Engineering

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SUBSIDENCE RISK OVER LIMESTONE QUARRY MINES

Most subsidence events from limestone mines are catastrophic and can even result in a seismic event felt in the area. These events typically have surface depressions which are 10's of feet deep with severely faulted to steep walled circumferences. See Figures 1 and 2. This significant drop of the ground surface is mostly related to the great extraction heights in the limestone formation or resource. Depending on the failure at mine level these depressions can go up to 100's of feet across.

FIGURE 1 40FT CRATER WHICH FAILED OVER A LIMESTONE MINE

Needless to say the collapse of limestone workings can be extremely dangerous to the environment or affected structures. Furthermore, these depressions can occur with little warning, although at depth they may be many years in the making.

FIGURE 2 FAULTED EDGE OF SUBSIDENCE OVER A LIMESTONE MINE

Limestone underground mine failures which result in surface subsidence occur from: (1) a roof collapse in mine entry; (2) a pillar compression failure; and (3) a floor bearing failure.

ROOF COLLAPSE IN AN ENTRY

When the roof rock caves into the mine void or entry, the roof failure can progress upwards until it reaches either stronger bedrock or the expanded volume of collapsed rock or cave chokes off preventing further upward collapse. This mechanism of roof failure is called chimney subsidence, and typically results in a deep sinkhole at the ground surface. See Figures 1 and 3.

PILLAR COMPRESSION FAILURE

Pillar compression failures commonly occur when narrow pillars are present with width to height ratios of typically less than 0.8. These failures result adruptly and involve a number of pillars resulting in very large sinkholes. See Figure 4. Where the failure cannot be explained by a higher extraction overstressed area alone, other factors may have been in play to cause pillar failure. This can be related to the concentration of adverse geologic conditions which impact the overall strength of the limestone pillars. These geologic conditions related to

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pre-existing rock fracturing or karst defects in the limestone, weak non-durable interbed(s) in the limestone pillar and weak immediate floor (which is discussed below).

FLOOR BEARING FAILURE

Surface subsidence can also result from a mine floor failure. This can take the form of the pillars punching into the weak floor materials (see Figure 5), or the lateral spreading apart and collapse of the pillar itself from squeezing out of the underlying weak floor materials. These floor failures are more massive resulting in larger sized depressions on the ground surface. However, where a floor squeeze results (without pillar collapse), the subsidence movements are much more time dependent and gradual than from a pillar collapse failure.

MITIGATION OF RISK

Whether subsidence mitigation will be performed depends on the stakeholder(s) acceptance of reported risk (Property Management System for Geotechnical Risks). Therefore, the need for mitigation of any estimated future subsidence impacts on existing of proposed infrastructure is highly dependent upon the assessments of the subsidence and damage potentials and the reliability or trust in those assessments. This depends upon: (1) the assessed risk and certainty of such risk of a subsidence event(s); (2) the probabilistic analysis of the severity of the nature of the future land subsidence movements expected if an event occurred; and (3) resulting spectrum of potential damage.

There is a sundry of approaches to reducing the subsidence and damage potentials. The select measure (s) taken depend on the acceptable level risk, the nature and severity of the subsidence movements, infrastructure movement sensitivities and any environmental impacts. However in the vast majority of cases, the predicted infrastructure and environmental damage is ultimately the most important factor, and thus should be a focus of any such investigation.

