DANGERS POSED TO HIGHWAY 7

BY HIDDEN QUARRY FLYROCK

WILLIAM HILL P. ENG.

FOR WILLIAM HILL MINING CONSULTANTS LIMITED

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FOREWORD

This study on the dangers of flyrock to highway 7 is prepared by William Hill P. Eng. of William Hill Mining Consultants Limited. William Hill has over 50 years of experience in open pit and underground mining and has overseen the movement of approximately 1.2 billion tonnes of rock by blasting and therefore is qualified to address the problem of blasting and flyrock in relation to the proposed Hidden Quarry in Rockwood.

William Hill lives on a farm 700 m north of the proposed quarry, a location which may imply to the reader personal conflict on his part in the preparation of this report. Therefore, rather than relying exclusively on William Hill's experience, this report is based on extensive research and review of independent reports by experts in the field (with one exception – a reference to an incident in 1963 which is applicable to the subject of flyrock included as the first topic in the Appendix).

Extensive data is available in the published and internet literature on the subject of flyrock. The key words of reference "flyrock, blasting and flyrock, fatal accidents-flyrock-blasting etc." produce hundreds of references to the subject by experts from all parts of the world. Seventeen examples of flyrock problems are included in the Appendix at the end of the report and sixteen web sites are included in the section following the Appendix as "References". These thirty-three examples and references are but a small portion of the data which is available and indicates the magnitude of the flyrock problem.

INTRODUCTION

James Dick Construction Limited (JDCL) has applied to the Guelph/Eramosa Township (GET) Council to provide a change in zoning designation to develop a quarry on a 100 acre property abutting the north side of Highway 7 and east of the Guelph/Eramosa 6th line (Fig. 1. Page 17). The proposed operation would involve the extraction of dolostone by open pit mining including drilling, blasting, excavation by dragline, crushing, and transport by truck to market for 17 years at the rate of 700,000 tonnes per year.

The location for the proposed quarry is poorly suited for many reasons; however, this report concentrates on factors related to Highway 7 particularly with respect to safety issues associated with flyrock generated by blasting of rock.

SUMMARY AND CONCLUSIONS

“Flyrock” is generally defined as the undesired propulsion of rock fragments through the air beyond the normal blast zone by the force of the detonation of explosives being employed to fragment the rock. A more thorough discussion of flyrock and the factors that cause it follows in this report on page 6.

Most technical personnel with extensive experience in hard rock open pit mining know that problems associated with blasting, particularly with respect to flyrock, can be controlled much of the time but human errors and or geological factors will sometimes result in rocks being violently ejected, potentially causing property damage, injuries, and fatalities.

Over the years as a result of experience, the flyrock problem in open pit mines has become understood but has not been completely eliminated. To date, the major development has been the acceptance by government authorities and mine operators in many countries that exclusion zones are necessary for the safety of people and the protection of property.

A substantial number of studies have been carried out to determine the parameters for establishing the acceptable range of exclusion zones from blast sites. The conclusions arrived at by those studies are the universally accepted fact that flyrock cannot be eliminated but through tight control and experience the distance from the blast area for normal flyrock throw can be estimated.

In general the results of studies indicate that seven major factors, which have controlling influence on flyrock, should be taken into account in determining the exclusion zone, these are;

1. Geology and material to be blasted, (ten references on pages 12 to 15);
2. Blasting experience at the mine;
3. Blast patterns;
4. Burden, depth, diameter, and angle of the holes;
5. Delay systems, powder factor, and pounds per delay;
6. Type and amount of explosive;
7. Type and amount of stemming;

It is important to note that items 3 - 7 can be controlled and adjusted. As well, there exists an extensive roster of experts who specialise in giving advice to start-up mines.

Item 2 . . . The mine in question has to have been in production for some time to accumulate experience. The bed rock in Hidden Quarry has not been mined in any way to have provided that blasting experience.

Item 1 . . . Geology cannot be adjusted – you only get what is given to you. The geological structure in the HQ site is the product of acid leaching of the carbonate rocks, (limestone and dolomite), i.e. subjected to Karst type of leaching. This leaching converts minor fissures and fractures into major cavities which predominate the whole area around the HQ, as exemplified in the Rockwood Conservation Area.

