RocTunnel3

Block Computations

Verification Manual

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Introduction

This document presents examples that are used to verify the validity of blocks formed by the Block Engine in RocTunnel3. For a block to be correctly determined, the following must be established:

1. Joint surfaces intersect the material volumes to 'cut' the material volumes into finite volume pieces.
2. For each volume piece, determine:
   a. The volume
   b. The faces:
      i. If the face is a joint face and which joint cut it.
      ii. If the face is a material boundary (i.e., surface separating two different volume pieces belonging to the same block).
      iii. If the face is a free face (i.e., daylighting face of the block).
3. For each block, determine the volume piece(s) which belong to the same block.
4. The determination of the non-terrain surface which encompasses the sides and the bottom of the external geology. Any blocks attached to the non-terrain surface are considered invalid.

1. Block Verification #1

[RocTunnel3 Build 1.001]

1.1. Problem Description

For this verification, a 10 x 10 x 10 axis-aligned box is used as the External.

The table below outlines the coordinates used to form the external box.

Table 1.1: External Box Coordinates

Box Corners	X	Y	Z
First Corner	0	0	0
Second Corner	10	10	10

Table below outlines the three joint properties defined in the model.

Table 1.2: Joint Properties

Joint Property	Strength	Cohesion (MPa)	Phi (⁰)	Override by Material	Waviness (⁰)	Water Pressure Method
1	Mohr-Coulomb	0	35	No	0	Dry
2	Mohr-Coulomb	0	20	No	0	Dry
3	Mohr-Coulomb	0	10	No	0	Dry

Four materials are defined, their properties are listed in the table below.

Table 1.3: Material Properties 1 – 4

Material 1

Rock Mass Unit Weight	0.026 MN/m^3
Groundwater Method	Water Surfaces
Water Surface	None

Material 2

Rock Mass Unit Weight	0.03 MN/m^3
Groundwater Method	Water Surfaces
Water Surface	None

Material 3

Rock Mass Unit Weight	0.034 MN/m^3
Groundwater Method	Water Surfaces
Water Surface	None

Material 4

Rock Mass Unit Weight	0.038 MN/m^3
Groundwater Method	Water Surfaces
Water Surface	None

2 planes are used to divide the external into 4 equal sub-regions. Their geometry is listed in the table below.

Table 1.4: Geometry of planes that divide the External into 4 equal sub-regions

Plane	Origin (x, Y, Z)	Defined by	Plane Orientation (X, Y, Z)	Role
1	(5, 5, 5)	Normal Vector	(0.7071, 0.7071, 0)	Geology
2	(5, 5, 5)	Normal Vector	(-0.7071, 0.7071, 0)	Geology

Four material pieces exist, each assigned to a sub-region of the external.

Table 1.5: Material Assignments for External Regions

Region	Material

External_1	Material 1
External_2	Material 2
External_3	Material 3
External_4	Material 4

Three sets of orthogonal joints which persist the entire external extents are added and spaced consistently at 2 m apart.

Table 1.6: Synthetic Joint Data

Synthetic Joint Set Number	Joint Property Number	Dip (º)	Dip Direction (º)	Radius (m)	Spacing (m)	Traverse Start [X, Y, Z] (m)	Traverse End [X, Y, Z] (m)
1	1	90	0	20	2	5, 0, 5	5, 10, 5
2	2	90	90	20	2	0, 5, 5	10, 5, 5
3	3	0	0	20	2	5, 5, 0	5, 5, 10

1.2. Blocks

125 blocks are expected from the division of a 10 m x 10 m x 10 m external box, by three orthogonal sets spaced at 2 m.

$$total\ number\ of\ blocks = (10\ m/\ 2\ m) * (10\ m/\ 2\ m) * (10\ m/\ 2\ m) = (5\ blocks) * (5\ blocks) * (5\ blocks) = 125\ blocks$$

1.2.1. Number of Valid Blocks

Of those blocks, the ones which have a free surface on the sides or bottom of the external box will be considered invalid. Invalid blocks are those that touch the non-terrain, which in this case would be the four vertical sides and the bottom of the external box.

