ROCSCIENCE

CPillar

Crown Pillar Stability Analysis

Verification Manual

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1. CPillar Rigid Analysis Verification

This document presents several examples, which have been used as verification problems for CPillar. CPillar is an engineering analysis program for assessing the stability of surface or underground crown pillars, and laminated roof beds, produced by Rocscience Inc. of Toronto, Canada.

The results produced by CPillar agree very well with the documented examples and confirm the reliability of CPillar results.

2. CPillar Verification Problem #1

[*CPillar Build 5.001*]

2.1. Problem Description

In this verification example, the Rigid analysis results of a rectangular pillar in CPillar are verified against the sensitivity analysis conducted in the paper, “A Limit Equilibrium Analysis of Surface Crown Pillar Stability”, by Hoek (1989). The Rigid analysis method in CPillar uses the same equations as Hoek (1989), whereby only shear failure (sliding) along the abutments are considered. The computations should yield identical results.

2.2. Analytical Solution

The model geometry, lateral stress and strength parameters are from Hoek (1989).

2.2.1. Geometry and Material Properties

Table 2.2.1: Pillar Geometry and Materials

Geometry Input Data	
Pillar Length (m)	7
Pillar Width (m)	20
Pillar Height (m)	5
Rock Unit Weight (MN/m^3)	0.027
Overburden Unit Weight (MN/m^3)	0
Water Unit Weight (MN/m^3)	0.01
Pillar Permeable	Yes

2.2.2. Lateral Stress

Table 2.2.2: Lateral Stress

Lateral Stress Input Data	
Stress Type	Gravity
Water Height (m)	5
Overburden Height (m)	0
Locked In Stress (MPa)	0
Horizontal/Vertical Kx	0.5

Horizontal/Vertical Ky	0.5

2.2.3. Strength

Table 2.2.3: Strength Criterion

Strength Input Data	
Strength Type	Hoek-Brown
Intact UCS (MPa)	60
Rock Mass Rating $\boldsymbol{RMR}$	40
Material Constant $\boldsymbol{m_i}$	10
Rock Mass $\boldsymbol{m}$ Value*	0.1376
Rock Mass $\boldsymbol{s}$ Value*	4.54×10^{-5}

* See equations below for computation.

Rock mass m value is calculated from m_i and RMR using:

$$m = m_i \exp\left(\frac{RMR - 100}{14}\right) = (10)\exp\left(\frac{40 - 100}{14}\right) = 0.1376$$

Rock mass s value is calculated from RMR using:

