EVALUATING AND MANAGING CONSTRUCTION BLASTING RISK

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ABSTRACT: While representing owners at projects where explosives are used to excavate rock or demolish concrete, engineers participate in the management of blasting risk when they a) design projects, b) develop contracting methods, c) write blasting specifications, and d) oversee fieldwork. In performing this work, the engineer assumes the responsibility of managing the many risks associated with blasting operations. Although rare, terrorist acts and incidents involving explosives create negative public perceptions. Despite these incidents, explosives are safely used to excavate rock at thousands of projects throughout the US each year. This article defines various forms of blasting risk, illustrates them with case histories, and offers practical guidelines for identifying and managing them.

INTRODUCTION

Over ten million pounds of explosives are used daily to excavate rock by blasting in mining, and construction operations throughout the United States. Despite the immense volume of explosives used, serious incidents involving the legal use of explosive materials are rare. Unfortunately, when incidents involving explosives arise, they are well publicized, whereas the great majority of blasting projects—even the most challenging ones--quietly occur without incident or public recognition. Although unfair, media coverage focuses on those few incidents and/or accidents, and as a result skews the public's perceptions of our industry. Negative perceptions about blasting can profoundly affect construction work. Many projects have been halted or delayed by community groups concerned about the potential damage or environmental impacts of blasting. Other effects are more insidious and long lasting. For instance, planning engineers or government agencies often prohibit blasting to avoid the public's adverse reaction or because of general fear of blasting impacts. As regulations and specifications become increasingly more restrictive, the net effect is an increase in the cost of rock excavation.

Experienced blasting professionals acknowledge that blasting--even under the most challenging conditions--can be accomplished without incident if proper blasting controls are applied. In construction work, engineers and planners representing project owners and government agencies are jointly responsible for insuring that blasting is performed safely and with minimum financial risk.

This article defines the blasting industry's challenges, reviews public perceptions, explains types of blasting risk, presents a system for managing blasting risk, and offers a practical guide for identifying and managing various forms of blasting risk.

THE CHALLENGE

For engineers, blasters and project supervisors, managing risks associated with blasting is becoming an ever increasing challenge as work inevitably occurs in more populated areas. Not only is the work closer to people, structures and utilities, but environmental concerns about blasting effects on animals are also increasing. In some cases, owners and engineers simply avoid the risks of blasting by specifying that only mechanical methods be used for excavating rock. Unfortunately, this surrender to alternative methods usually increases the cost of the work. In a few cases, mechanical excavation methods are ultimately unsuccessful, necessitating the last-minute introduction of blasting methods. Without proper planning and controls, blasting at the eleventh hour is costly and increases risk because proper specifications have not been written and claim-prevention activities have not been done. At some large civil construction projects, blasting is often only a small part of the overall work. As such, blasting specifications and other controls are often not addressed as rigorously as they should be in project documents. Regardless of the scale of blasting work, when engineers or planners underestimate the importance of preparing adequate blasting controls and community relations programs, the consequences can be severe. Uninformed citizen groups can stop or delay work by applying a wide array of political and legal actions. Anti-blasting groups have exercised their rights by stopping or delaying work in the following ways:

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- Appeals to Government Agencies or Officials
- Endangered Species Act
- Declaring Neighborhoods as Historical Districts
- Legal Injunctions
- Forcing Environmental Impact Studies
- Delaying Project Approvals via Actions at Public Hearings
- On-Site Protests

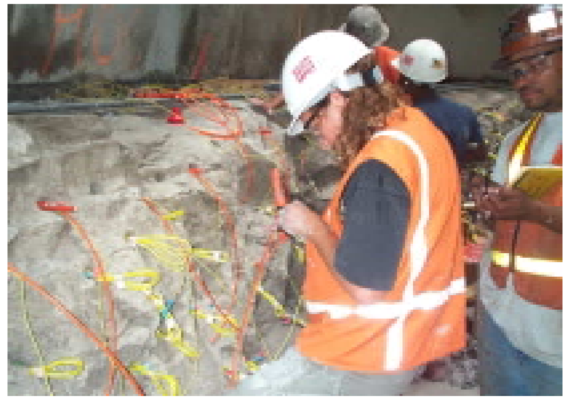

Figure 1 – Blasting very close to a concrete caisson

In the light of public and media scrutiny of blasting operations, a great disservice to our industry occurs when we collectively fail to avoid preventable incidents. The author has investigated blasting incidents caused by complacency and/or ignorance by workers, engineers and inspectors. Problems occur when engineers developed poor specifications, workers have inadequate experience, and inspectors are untrained. We have the tools, skills, and the knowledge and experience to avoid these types of incidents. How often have we assured project owners, the public and government officials that blasting could be done safely at a particular project—then privately worried because we lacked complete control over all the critical aspects of the work. Our broad challenge as an industry is to understand how to control blasting through regulation, project design, specifications, and on-site execution and field oversight.