$$total\ number\ of\ valid\ blocks = (5-2) * (5-2) * (5-1) = 36\ blocks$$

In RocTunnel3, the Block Information lists 36 blocks when viewing All Valid Blocks. This validates that the correct number of expected sub volumes are created. Also, the correct non-terrain surface is computed and the blocks touching the non-terrain are being properly discarded as invalid blocks.
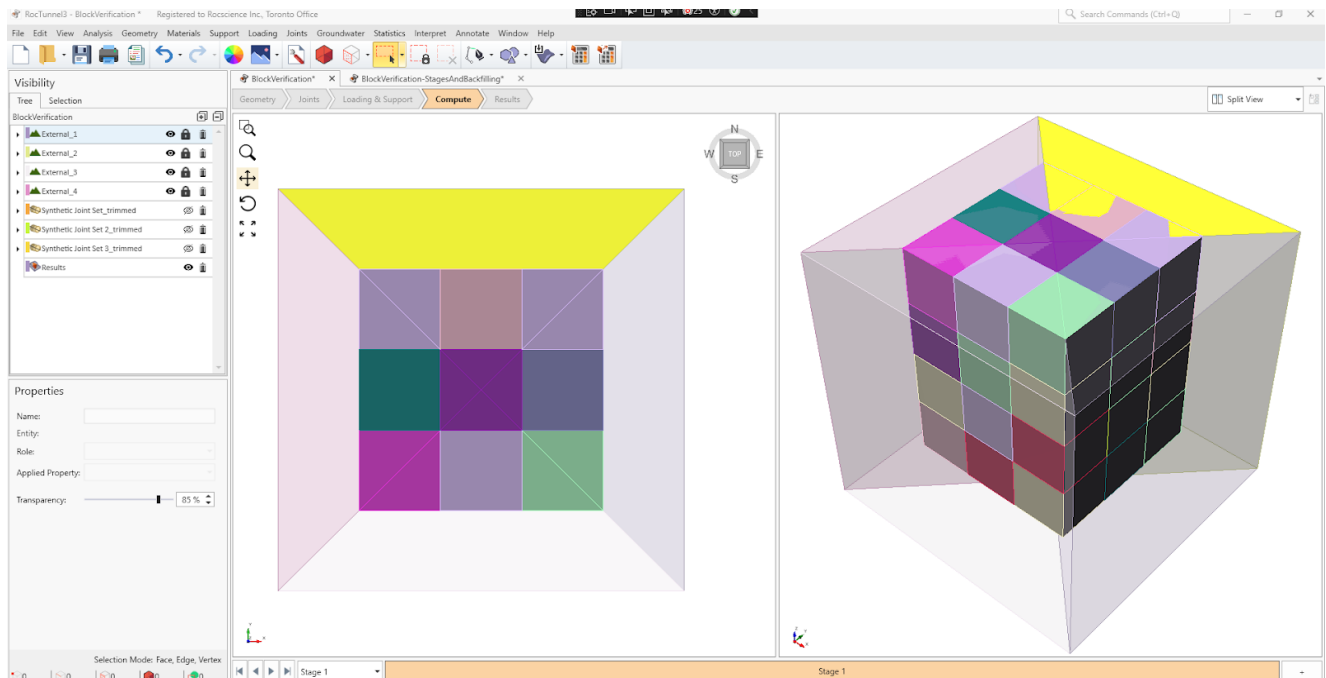
Figure 1.1: RocTunnel3 3D CAD View showing All Valid Blocks

1.2.2. Volume

Each block should have the same volume formed by 2 m x 2 m x 2 m joint spacing.

$$block\ volume = (2\ m) * (2\ m) * (2\ m) = 8\ \text{m}^3$$

In RocTunnel3, all Valid Blocks in the Block Information pane have a Volume of 8 m^3. This validates that the correct volume is computed for each material piece. For blocks which have more than one material piece, this also validates that the correct material boundaries are mapped to determine the adjacent volume piece(s) which belong to the same block.