$$s = \exp\left(\frac{RMR - 100}{6}\right) = 4.54 \times 10^{-5}$$

2.3. CPillar Analysis

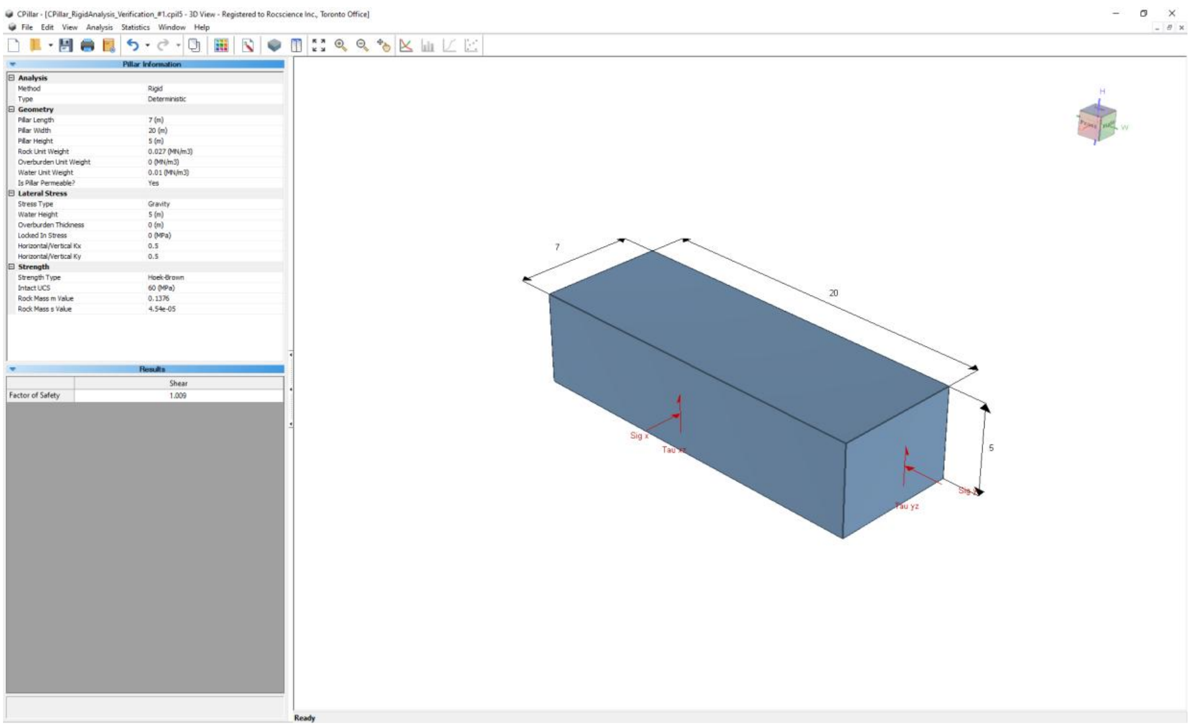
2.3.1. Deterministic Analysis

Set the Analysis Method in CPillar to Rigid and Analysis Type to Deterministic.

2.3.2. Enter the input values from Table 2.2.1, Table 2.2.2, and

Table 2.2.3 into CPillar.

The CPillar model looks like this:



2.3.3. Sensitivity Analysis

A sensitivity analysis is performed in CPillar to see how sensitive the Factor of Safety is to changing parameters. The following parameters were varied:

Table 2.3.1: Sensitivity Ranges

Sensitivity Parameter	Range	
	Minimum	Maximum
Rock Mass Rating RMR	1	80
Horizontal/Vertical Stress Ratio K ($K_x = K_y$)	0.1	5
Water Height Z_w (m)	0	5
Pillar Height Z (m) ($Z_w = Z$)	0.1	30
Material Constant m_i	5	30

Intact UCS (MPa)	20	100

Note that:

When varying the Horizontal-to-Vertical Stress Ratio (K), both K_x and K_y are changed simultaneously in CPillar.

When varying Pillar Height (Z), Water Height is changed simultaneously in CPillar to reflect a fully wetted pillar.

When varying Rock Mass Rating (RMR) or Material Constant m_i, the CPillar inputs for m and s are calculated based on the equations in Section 1.2.

2.4. Results

2.4.1. Deterministic Analysis

The deterministic inputs were calibrated by Hoek (1989) to give a Factor of Safety of approximately 1. The Factor of Safety computed by CPillar using the deterministic inputs is 1.009 ≈ 1.

2.4.2. Sensitivity Analysis

By comparing the sensitivity results of Hoek (1989) and CPillar, it can be seen that they produce identical results, with the exception of the first data point in Factor of Safety vs. K plot. This discrepancy is due to the fact that CPillar will set a very small effective lateral stress limit (close to 0) when the water pressure exceeds the total lateral stress. This ensures that the effective lateral stress used to compute the shear strength is never less than zero.

