Mining induced vertical stress change monitoring at Rocanville potash mine

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Summary

The Geokon model 4300BX soft rock borehole stressmeters were installed into potash pillars to monitor mining induced vertical stress change at the Rocanville potash mine. Field monitoring result are compared with numerical modeling result.

Introduction

Rocanville division is one of the conventional underground potash mines operated by Nutrien Inc. in Saskatchewan. Potash is mined from a relatively flat tabular ore body at approximately 1000 m below the surface. Long room and pillar mining method is employed at the Rocanville potash mine. As shown in Figure 1, production rooms with height of 2.44 m are mined in three passes using four-rotor boring machines. Potash pillar are left between production rooms to support the overburden. To understand the impact of mining on the potash pillar, the Geokon vibrating wire model 4300BX borehole stressmeters for soft rock [1] were installed into the potash pillar to monitor mining induced pillar vertical stress change.

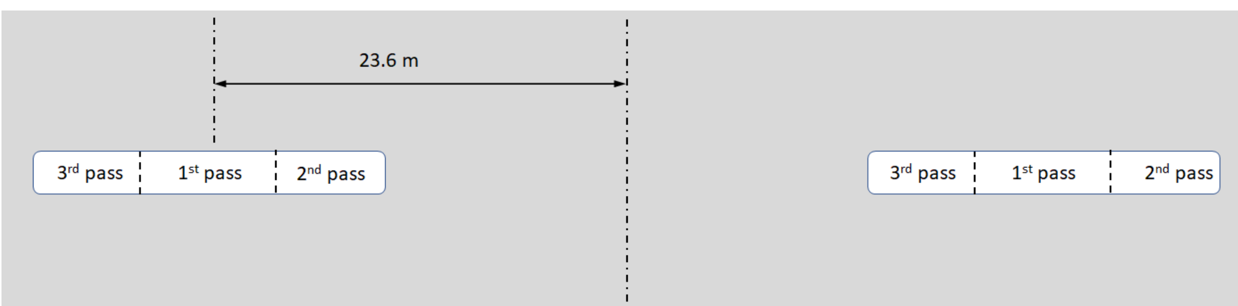

Figure 1. Schematic vertical section view of Rocanville long room & pillar mining (look into the mining direction)

Method / Workflow

Figure 2 shows a plan view of the mine layout with Geokon vibrating wire model 4300BX borehole stressmeter installation locations. After the travel way, belt entry and Room #1 were mined out, three boreholes with depths of 6.1 m, 9.1 m and 12.2 m respectively were drilled into the middle height of pillars at locations A, B and C, using the Jumbo drill. In total, nine stressmeters were installed vertically inside the boreholes. In theory, mining Rooms #2, #3, and #4 would impose changing loads on the stressmeter inside the borehole, which then cause the stressmeter vibration frequency to change. By installing the stressmeter vertically inside the borehole, the mining induced vertical stress change is monitored. The vibration frequency change is believed to be proportional to the stress change in the surrounding rock. The ratio of stress change to vibration frequency change is called sensitivity factor which is typically determined through laboratory and/or field calibration. Since no calibration data for the model 4300BX soft rock stressmeter is available, a sensitivity factor of 0.0138 MPa/digit was assumed in order to convert vibration frequency change into stress change. In addition, a FLAC3D [2] model was built and calibrated using room convergence and roof expansion data collected in the same mining area. Vertical stress change monitoring data from the field was then compared with the numerical modeling result.

