***May 13, 2020 Supplement to April 24, 2020 Flyrock and Other Impacts******from Quarry Blasting Operations***

According to a January 2020 article appearing in the Journal of Mining and Environment (JME),[[1]](#footnote-1)

*[I]n China, flyrock is the reason of about 27% of surface mine disaster events [p. 1][[2]](#footnote-2)*

*…Flyrock…is one of the most hazardous phenomena in the drilling and blasting operation of surface mines. This phenomenon is defined as driving rock fragments beyond a desired area, which can result in human injuries, fatalities, and structure damages [p. 1].[[3]](#footnote-3)*

*There can be many reasons for the flyrock phenomenon occurring ranging from deviations in the blast pattern design or their implementation, explosive use, and known or unknown ground conditions [p. 1].*

A case study of a flyrock incident presented in an April 2020 article appearing in J. Inst. Eng. India Ser. D,[[4]](#footnote-4) addresses the comparative dangers of flyrock occasioned by blasting and identifies some of the underlying causes of flyrock:

*In blasting operations, flyrock (uncontrolled flying fragment) is one of the main causes of accident. The other blasting impacts to the surroundings such as ground vibration, noise (air overpressure/air-blast), fumes and dust can hardly cause direct injury and fatality to human, although they may cause structural damage and nuisance to the nearby residential houses and habitats.*

*The accident due to flyrock remains one of the major contributors of fatal and serious accidents in opencast mines. The ‘Danger Zone’ as given in Coal Mine Regulations [1] has already been increased from 300 to 500 m in the new Coal Mines Regulation [2] [Reg. 196 (2) (b)] to avert flyrock-related accidents in opencast coal mines.*

*There are many reasons for flyrock causes and associated accidents during blasting in opencast mines. Overcharging of holes with explosive, less stemming length, improper stemming, less burden, undercut, overcut/break-back/end-back due to previous blasting, presence of loose material in the strata, cavities, improper initiation sequence among others are the common causes of flyrock in bench blasting. The reasons for accident due to flyrock also include failure to evacuate the area, failure to take shelter, failure to communicate, taking unsafe shelter, etc.*

According to Dr. Sam Kiger, a now-retired Civil and Environmental Engineering professor at the University of Missouri, flyrock is a significant concern to both quarry workers and nearby residents, as identified in his response to a proposed rezoning to permit a quarry:[[5]](#footnote-5)

*“Flyrock” is rock that is ejected from the blast site in a controlled explosion in mining operations. The term refers to rock that flies beyond the blast site, potentially causing injuries to people and damage to property. This is considered a significant issue in mining. Indeed, between 1994 and 2005, 32 miners were injured by flyrock.[[6]](#footnote-6) Flyrock can vary in mass from marble-sized to car-sized.*

*At quarry blasting operations flyrock is a constant hazard not only to the workers at the quarry, but also to nearby homes and residents. Flyrock can be produced when the holes filled with explosive intersects a naturally occurring fracture or soft loose material in the rock being quarried. This fault in the rock provides a path for the shock wave generated by the detonation wave in the explosive to escape and propel a part of the surface rock into the air. The shock wave is moving at a very high speed so it can propel the flyrock great distances. Note that a shock wave is defined as a disturbance in the atmosphere moving at a speed greater than the speed of sound (1,100 feet per second at sea level).*

*The shock wave will be very disturbing to anyone within one to two miles of the blast (there are more than 100 homes within 0.75 miles of the proposed quarry pits in Alvaton). The escaped shock wave might even crack windows in this area. The shock wave is very similar to the sonic boom generated by a jet airplane when it “breaks the sound barrier.” I have reviewed the reports by two geologists provide[d] by the clients which state that preliminary geologic mapping suggests that there are pervasive schist interlayers within the granite body with pervasive intergranular fractures. As stated above, such fracturing increases the likelihood for blasting to produce flyrock at the proposed quarry.*

*Another way these unwanted events of flyrock and/or blast shock waves often occur is when the drill hole encounters a void, or open crack at the depth of the explosive. The explosive material is most often in the form of slurry*[[7]](#footnote-7) *and is pumped into the blast hole. If there is a void or open crack too much explosive can collect and the resulting blast will blow out producing a shock wave into the atmosphere and, potentially, flyrock.[[8]](#footnote-8)*

*In Miller Paving Ltd. v. McNab/Braeside (Township)*,[[9]](#footnote-9) Dr. Kiger addressed the high probability of damage to neighbouring structures (homeowners’ property) resulting from repeated blasting, even at low ground-vibration levels.