PUBLIC PERCEPTION

Public perceptions about blasting are formed from scenes in movies like *Die Hard* and *Apocalypse Now*. People generally do not want it occurring near their property or families, nor do they want explosives stored near their homes. Horrible incidents involving explosives have heightened public fears. The Oklahoma City tragedy and the World Trade Center bombing have increased public fear about blasting, which in turn has influenced how project planners and regulators consider it as an excavation method.

In light of these liability and public relations issues, it is not surprising that engineers and government agencies are increasingly specifying that, in lieu of blasting, "rock excavations shall be made by mechanical means." The surrender to mechanical excavation using hydraulic breakers mounted in back hoes (Hoe-Rams) or the use of expanding chemical agents (Bristar) almost always increases the duration and cost of excavation work. Ironically, since hoe-ram excavation extends the duration of the work project neighbors might be subjected to months of continuous hammering noise and other construction effects, versus feeling a few instances of blasting vibrations lasting only a few seconds. At a large transportation project, the contract called for the removal of 30,000 cubic yards of hard basalt located between the State's busiest highway and a suburban neighborhood. The State's Department of Transportation vigorously opposed any blasting because they feared it would cause prolonged road closures. The contractor and owner were also concerned about vibration damage lawsuits from the nearby homeowners. With these fears in mind, the contractor used an impact ripper, and a hoe-ram to mechanically excavate the basalt. They intermittently ripped and hammered this rock over an extended period, versus removing it in less than a week by blasting. Throughout this long period, nearby homeowners were disturbed by the continuous hammering noise from a D-10 Impact-Ripper and Hoe-Ram. Some neighbors were even temporarily relocated to off-site accommodations at the owner's expense. The basalt could barely be ripped, so the contractor's excavation and maintenance costs were extremely high. The mechanical excavation cost was around $ 5.55 per cubic yard. For a comparable cost of $1.50 per cubic yard, the same rock could have been removed by controlled blasting methods. In spite of the lower cost of blasting, the contractor opted to use mechanical methods due to the legitimate fear of blasting vibration claims.

Despite the risk, blasting has been and can be performed safely and with economic benefits at many extremely challenging projects. In one such case, controlled blasting methods were used to excavate a U-shaped cut to create a vertical rock needed to establish portals for light rail tunnels for the TRI-MET light rail project near Portland, OR. Blastholes drilled in hard basalt at one side of the cut were drilled within a foot of soldier piles supporting overburden above the cut. As shown in Figure 2, light charges using 200-grain detonating cord were used to prevent damage to the piles and to produce smooth walls. Again, the primary challenge of blasters, project designers, engineers and inspectors is to jointly insure that proper blast management methods are used so all blasting operations are performed without incident.

TYPES OF BLASTING RISK

Various forms of risk are present during the planning, execution, and closure phases of projects with rock-blasting work. Project planners and engineers usually evaluate in situ rock conditions in order to determine applicable excavation methods and cost. When geotechnical investigations are inaccurate or incomplete, severe work delays might occur and contractors are likely to make claims for increased costs. For construction work, specifications are usually developed to ensure that blasting is done safely and in conformance to the requirements of the project. The quality and thoroughness of specifications can greatly impact the project's outcome. Incomplete or ambiguous specifications can invite contractual claims or allow substandard work. Specifications often contain language that attempts to transfer liability from owners and engineers to contractors and consultants. These clauses typically specify that the contractor is responsible for all blasting damage claims and often requires the contractor to indemnify the owner and fund any legal expenses incurred by the owner. Fortunately, courts in most jurisdictions rarely enforce such clauses because--in addition to contractors and blasters—owners, engineers and explosive suppliers share the responsibility to ensure that blasting work is done safely. Ironically, project owners, consulting engineers and product suppliers often become targets of damage claims because, unlike contractors, they are not protected by the liability limits of workers compensation laws. Incidents have been blamed on the owner because they *"pushed the contractor too hard,"* by enforcing a contract, hence forcing shortcuts and unsafe practices. Explosive suppliers are sued because they *"failed to adequately teach their customer how to use the explosives safely."*

Figure 2 – Using very light charges to prevent damage to soldier piles and to produce smooth walls.