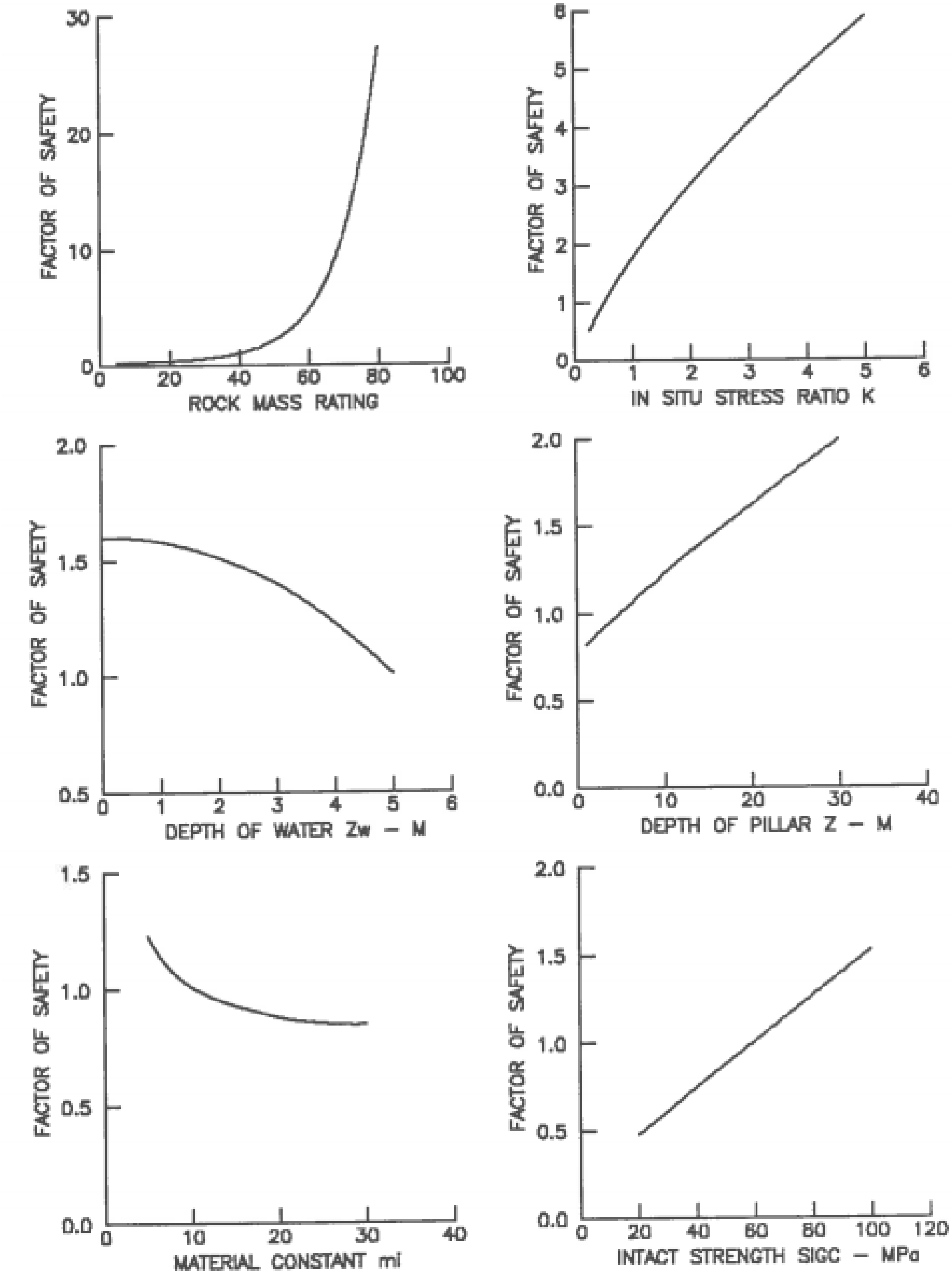


Figure 2.4.1: Sensitivity Plots Provided by Hoek (1989)