1.2.3. Slope Face Area

For blocks that daylight (i.e., have a face on the top of the external box), the daylighting area should be a square with 2 m x 2 m dimensions.

a)   The slope face area for:

- A daylighting block is computed as:

$$block\ slope\ face\ area = (2\ m) * (2\ m) = 4\ \text{m}^2$$

- For non-daylighting blocks:

$$block\ slope\ face\ area = 0$$

b)   The total number of blocks which daylight should only include the top blocks:

$$total\ number\ of\ daylighting\ blocks = (5-2) * (5-2) = 9\ blocks$$

In RocTunnel3, 9 of the Valid Blocks in the Block Information have a Slope Face Area of 4 (these are the daylighting blocks) and the remaining 27 blocks have a Slope Face Area of 0. This validates that the free surfaces of blocks are determined correctly.

1.2.4. Joints

For blocks which daylight (i.e., have a face on the top of the external box), they should have 5 joint faces (2 joint faces from Synthetic Joint Set 1, 2 joint faces from Synthetic Joint Set 2, and 1 joint face from Synthetic Joint Set 3).

For non-daylighting blocks, they should have 6 joint faces (2 joint faces from Synthetic Joint Set 1, 2 joint faces from Synthetic Joint Set 2, and 2 joint faces from Synthetic Joint Set 3).

In RocTunnel3, 9 of the Valid Blocks in the Block Information pane have a value of 5 for # of Joints (these are the daylighting blocks) and the remaining 27 blocks have a value of 6 for # of Joints.

In RocTunnel3, the Detailed Block Information for any given non-daylighting block will indicate that the there exists:

• 2 parallel vertical joints with:

- Dip = 90, Dip Direction = 0 or 180
- Joint Property = Joint Property 1
- Area = 4 m^2

• 2 parallel vertical joints with:

- Dip = 90, Dip Direction = 90 or 270
- Joint Property = Joint Property 2
- Area = 4 m^2

• 2 parallel horizontal (or a single horizontal joint if non-daylighting) joints with:

- Dip = 0, Dip Direction = 0 or 180
- Joint Property = Joint Property 3
- Area = 4 m^2

This validates that the joint surfaces of blocks are determined correctly and that their assigned joint properties are also getting mapped correctly.

1.3. RocTunnel3 Results

The RocTunnel3 results are summarized below.

Table 1.7: RocTunnel3 Results

ID	Volume (m³)	Slope Face Area (m²)	Number of Joints
1	8.01	0	6

2	8	0	6
3	8.01	0	6
4	8	0	6
5	8	4	5
6	8	0	6
7	8	4	5
8	8	0	6
9	8	0	6
10	8	0	6
11	8	4	5
12	8	0	6
13	8	0	6
14	8	0	6
15	8	0	6
16	8	4	5
17	8.01	0	6
18	8.01	0	6
19	8	0	6
20	8	4	5
21	8	0	6
22	8	4	5
23	8	0	6

24	8	0	6
25	8	0	6
26	8	4	5
27	8	0	6
28	8	0	6
29	8	0	6
30	8	0	6
31	8	4	5
32	8	0	6
33	8	4	5
34	8	0	6
35	8	0	6
36	8	0	6

Detailed block information (block 5).

Table 1.8: Block 5 Detailed Block Information

ID	Area (m²)	Joint Property	Dip (⁰)	Dip Direction (⁰)
1	4	Joint Property 2	90	90
2	4	Joint Property 1	90	0
3	4	Joint Property 3	0	180
4	4	Joint Property 2	90	270
5	4	Joint Property 1	90	180

2. Block Verification #2

[RocTunnel3 Build 1.001]

In this example staging and results after backfilling will be tested. The external box and joints used in this example are same as Block Verification #1. Please refer to its Problem Description (Section 1.1) for geometry details.

It is important to note that three stages are defined for this verification. Materials assigned to each sub-external region are different in each stage. Assignments can be seen in the table below.

Table 2.1: External Region Material Assignments

Region	Stage 1	Stage 2	Stage 3
External_1	Material 1	No Material	Material 2
External_2	Material 2	Material 2	Material 2
External_3	Material 3	Material 3	Material 3
External_4	Material 4	Material 4	Material 4

Now expected results will be compared to the observed results in each stage.

2.1. Stage 1 Results

Since all the settings, geometries and material assignments remain consistent between Stage 1 of this verification and Block Verification #1, the observed results from Block Verification # 1 should also apply here.