When blasting is underway, contractors and blasters usually understand the risks associated with the work. Occasional accidents and incidents are the worst outcomes when blasters and blasting oversight personnel fail to employ adequate blast design and control practices. The blasting industry understands the real and severe consequences of serious blasting incidents caused by flyrock or premature detonations. Consequently, most blasting personnel conduct their work with serious resolve and vigilance. Along with these primary risks are the less apparent risks resulting from the secondary effects of blasting. These include vibration, air-overpressure, environmental pollution and other physical and psychological impacts on humans and animals.

Secondary activities associated with blasting include explosive manufacturing, distribution, and storage and transportation. These activities create additional risks for explosive makers, distributors, surety companies, project owners and explosive users. Examples of the secondary risks to parties not directly involved in the blasting work are provided in the case histories section of this article.

A BLAST MANAGEMENT SYSTEM

Managers, engineers and blasters can use the following system to manage blasting risk. As shown in Figure 3, safe and efficient blasting programs are supported by four different fundamental activities. The first supporting leg is to ensure that the project Design and plans are practical and adequate. The second leg is Pre-qualification requirements ensuring that only blasters or contractors with appropriate experience are allowed to perform the work. The third leg is the development of Specifications or rules that clearly define the performance and safety requirements of the work. Specifications should also cover some pre-qualification needs by defining specific experience requirements for blasters and blasting consultants. The fourth and final leg is an Oversight program by capable supervisors, inspectors and—if needed—consultants who ensure the work is indeed done safely and in compliance with project specifications or company rules. The degree to which these protections are applied should be commensurate with the risks of the work.

The following case histories illustrate how problems can occur when any of the key "legs" of blasting risk management plans are not fully implemented. These cases also reveal instances where blasting risks were not readily apparent.