If a hole is unknowingly drilled close to one of these cavities the resulting detonation of up to 700 kg of explosives could blow-out in an uncontrolled manner ejecting rocks in all directions and over long distances. Rocks close to 50 kg in mass have been known to travel up to 1200 m with speeds of 600 km/h with destructive effect.

Research and statistical evidence show that the expected normal range of flyrock travel is 300 m. Close to 90% of the ejected flyrock will fall within a three hundred metre radius from an errant blast hole (Ref. #2). Sufficient experience has been accumulated over years to justify an exclusion or buffer area around blasts to protect structures and people from what is termed “wild flyrock”. A 500 m exclusion zone is used in Scotland, Wales, and Australia (Ref 11). Similar statutes exist in the US (Ref. 10). These exclusion zones are set to protect individuals and property, including road ways, from potential damages resulting from flyrock.

If these statutes were to be applied to the HQ project, Highway 7 would be located for one kilometer of its length within 150 m from blasts or well within the danger zone of normal flyrock, in an area with the highest probability of danger. As well, a section of the highway totalling 1500 m lies within the 500 m exclusion zone if it were applied.

RECOMMENDATIONS

The inherent risks are so high that:

- The highway should either be relocated out of the danger zone,
- Or the HQ operation should not be allowed to proceed.

Flyrock

Definition and Causes

Flyrock is generally defined as “the undesired propulsion of rock fragments through the air beyond the normal blast zone by the force of the detonations of explosives being employed to fragment the rock”.

In general flyrock is caused by two main factors – either too little or too much confinement. Confinement, also referred to as “burden”, is the amount of rock placed in the way of the intended direction in which the broken rock should be thrown.

In most pits, including the HQ, the intended direction of throw is horizontal. If too little confinement is provided in the horizontal direction the blast “blows out”, causing flyrock to be thrown at a low angle above horizontal. In the HQ the lateral blow-out should not be a problem because the pit is expected to be eventually filled with water which will dampen the blast.

In the HQ any flyrock will be propelled by the relative amount of confinement in the lateral direction as compared to the vertical. The result of too much lateral confinement is the tendency for blow-outs in the vertical direction. This type of blow-out generally is strongly influenced by geological conditions. Karst type of weathering, which is present in the Rockwood area, could pose a very serious problem with flyrock because of the difficulty in knowing where the geological conditions giving rise to this type of blow-out may occur (Ref 14 –Ontario Department of Mines).

Impact Zone

There are recorded instances where fragments of flyrock as large as one cubic foot (described in one report as being roughly the size of a “microwave oven”) (Ref. 5) have been propelled as far as 1.2 kilometers from the blasting site with a potentially enormous destructive capacity (Ref. 9).

More commonly, rocks about the size of a baseball are propelled at speeds measured at up to 600 km/h at their point of impact. These too may have devastating consequences including property damage, **injuries and fatalities**.

Frequency of Occurrence

The distance of flyrock travel in reported incidents was analyzed in the United Kingdom, over a five year period. The range is illustrated in the table that follows. The distribution indicated below shows that “normal flyrock” could be assumed to affect an area extending outwards 300 m in all directions from the blast. To mitigate risk, an exclusion zone could be reasonably set at 500 m (Ref. 2, 12).

Distance from blast (m)	Number of incidents	Percent of total	Cumulative %
100	17	20	20
200	22	26	46
300	25	29	75
400	7	8	84
500	8	9	93
600	2	2	95
700	3	4	99
800	1	1	100
total	**85**	**100%**	

It is necessary to point out that most of the statistics on flyrock are based on reported resulting incidents and accidents. The vast majority of the ejected rocks are either unreported or unnoticed (Ref. 2). Only when an incident such as a recent occurrence in Malaysia where one person was killed, ten were injured, eighteen cars were destroyed and ten structures were damaged does it get recorded. Operators are well aware that most non-injurious incidents are settled without notoriety. One incident which illustrates this statement occurred recently in Marmora, Ontario where flyrock caused damage; however, the incident went unreported to the Ministry of the Environment (Ref. 6). The result is that the available statistics tend to understate the severity of the problem. One study has estimated that this lack of reporting tends to understate the problem by as much as ten times.

Severity

There are, broadly speaking, two types of flyrock. The first simply called “flyrock”, is the undesired but statistically expected fragment of rock which is expected to fall within a prescribed area of exclusion – typically between 300 and 500 m from the blast (Ref. 2). When blasting is carried out, preparations are made to evacuate all personnel to a safe distance beyond the blasting area.