*In the…1980 report [prepared for the US Bureau of Mines] by Siskind et al,*[[10]](#footnote-10) *the authors establish 0.5 in/sec (12.7 mm/s) as the “threshold” for damage to structures, and they define “threshold” as a 5% probability of cosmetic damage. The probability of damage to a home may be relatively small in any single blasting event. However, numerous opportunities for an unlikely occurrence (like damage to the home) will result in a very likely occurrence of damage. For example, if the probability of damage (Pd) in any single blasting event is 0.05, or 5 percent, then the probability of not being damaged (Pu) is 95 percent. One can use the probability law of independent events to calculate the probability of damage occurring at least once in 100 events….[F]or example see Page “Introduction to Probability and Statistics” Third Edition, 1964, by Henry L Alder and Edward B Roessler; published by W.H. Freeman and Company. Thus, assuming the probability of damage is the same for each event, 0.05, then the probability of not being damaged at least once in 100 events is:*

 Pu-100 = (0.95)100 = 0.006

*And the probability of the structure being damaged in 100 explosions is 1 minus the probability that it is not damaged, thus:*

 Pd-100 = 1 - 0.006 = 0.994

*This implies that the probability of damage in 100 events is about 99 percent, meaning damage is almost certain if the homes are subjected to these blast induced ground vibrations numerous times. Thus, even though damage is unlikely to result from any single blasting event, some damage in the form of cracking of walls, ceiling, tile, concrete, nail popping, loosening of framing joints, etc. becomes very likely over time with numerous repetitions of blast-induced ground vibrations. And once damage occurs (like cracking, nails pops, or framing joints loosening) that damage will rapidly increase with repeated exposure to the vibrations, even at lower levels of vibrations.*

*In recognition of the fact that damage to residential homes can occur even at low ground-vibration levels, other countries have set much more stringent limits on allowable peak ground vibrations….[R]egulatory agencies in Leicestershire County, UK have established the upper limit on allowable peak particle velocity as 0.24 in/sec (6.096 mm/sec); in Australia the common limit is 0.2 in/sec (5.08 mm/sec) and it is 0.001 in/sec (0.00254 mm/sec) for historical buildings and monuments for frequencies less than 15 Hz.*

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On April 5, 2017, at an opencast coal mine in Ramgarh District of Jharkhand State, a blaster’s helper was killed after being struck by flyrock at a distance of 280 metres from the blast site.

*The maximum possible travel distance of flying fragments based on different flyrock prediction models was 227 m. In the synonymous blast, only vertical throws of the flying fragments up to 70 m (approximate) height were observed. It was difficult to find out the exact cause of [the] flyrock incident. However, based on the detailed investigation, it was concluded that the possible cause of flying fragments travelling up to a distance of 280 m could be due to the presence of a weak zone in the rock strata.*

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2. Fan L., Shen, w. and Li, Y. “The causes of flyrock and safety precautions in demolition blasting,” *Engineering Blasting of China*” 8 (1): 35-38. [↑](#footnote-ref-2)
3. Monjezi, M., Bahrami, A., Varjani, A.Y. and Sayadi, A.K. (2011). “Prediction and controlling of fly rock in blasting operations using artificial neural network.” *Arab J Geosci”* 4; 421-425. [↑](#footnote-ref-3)
4. C. Sawmliana, Panchanan Hembram, R.K. Singh, S. Banerjee, P.K. Singh and P. Pal Roy, “An Investigation to Assess the Cause of Accident due to Flyrock in an Opencast Mine: A Case Study,” *J. Inst. Eng. India Ser. D,* retrieved 12-May-2020 <https://doi.org/10.1007/s40033-020-00215-4>. [↑](#footnote-ref-4)
5. Rezoning denied and upheld on appeal. <https://flintriverkeeper.org/wp-content/uploads/2019/05/Randall_etal_v_Meriwether_County_etal_Final_Order.pdf>. [↑](#footnote-ref-5)
6. The National Institute for Occupational Safety and Health, *Mining Topic: Blasting and Explosives* (last accessed October 17, 2018), *available at* [www.cdc.gov/niosh/topics/explosives.html](http://www.cdc.gov/niosh/topics/explosives.html). [↑](#footnote-ref-6)
7. “Slurry” is defined as “an explosive material containing substantial portion of a liquid, oxidizers, and fuel, plus a thickener, [p. 12]” according to Geotechnical Engineering Manual Gem-22, Revision #4, August 2015, <https://www.dot.ny.gov/divisions/engineering/technical-services/technical-services-repository/GEM-22b.pdf>. [↑](#footnote-ref-7)
8. Dr. Sam Kiger, P.E., Professor Emeritus, Civil & Environmental Engineering, University of Missouri, “Proposed Granite Quarry in Alvaton, Meriwether County, GA,” October 20, 2018. [↑](#footnote-ref-8)
9. *Miller Paving Ltd. v. McNab/Braeside (Township),* PL130785, OMB, October 27, 2015 <http://www.omb.gov.on.ca/e-decisions/pl130785-Oct-27-2015.pdf>. [↑](#footnote-ref-9)
10. D.E. Siskind, M.S. Stagg, J.W. Kopp, and C.H. Dowding, “Report of Investigations 8507: Structure Response and Damage Produced by Ground Vibration From Surface Mine Blasting*,*” (1980), prepared for US Bureau of Mines. Online at <http://www.osmre.gov/resources/blasting/docs/USBM/RI8507BlastingVibration1989.pdf> [RI 8507]. [↑](#footnote-ref-10)