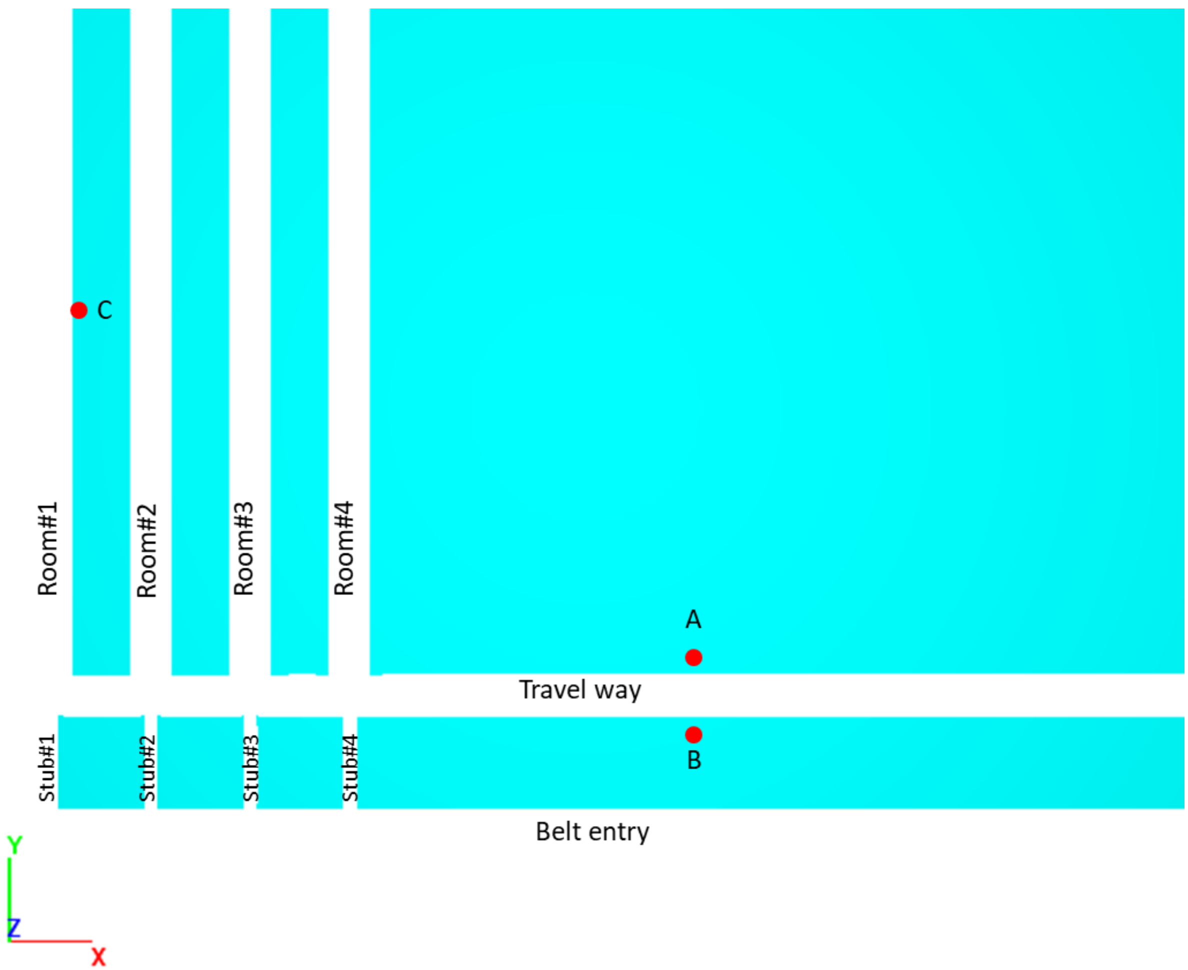

Figure 2. Plan-view of the mine layout showing locations where the Geokon borehole stressmeters were installed

Results, Observations, Conclusions

The initial vibration frequency after installation of these nine stressmeters varied from 4000 (Cell#1 at location A) to 5400 (Cell#5 at location B) digit units, which was believed to be in the typical range of Geokon 4300BX soft rock stressmeter installed in potash rock boreholes. Datalogger started recording data in January 2015. Due to connecting cable damage, power outages and other technical issues, only the six stressmeters installed at locations A & B captured the potash pillar ground response to the mining of Rooms #3 & #4 which occurred from the end of June to the end of September 2015. The shortest linear distances from Room#4 to locations A & B are 160 m and 161.2 m respectively.