As expected, 36 valid blocks are observed, each with a volume of 8 m^3. 9 of those blocks are removable, while the remaining 27 blocks have a Slope Face Area of 0. This confirms the validity of our Stage 1 results.
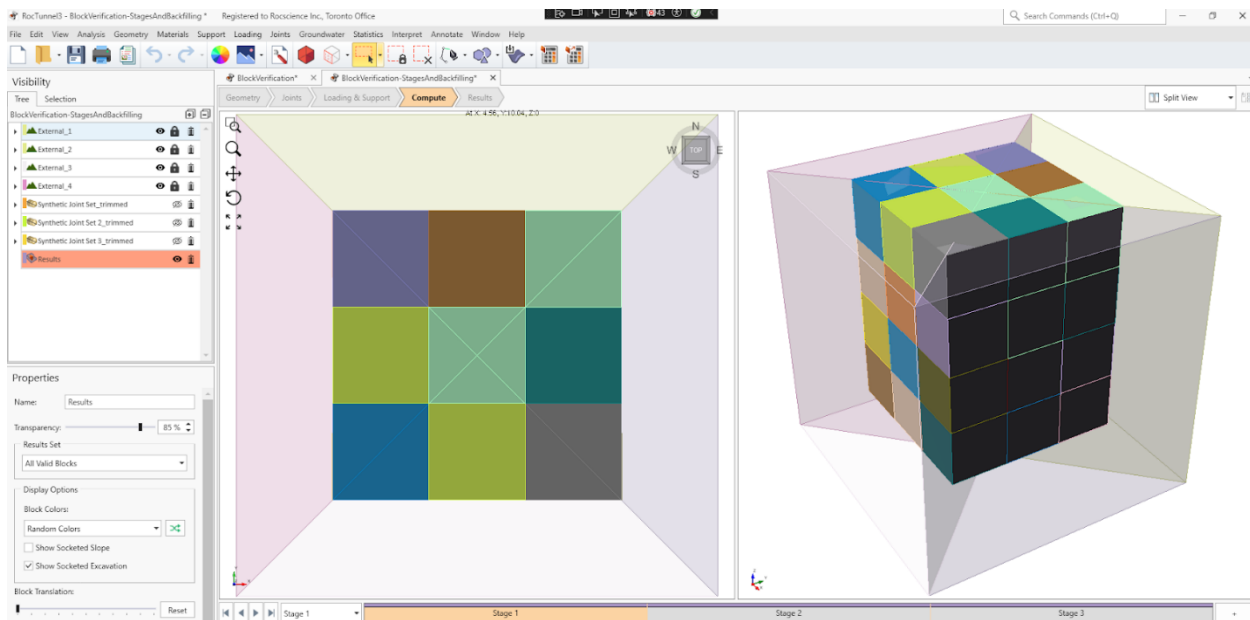
Resulting geometry can be seen in Figure 2.1 below.

Figure 2.1: Stage 1 Model After Computing Results

2.2. Stage 2 Results

We expect blocks to be absent in External 1 in this stage. This absence is attributed to Box 1 lacking any assigned material; hence no blocks should be formed.

In the "all valid blocks" section of the results, our anticipation aligns with the actual outcome: 8 blocks with half the volume (4 m^3) and 4 blocks with 3/4ths (6 m^3) of the volume of a full block (8 m^3). This alignment verifies the accuracy of our expectations.

This also verifies that staging is working as expected, since we see different and expected results in Stage 1 and 2.