The second sometimes termed “wild flyrock” (with ranges up to 1200 m) is statistically rare but can occur with disastrous and sometimes tragic results (Ref. 2).

The severity of flyrock incidents is illustrated in statistics published by the **US Mine Safety and Health Administration (MSHA)** for a period covering 1978 to 1998. During that time, there were 281 injuries in the US caused by flyrock. Roughly half of the injuries were the result of “wild flyrock”. 16% of the injuries resulted in fatalities.

Numerous publications by blasting experts state that flyrock can be controlled for the most part, but the risk of occurrence can never be eliminated or ruled out entirety. All too often, the human element comes in to play with common mistakes like the use of too much explosive or the placement of the explosive too close to the rock surface (Ref. 1, 2, 3, 4, 7, 8, 10, 13, 15, 16).

Geological Factors

The most important factor influencing the launching of flyrock is the geology of the area where mining is carried out. With rigorous control and diligence human factors can be reduced, but geological conditions and rock structure variations often remain beyond technical control.

It is well known that limestone and dolomite which underlie the area of the proposed quarry are prone to dissolving and as a result producing irregularities such as sink holes, enlarged faults and fissures, and even caves. Review of aerial photographs around the HQ reveals traces of no fewer than ten sink holes including two on the HQ property itself. Areas with these characteristics are termed to have Karst Topography (Ref. 14).

The process for Karst weathering is often referred to as “carbon dioxide cascade”. This is explained as follows;

1. As rain falls through the atmosphere it picks up Carbon Dioxide which dissolves in the droplets.
2. Once the rain hits the ground it percolates through the ground and picks up more Carbon Dioxide to form a weak solution of Carbonic Acid.
3. The infiltrating acid water naturally exploits any cracks or crevices in the underlying rocks.
4. Over long periods of time, the rock is dissolved by the acid waters leading to the propagation of solution cavities and widening cracks
5. Visual evidence of this phenomenon is prevalent in the Rockwood Conservation Area.

The problem which will most likely be encountered in drilling and blasting in this geological environment is that if a drill hole is inadvertently located too close to a cavity or enlarged fissure the blast will likely take the path of least resistance -- that is, into the cavity. This could result in cratering at surface and the ejection of rocks at extremely high velocities.

A tragic reminder of what can happen as a result of geological conditions –occurred in Campbell County, Tennessee on June 4, 1993.

> "A 16 year old passenger, in a car driven by his parent on Interstate I-75 was fatally injured by flyrock originating from an overburden blast in a nearby coal mine…(The official report stated)…***The blaster, apparently was unaware of the presence of an 8-ft thick layer of clay"***" (Ref. 4)

Exclusion Zone

During the proposed 17-year life of the HQ project there could be 20,000 to 50,000 individual holes blasted which will provide ample opportunity to cause injuries and deaths as well as property damage including vehicles on Highway 7 and neighbouring side roads.

The only solution available to reduce the risk (even with rigorous control) of human injury or death and damage to property is to set blast clearance through the aforementioned exclusion zones. These exclusion zones establish minimum distances from inhabited buildings and roads to the blast sites.

In Scotland and Wales the minimum distance is set at 500 m after a "tragic accident" in Burnfoot Moor in 1998 (Ref. 11). Western Australia has established a minimum limit of 400 m. If these same regulations were applied in the HQ case, mining would likely not be permitted at the site.

In the US, the Federal Office of Surface Mining (OSM) regulations specify that "flyrock shall not be cast from the blasting site –

- More than half the distance to the nearest dwelling or other occupied structure,
- Beyond the area of control required under 30 816.66(6) CFR (exclusion zone), or
- Beyond the permit boundary".

If the OSM regulations were adopted, it is possible that none of the proposed HQ operating area would be permitted for blasting as the closest structure is only 80m from the boundary.

Exclusion zones also very deliberately apply to highways. If the HQ is allowed to proceed there will be approximately 1.5 km of Highway 7 within what could be deemed the exclusion zone. There occurred a fatal flyrock occurrence in a car traveling on I-75 and also one on the M1 in the UK at greater distances than the HQ property is from Highway 7.