Monitoring data collected from stressmeters installed at locations A and B is converted into vertical stress change (Figure 3) by assuming sensitivity factor of 0.0138 MPa/digit. As can be seen from Figure 3, stressmeters at locations A and B responded to the cutting of Room#3 third pass and Room#4 first pass & third pass quite well - the increase of vertical stress is obvious in Figure 3. However, the magnitudes of vertical stress changes varied from 1.1 to 6.97 MPa. Stressmeters Cell#1 at location A and Cell#4 at location B were installed roughly same pillar depth of 12.2 m. The vertical stress change for Cell#1 is two times of that for Cell#4 (6.97 MPa Vs 3.41 MPa). For Cell#2 at location A and Cell#5 at location B which were installed ~ 9.1 m into the pillars, the vertical stress change magnitudes are similar (3.7 MPa Vs 3.42 MPa). Stressmeters Cell#3 at location A and Cell#6 at location B were installed approximately 6.1 m into the pillars. The vertical stress change for Cell#3 is 3.5 times of that for Cell#6 (3.87 MPa Vs 1.1 MPa). Results from six stressmeters at locations A & B indicate variable responses to the same mining activity. It is believed that the borehole circumference condition might be the main factor causing the large variation on those six stressmeters monitoring results. Although every effort was made to ensure relatively straight borehole, small undulation of the drillhole trajectory was observed during the installation when trying to push the stressmeter into the borehole and to the designated depth. Uneven borehole circumference surface could affect the contact interface between the rock and the stressmeter, which affects the stressmeter vibration frequency. If the maximum of 6.97 MPa and minimum of 1.1 MPa field data are treated as outliers due to uneven contact interface between the rock and stressmeter, these two measurements can then be discarded. And mining-induce average vertical stress change in the 6 – 12 m pillar depth range for locations A & B is estimated to be approximately 3.6 MPa for the field measurement.

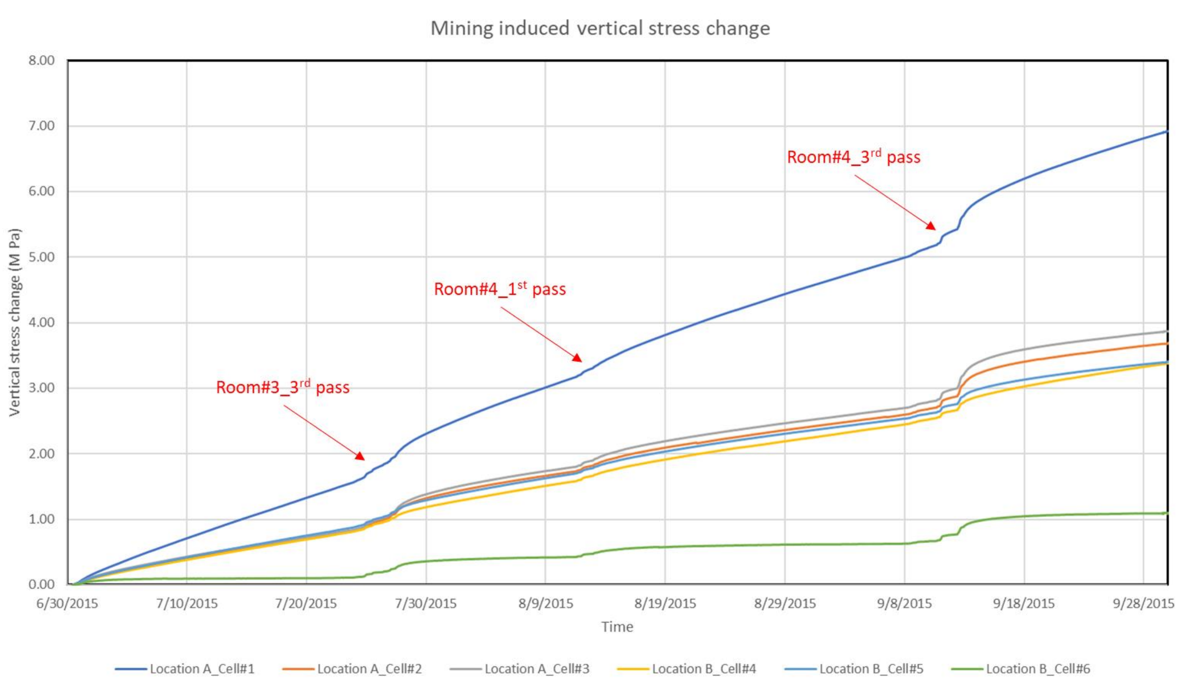

Figure 3. Mining induced vertical stress changes from borehole stressmeters installed at location A & location B

