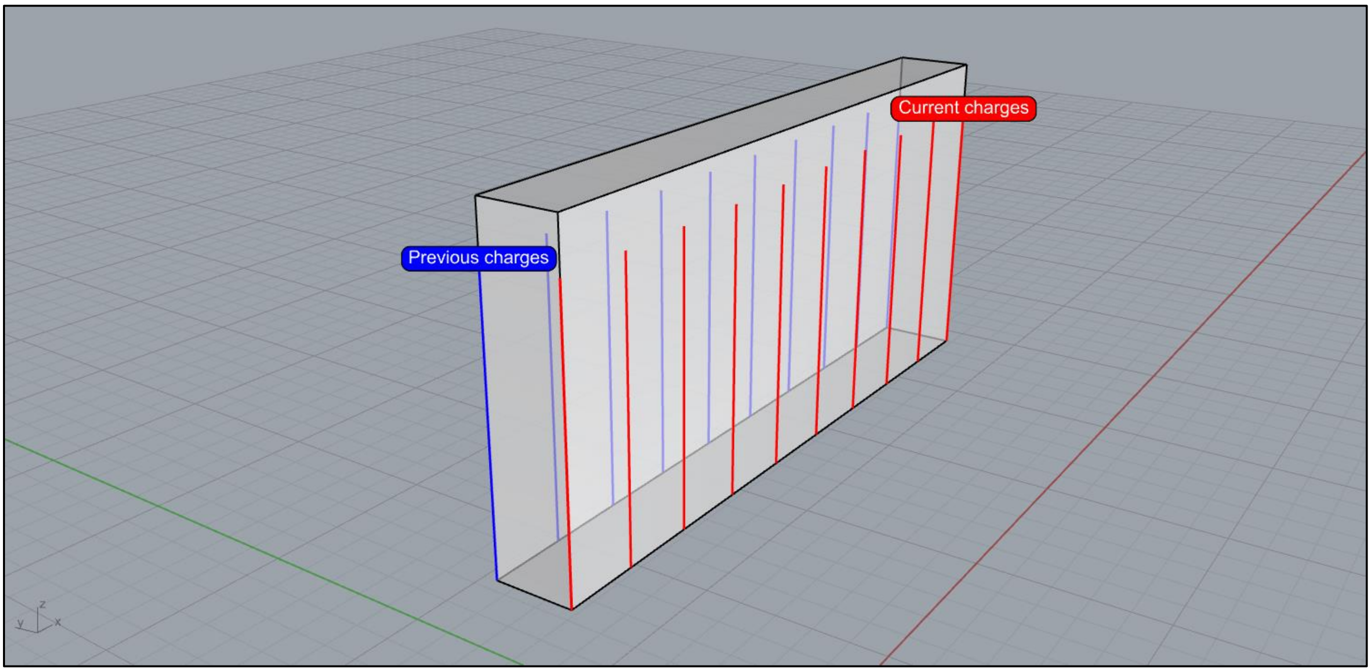


Figure 4 Solid block with current and previous charges

Important parameter for blast fragmentation analysis is primary block size or presence of natural fractures that will limit propagation of pressure wave generated by detonation, and therefore length of the blast induced fractures. Here we handle this phenomenon by introducing *Discrete Fracture Network* into analysis*.* DFN generation will be supported in close future, but for now DFN has to be generate in other way. DFN should be in form of disk/circle shaped surfaces.