During its 17-year operating life the HQ will probably have blasted between 25,000 and 75,000 separate explosive charges (drill holes) of between 150 kg and 700 kg. It is impossible to estimate the number of “rogue holes” that may propel flyrock, but, considering the high number of blasts, and the unpredictable nature of the rock structure in the area, there is a considerable probability for causing injuries and damage.

Appendices

Examples of Flyrock Incidents

1. The first example of flyrock is taken from the personal experience of the writer, William Hill P Eng.

In 1963 the William Hill was working in the McCune Open Pit of Cerro de Pasco Corporation (CDP) in Peru. Underground mining had been carried out at that time for close to 400 years and the city of Cerro De Pasco was built up close to the mine shafts. Upon starting the open cast operations the city was close to the eastern border of the pit because of the location of the ore body. The closest distance from the mining operations to habitations was less than 100m, consequently every blast was monitored with great care. The open pit operations had been relatively successful for an extended period of time, probably more than a year, with only minor complaints regarding some damage from flyrock, noise and vibration which was easily taken care of (remembering that this was a company town – only one employer) by help with the repairs. Guards were sent into the populated area during each blast and warning sirens were placed in all areas where there was the remotest chance of flyrock falling.

In 1963 a catastrophic event took place. One drill hole blew upward causing a huge explosive noise and a serious propagation of flyrock. The damage, by a stroke of good luck, included only minor injuries (probably because the people, accustomed by lesser events, took shelter) but the incident also resulted in extensive damage to more than 300 houses, some up to 300 m from the blast. The outcome of that blast was that a large portion of the city was moved to a safer location with an expenditure in today's dollars close to $50 million.

Other examples of flyrock incidents found in the literature are summarized in the following brief paragraphs:

2. **Burlington, Vermont - September 2008** – detonated a blast that threw flyrock several hundred yards and resulted in damages estimated to be a million dollars to aircraft, vehicles, buildings and the grounds at the Burlington International Airport"

3. **West Lebanon, New Hampshire - June 11, 2007** – a quarry blast resulted in flyrock being thrown 3000 feet into an industrial park; the same blast also sent flyrock about 4000 feet landing on the airport property including the runway - "flyrock as big as a bucket".

4. In a study of a serious blasting problem researched by the **Department of Mining Engineering of the University of Belgrade** reference is made to the following.

“Some of the flyrock traveled a distance of 600 metres and had speeds estimated at 600 km/h. Rocks up to 200 kg were projected over a distance of 300 metres”.

Fatalities from flyrock incidents

Most fatalities attributed to flyrock involve operators of mines principally because the mines or quarries are generally situated in remote areas with sparse population. There are cases which illustrate that flyrock is dangerous to people who are not associated with the operations. Examples of these are as follows:

5. (Repeated for emphasis) “A sixteen year old passenger in a car driven by his parents on interstate I – 75 was fatally injured by flyrock originating from an overburden blast in a nearby coal mine”.

6. A resident in the vicinity of a coal mine unknowingly drove up a trail and parked his ATV about 35 m from the blast area and was killed by flyrock.

7. “flyrock from a limestone quarry traveled about 300 m and fatally injured a resident who was mowing grass in his yard”.

8. **Shawinigan Lake Gravel Pit, September 2011**. A 50 year old woman observing the pit lost her arm to flyrock. “Debris flew 400 m”.

A few examples of fatalities by flyrock mostly near the working area are listed as follows:

9. In a report by the **US Department of Labor** regarding a coal mine in Kentucky, 2007: a fatal accident occurred killing a miner with 20 years of experience. “The flyrock that struck the victim traveled approximately 1500 feet (483 m) into an area where miners parked their personal vehicles; the rock passed over a 20 m high embankment” Pieces of rock “16 x 20 inches (50 kg) also hit close to where the man had been standing”.

10. An equipment operator with seven years’ experience at the mine was in his pickup guarding the access to the pit 270 m from the blast. Flyrock entered by the windshield and killed the operator.

11. “A foreman was fatally injured when flyrock struck the roof of his ¾-ton truck. The impact caused the roof to bend downward and strike the foreman’s head. Upon firing the shot, a sandstone rock weighing 8.5 pounds traveled 50 m and hit the roof of the cab”.