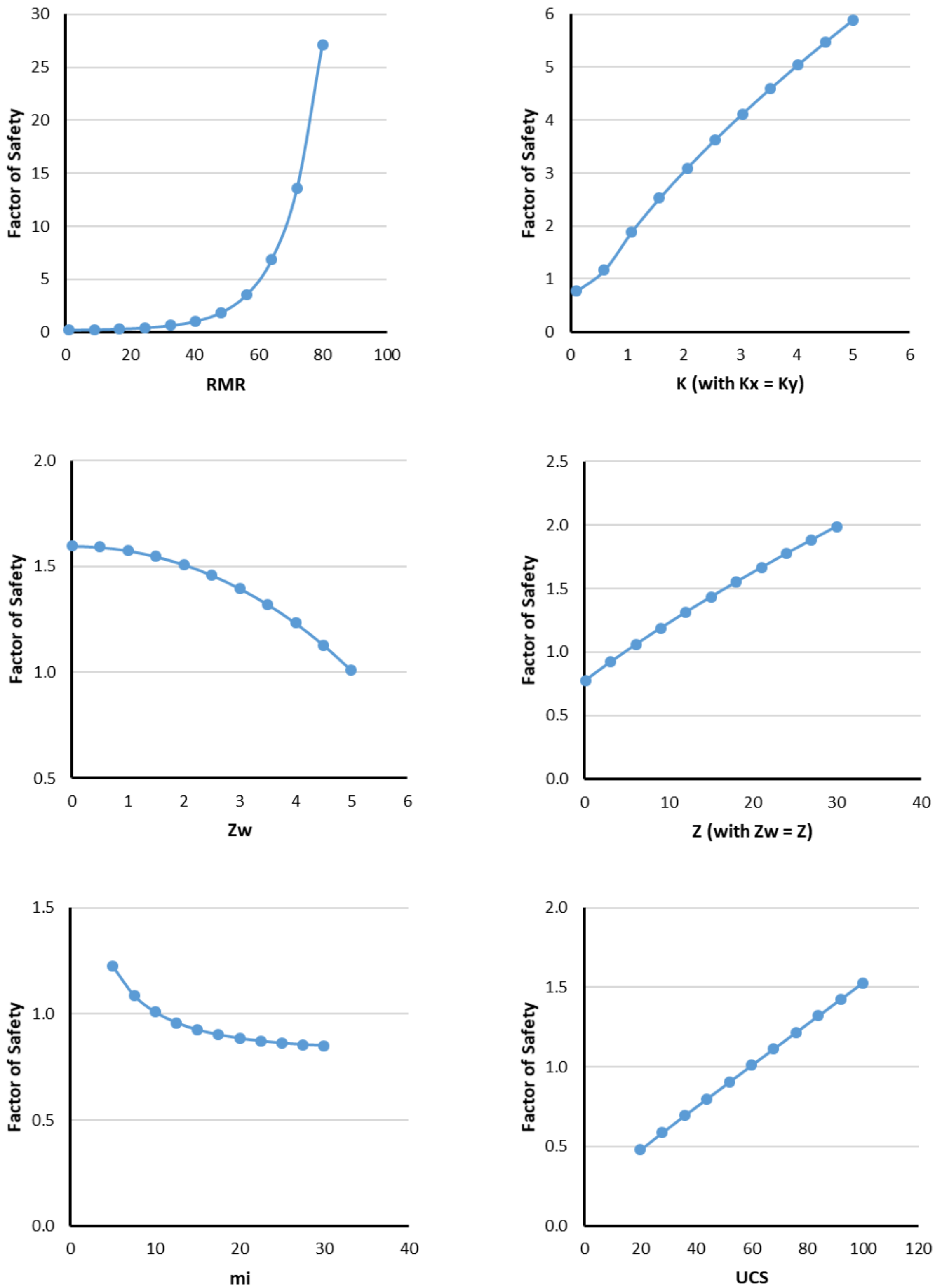


Figure 2.4.2: CPillar Sensitivity Analysis Results

Therefore, CPillar's results have been verified with Hoek's results.

3. References

Hoek, E. (1989) A Limit Equilibrium Analysis of Surface Crown Pillar Stability. Proc. Int. Conf. on Surface Crown Pillars Active & Abandoned Metal Mines Timmins, pp. 3-13.