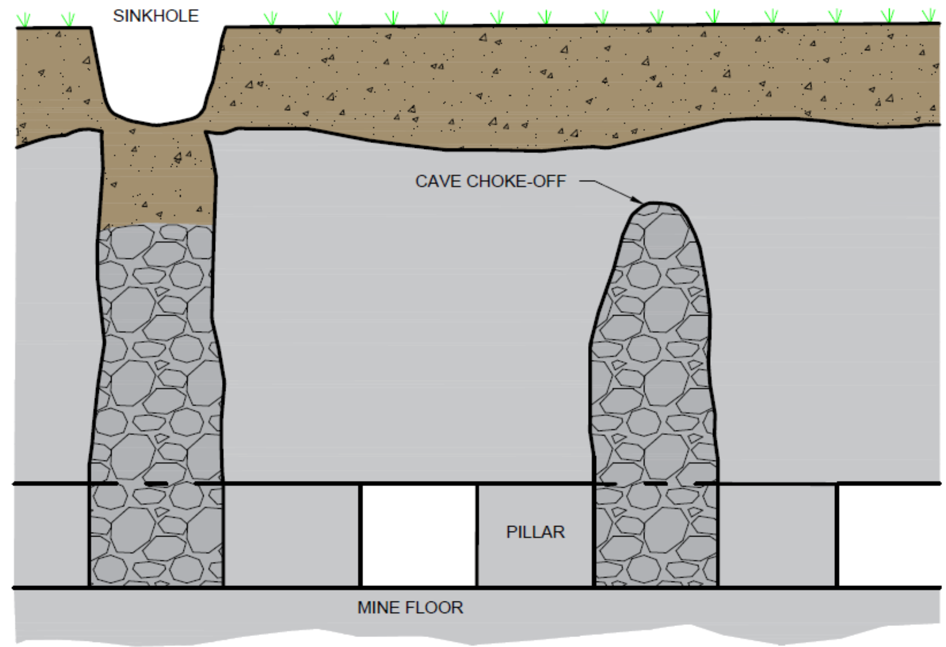

FIGURE 3 ILLUSTRATION OF CHIMNEY SUBSIDENCE

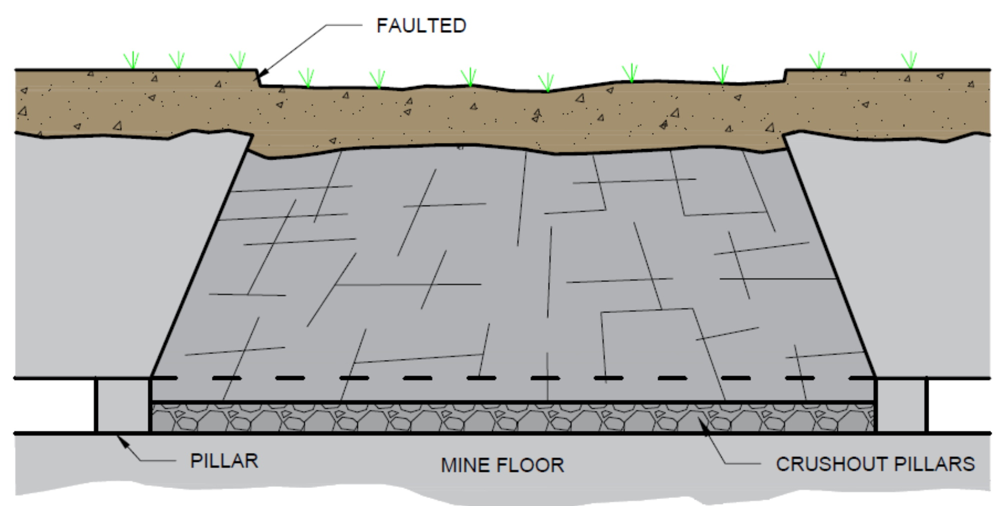

FIGURE 4 ILLUSTRATION OF SUBSIDENCE FROM PILLAR COMPRESSION FAILURE

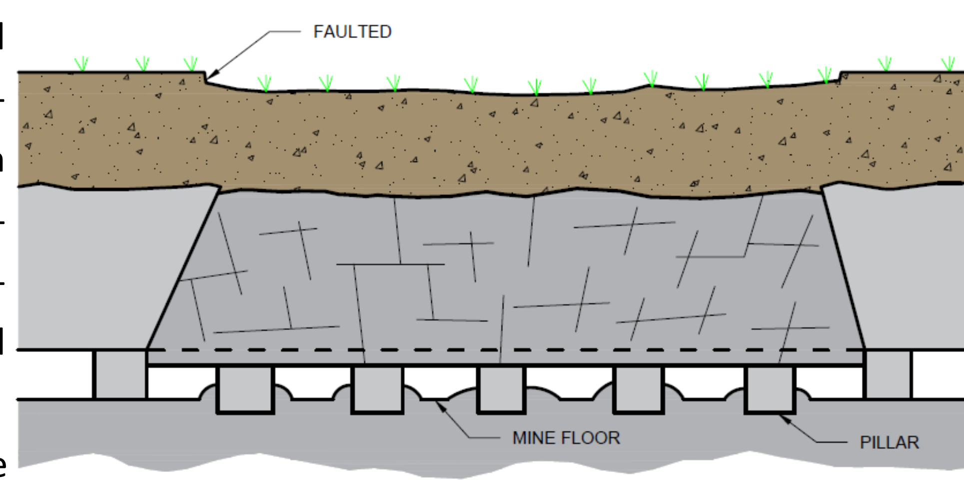

FIGURE 5 ILLUSTRATION OF SUBSIDENCE FROM PILLAR PUNCHING FLOOR FAILURE

Other MEA Publications that may be of Interest:

UPDATE #24 — Anatomy of Grouting Mine Voids

UPDATE #36— Moisture Softening Effects on Mine Floors

UPDATE #54— Handling Potential Mine Subsidence at a Project Site

Blog—Performing a Proper Land Development Feasibility Analysis

ABOUT MEA: Marino Engineering Associates, LLC focuses on engineering research, practice and expert evaluations and is licensed in 30 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact MEA at the address listed below.

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