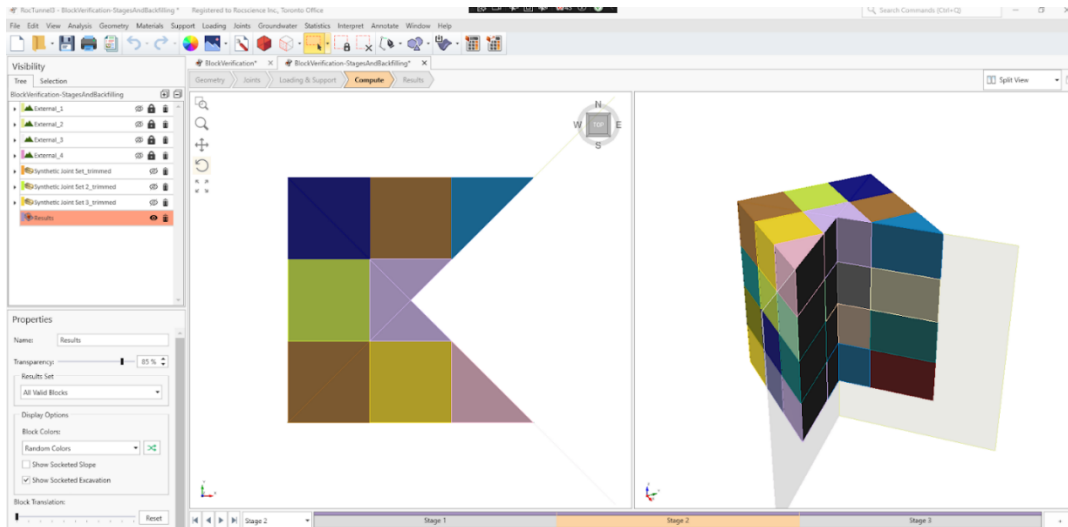Resulting geometry can be seen in Figure 2.2 below.

Figure 2.2: Stage 2 Model After Computing Results

2.3. Stage 3 Results

In Stage 3, Material 2 is assigned to External 1, effectively backfilling it. Consequently, the expectation is that:

- No blocks will form in External 1 as joints were previously excavated in Stage 2 and do not occur in the backfill material.
- No blocks touching External 1 are valid since they are assumed to be "cemented" to the backfill.

As anticipated, a total of 20 valid blocks are observed, none of them inside or touching External 1 volume, verifying the expected block results. This verifies that staging is working as expected.
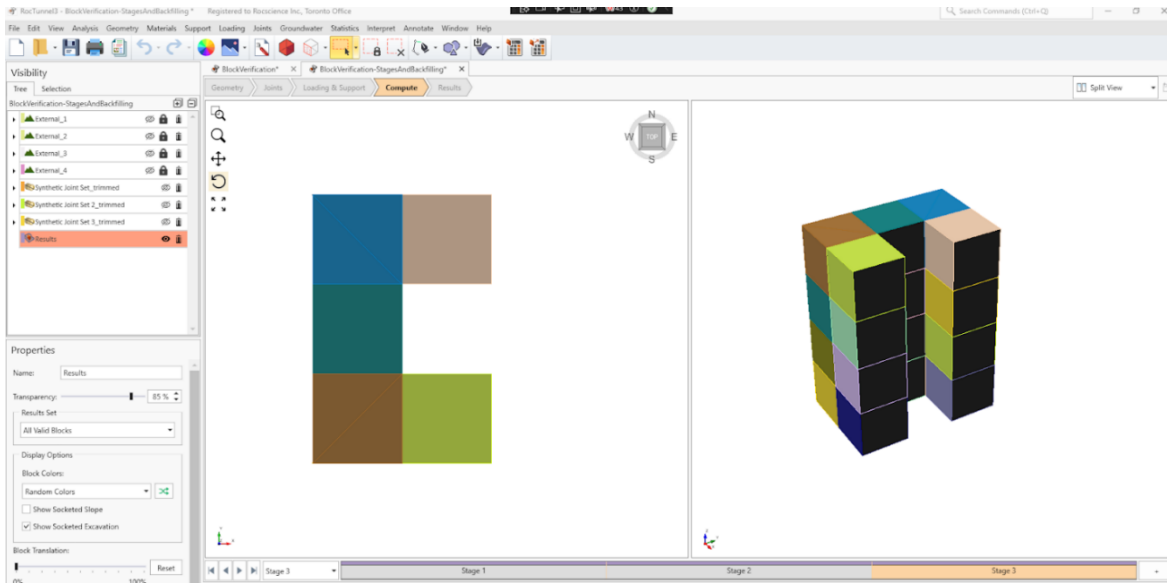
Resulting geometry can be seen in Figure 2.3 below.

Figure 2.3: Stage 3 Model After Computing Results