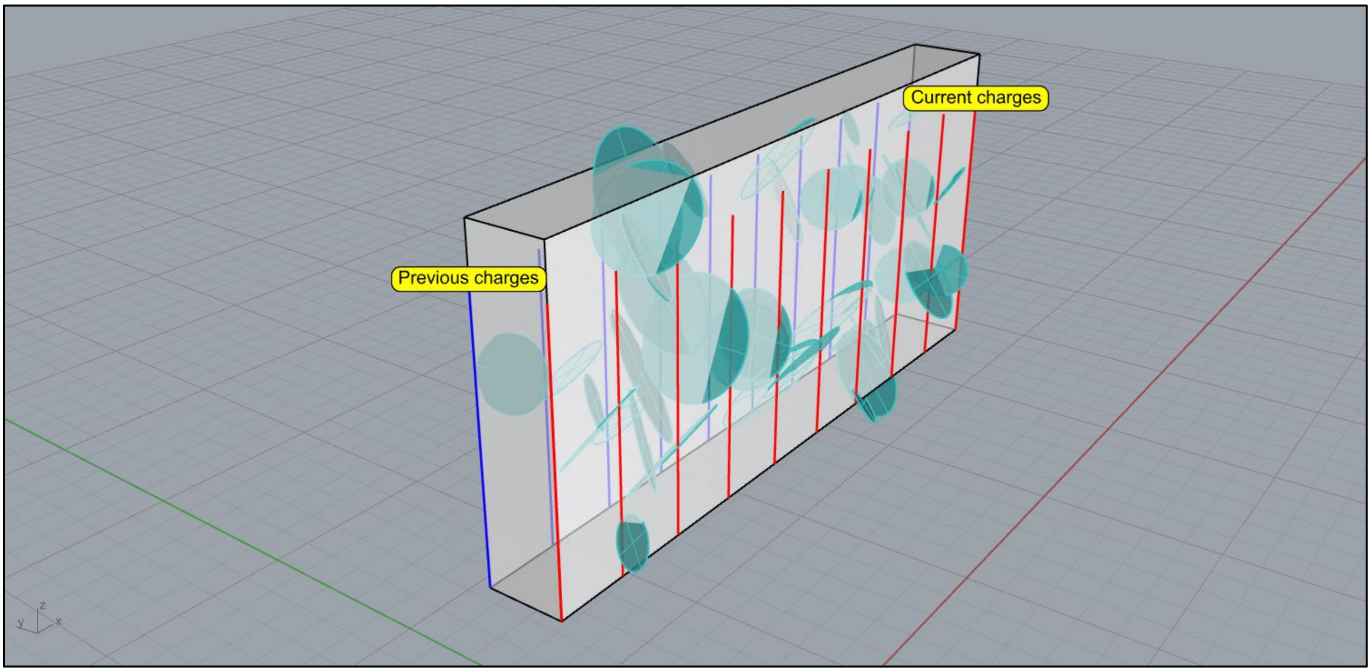


Figure 5 Solid block with DFN

Once DFN is incorporated in model we are ready to start.

Make sure current layer is set to ***Blocks.***

First command to be executed is ***primaryBlocks***. This command will split solid block into primary blocks as illustrated in

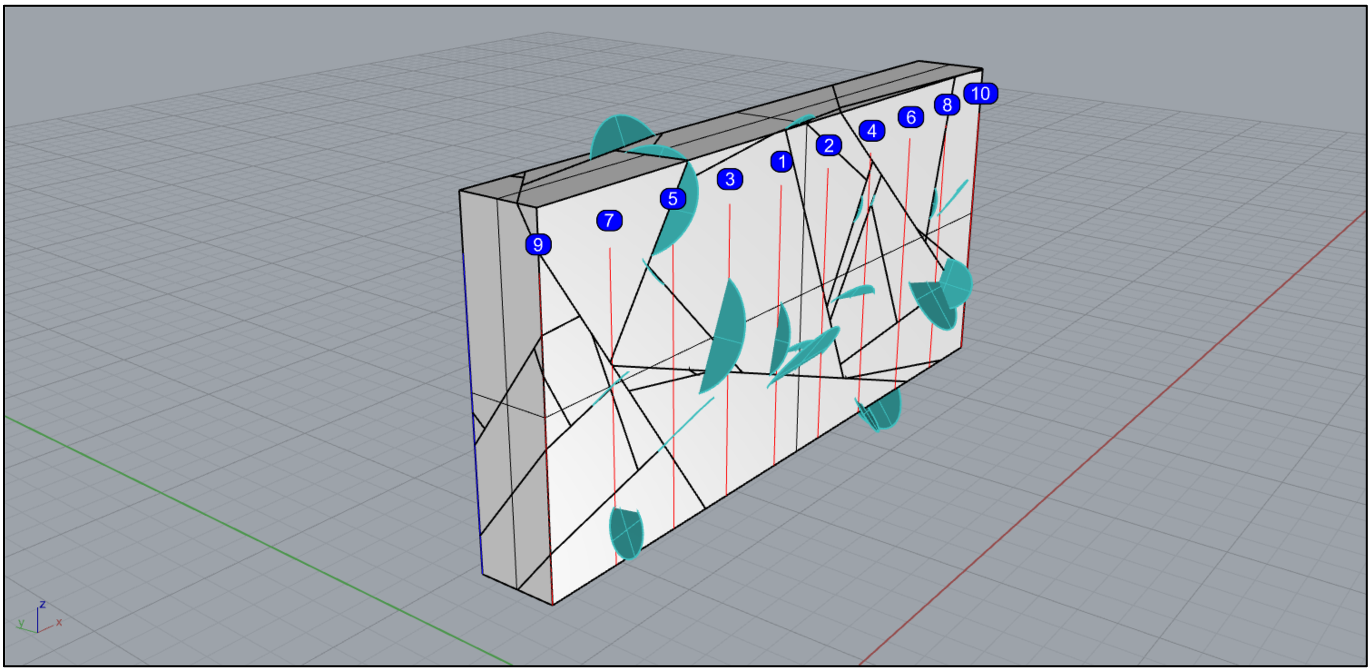
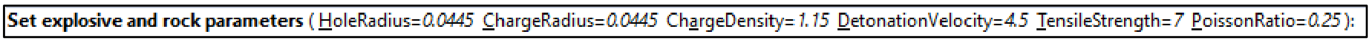