Figure 4 shows mining induced vertical stress changes from FLAC 3D modeling for various pillar depths at locations A & B. Numerical modeling results indicate that less than 0.5 MPa vertical stress change in the pillar depth of 6 – 12 m was induced by mining activity more than 160 m away. For similar pillar depths, mining activity induced slightly higher vertical stress change at location B than that at location A. Similar to the field monitoring data, the vertical stress changes from numerical modeling correspond to relevant mining activities very well. In the same time period from end of June to end of September 2015, numerical modeling predicted vertical stress changes of 0.41 MPa, 0.33 MPa & 0.46 MPa for pillar depths of 12.2m at location A, 6.2m at location B & 9.4m at location B. The mining-induce average vertical stress change in the 6 – 12 m pillar depth range for locations A & B is estimated to be approximately 0.4 MPa. And the sensitivity factor for the Geokon model 4300BX soft rock used in potash rock is estimated to be 0.0015 MPa/digit. Comparing to the assumed sensitivity factor of 0.0138 MPa/digit, numerical modeling result suggests that the actual sensitivity factor is nine times smaller.

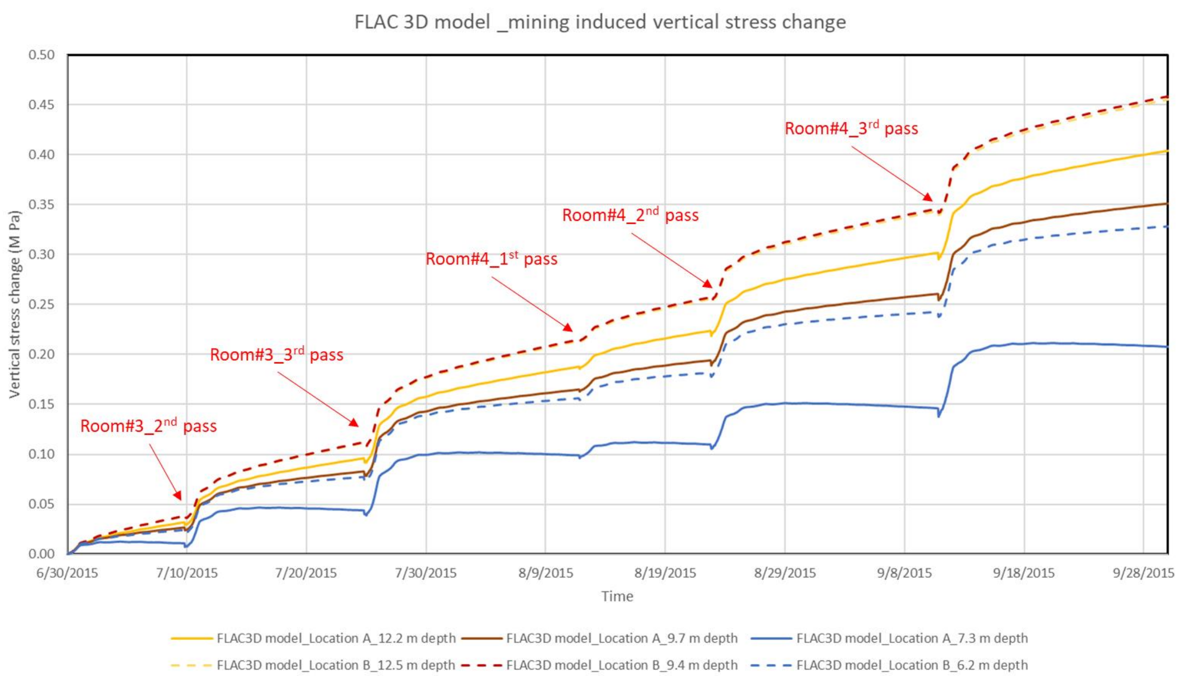

Figure 4. Mining induced vertical stress changes predicted by FLAC 3D model for various depth at locations A & B

In summary, a good quality of drillhole is essential for the Geokon model 4300BX soft rock borehole stressmeter to capture representative stress change in the field. Since the sensitivity factor (converting vibration frequency into stress change) for the Geokon 4300BX soft rock stressmeter is unavailable, numerical modeling was conducted to compare field measurement with modeling result. The average sensitivity factor for the 4300BX soft rock stressmeters installed into potash pillars at locations A & B is estimated to be 0.0015 MPa/digit.

Acknowledgements

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References

[1] Geokon. Model 4300 series VW Stressmeter (EX, BX, NX) Instruction Manual. Technical report, Document Revision: M| Release date: 10/1/20. URL https://www.geokon.com/content/manuals/4300EX-BX-NX_Stressmeters.pdf

[2] Itasca. FLAC 3D 9.0 - Itasca Software 9.0 documentation. Updated on November 12, 2022.