12. “a blaster was fatally injured by flyrock weighing 14 pounds traveling over a 200 foot highwall - about 600 feet from the blast holes”.

13. Preparing a logging road outside of the pit area: “The blast projected flyrock about 300 m and fatally injured the victim. Several boulders were scattered near the accident site”. “The MSHA investigation determined that a blown out shot caused the flyrock”.

14. A visitor and drill/blast helper were 50 m from the blast. The drill/blast helper was killed and the visitor was injured.

15. “A blaster was fatally injured by a 1 ft. 5 in. by 2 ft. 11 in. by 8.5 in. deep flyrock (MSHA 1992). The blaster positioned himself under a Ford 9000, 2 ½ ton truck while detonating the shot. A flyrock traveled 250 m.

16. “A crane operator was fatally injured when flyrock struck him on the back. During the blast the victim and the blaster were standing on a top bench 40 m from the nearest blast hole. The blast holes were covered with blasting mats”. ‘Upon initiation of the blast one of the holes threw flyrock toward the victim”.

17. In a report by the Department of Mining Engineering, Indian School of Mines, Dhanbad, flyrock from secondary blasting is discussed. “A study of blasting has revealed that more than 40% of fatal and 20% of serious accidents result from flyrock (Mishra 2003)” A boulder 3 m by 1.5 m by1.6 m 45 mm diameter - two holes 1.5 m deep were drilled and blasted. Two pieces of flyrock (2) were ejected 550 m causing damage to a building but narrowly missing the occupants.

REFERENCES

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9. The_Valley_Reporter - Danger from flyrock; www.valleyreporter.com › Home › News › MyView: *On June 11, 2007, in West Lebanon, NH, Green Mountain Explosives detonated a Briefing Note B1: 500 Metre Buffer Zones - Leicestershire Villagequarry blast that resulted in flyrock being thrown about 3,000 feet (10 football fields) into an industrial park doing damage to a building and vehicles. This same blast also sent flyrock about 4,000 feet that landed on Lebanon Airport property, including a runway*

10. PDF] Blasting Safety – Revisiting Site Security - Centers for Disease; Blasting Safety – Revisiting Site Security geology, by T. S. Bajpayee, Harry C. Verakis, and Thomas E. Lobb; www.cdc.gov/niosh/mining/UserFiles/works/pdfs/bsrss.pd

11. Briefing Note B1: 500 Metre Buffer Zones - Leicestershire Village; www.leicestershirevillages.com/uploads/84d256e73bcdd9019413303.doc; Briefing note on the 500 m buffer zone bill: *This was because of a serious fly rock incident at the Burnfoot Moor opencast site near Muirkirk in 1998, when rock dislodged from blasting travelled over 300 m ...*

12. SA11-05 People put at risk inside blast exclusion zone – NSW; www.resources.nsw.gov.au/__.../SA11-06-People-put-at-risk-inside-blast..*People put at risk inside blast exclusion zone, New South Wales, AU*

13. [PDF] Safety Evaluation of Blasting Flyrock Risk with FTA Method, ZHOU Zilong, LI Xibing, LIU Xiling & WAN Guoxiang. (School of Resources and Safety); miningandblasting.files.wordpress.com/.../safety-evaluation-of-blasting-f...

14. Ontario Department of Mines, Geological report 61, Pleistocene Geology of the Guelph Area, By P. F. Karrow - 1968

15. Mining and Blasting | Weblog of Partha Das Sharma For Discussing. miningandblasting.wordpress.com/; *The broken rock will be displaced upwards, with an increased risk of fly-rock -Factors responsible for this mismatch include: Abrupt decrease in rock resistance due to joint systems, bedding layers, fracture planes, geological faults, mud seams, voids, localized weakness of rock mass, etc.*
    GEOLOGY AND ROCK STRUCTURE: Sudden change in geology or rock structure can cause a mismatch between the explosive energy and the resistance of the rock. It is prudent to try to detect such changes in advance and adjust accordingly.

16. PAN 50 Annex D - Scottish Government, www.scotland.gov.uk › Publications › 2000 › February. *Feb 1, 2000 - Blasting at quarries and opencast coal sites can have adverse impacts that ... These regulations provided control over the possibility of flyrock – pages 5 and 6*

FIGURE 1.

HIGHWAY 7 DANGER CIRCLE

SCALE **I**___________1500 m___________I