Figure 6 Primary blocks generated after primaryBlocks command

Next, ***fragment*** command has to be called. This command follows initiation order of the explosive charges, determines what rock blocks certain charge passes through and preforms its fragmentation. At the beginning user is asked to provide input for fragmentation command:



```
Set explosive and rock parameters ( HoleRadius=0.0445  ChargeRadius=0.0445  ChargeDensity=1.15  DetonationVelocity=4.5  TensileStrength=7  PoissonRatio=0.25 ):
```

After confirmation of the input parameters user is asked to confirm their correctness and warned that computation may take some time depending on the system. Have in mind that at this stage huge models may take significant amounts of RAM to compute. All available cores are use to speed process up. Computation progress is monitored in lower right corner by progress bar telling you what percentage of computation is completed.

With further development it is expected that code will become more efficient regarding resource consumption.

After completing fragment computation layer *Blocks* will contain all computed fragments as seen in Figure 7. This model resulted in more 110 000 fragments and Rhino's RAM usage is around 8GB, saved file on disk takes around 2.5GB.

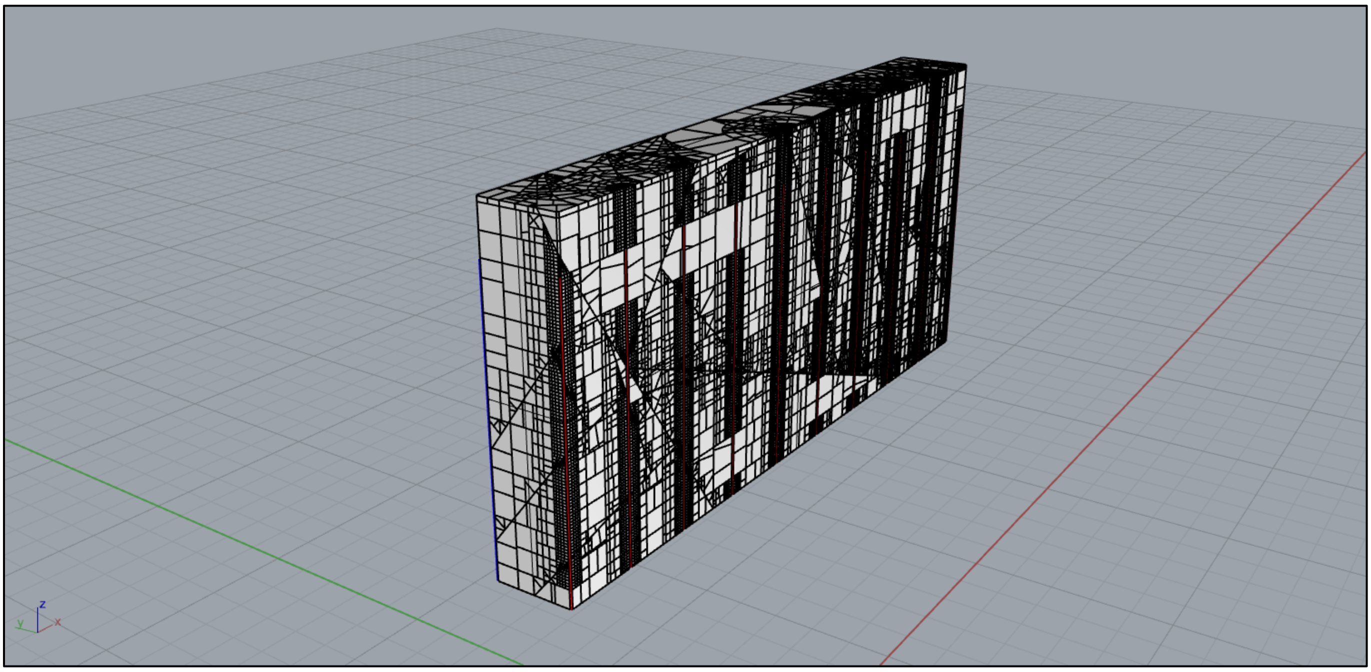


Figure 7 Computed fragments

By running ***analyze*** command results.csv file is exported containing volume and size of each fragment. This can be used to presents size distributions on plots in excel or other tools.

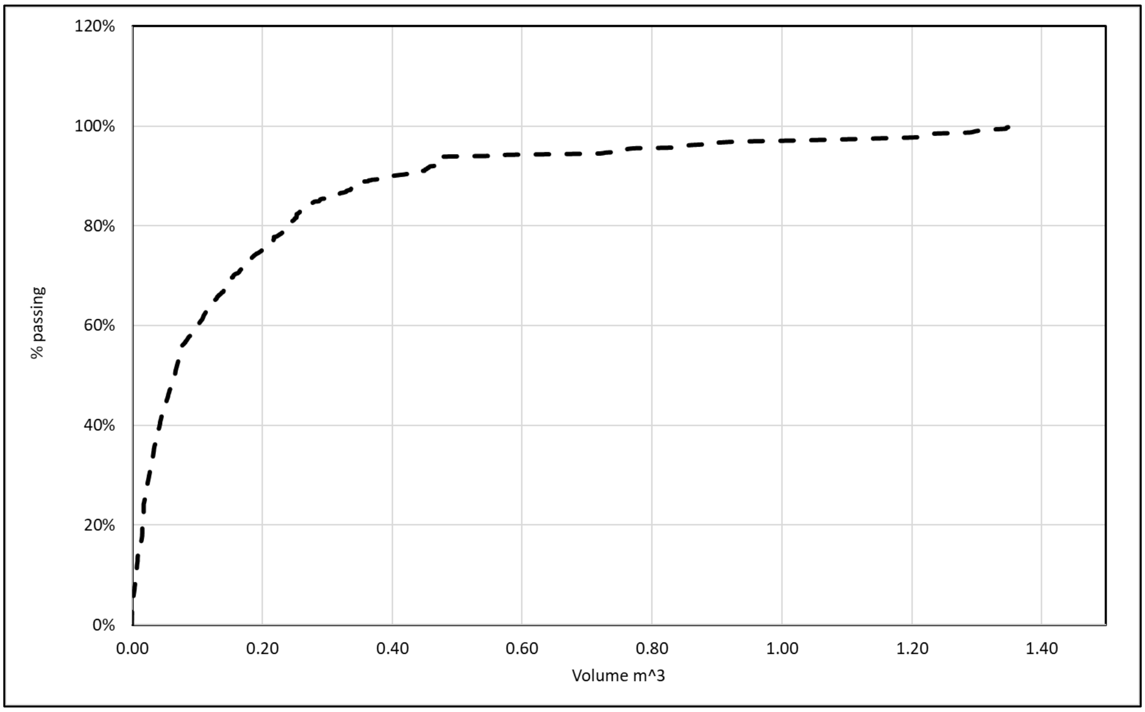


Figure 8 Resulting fragment size distribution

8 References

Torbica, S., & Lapčević, V. (2018). Rock fracturing mechanisms by blasting. *Podzemni radovi*, (32), 15-31.

Torbica, S., & Lapcevic, V. (2014). Model for estimating blasted rock fragmentation. *International Multidisciplinary Scientific GeoConference: SGEM*, *3*, 379.

Torbica, S., & Lapčević, V. (2016). Fragmenting of cylindrical rock specimens under explosive load: Comparison between model and laboratory results. *Mining and Metallurgy Engineering Bor*, (1), 103-114.