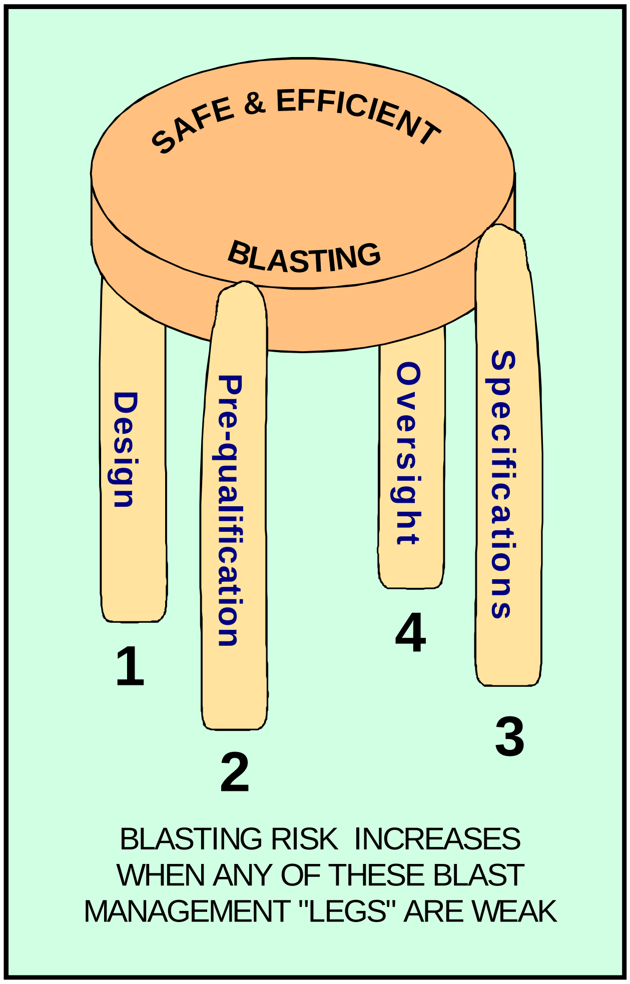

Figure 3 – Blasting Risk Management System

Case 1. The Dam that would NOT hold Water: In this case, blasting was required to excavate rock to create abutments and a spillway for a rock and earth-filled dam. When the dam was completed, it would not hold water. The project owner later alleged that the rock blasting cracked the abutment rock, hence increasing its permeability, which in turn allowed water to seep through it. Investigations of the site revealed that the blasting did indeed damage rock in the abutment of the dam. It was also found that the design of the dam, the blasting specifications and blasting-oversight methods were inadequate. The design did not include rock grouting in the rock abutments to ensure impermeability. The contract documents had no provisions to ensure that the contractor and blasters had adequate experience in dam-construction work. Project specifications contained inadequate controlled-blasting provisions, and the project inspectors had little knowledge about blasting techniques. In the final analysis, it could be said that the owner got what they paid for. They hired an engineering firm with inadequate dam design experience. Contract documents allowed an unqualified contractor to perform the work and the blasting work was overseen by inspectors with little knowledge about controlled blasting methods.

The engineering company responsible for the design, specifications and inspection work made a substantial out-of-court settlement to end a tort action made by the project owner. The contractor's surety company also paid to finance repairs to the dam. This case illustrates how the engineer and the contractor's bonding company were found responsible for the outcomes of poor blasting work.

Case 2. Boulders on Railroad Tracks: Several large boulders sloughed off a weathered cliff and fell onto a major rail line some minutes after a blast was fired in an adjacent rock quarry. Seeing the boulders, but unable to stop, a train locomotive was damaged when it ran in to them. No persons were injured in this incident. Since the rock falls occurred, shortly after the quarry had blasted, it was concluded that the ground vibration from the blasting stimulated the rock fall. Based on this finding, the quarry agreed to review and revise their blasting practices, stabilize the loose rock slope, and to pay for the damage to the train. This case reveals how blasting can cause damages that are not readily apparent and emphasizes the need to "look outside the box" when evaluating potential blasting risks.

Case 3. Impossible Blasting Noise Limits: Engineers representing an owner at a large civil construction project copied blasting noise limitations from the specifications another project. These limitations were much more stringent than those normally enforced by local government regulations. The lower-than-normal blast noise limits were not problematic at the prior project due to the great distance between the blasting work and the adjacent neighborhood. However, at the new project, the contractor quickly learned that it was impossible to comply with the extremely cautious noise restrictions because private dwellings were located much nearer to blasting work. After several higher-than-allowed noise incidents, the local regulating agency—charged with enforcing the agreed-to noise limit—shut down the project for several days. Following the mandated dispute review process for the project, the contractor prepared a claim for damages caused by the "defective noise specification." The dispute review board ruled in favor of the contractor, who was later compensated after negotiating a financial settlement with the project owner. This case shows how financial consequences can result from seemingly minor errors when preparing project specifications. It also highlights the dangers of copying specifications from one project to another without carefully evaluating the effects of different site conditions.

Case 4. The Big-Mine-Blaster at a Close-in Civil Dam Project: This case is about blasting work that occurred under extremely challenging conditions at a pre-existing hydroelectric dam. The project specifications included very restrictive vibration controls designed to protect the existing dam and its appurtenant structures. The area geology was extremely complex. In some zones, massive basalt had flowed over thick mud seams. In other areas, the rock was extremely jointed and weathered. The contractor, shorthanded at the time, hired a blaster from another State. The blaster's prior experience was all gained while working at large mining operations using 9-inch-diameter or larger holes loaded with bulk-explosive trucks. At this project, all holes were less than 3-inches in diameter and every blast was unique. In addition to tight vibration control limits, the specifications included strict requirements regarding overbreak and damage to final rock walls. Further complicating matters, the contractor was using a new initiation system, unfamiliar to the blaster. As the blaster struggled to learn close-in construction blasting techniques, and how to use the new initiation system, the project fell increasingly behind schedule. Some blasts failed due to misfires caused by improper use of the new initiation system. Results of other blasts suffered when huge basalt boulders were produced by blasts where primers were placed at the bottom of blastholes located in a large mud seam. Fortunately, no injuries or physical damage occurred as a result of the blaster's inexperience with close-in blasting and the new initiation system. However, the contractor did suffer financially due to delays and poor productivity caused by the poor blasting. The contractor attempted to recover some of the losses by pursuing a classic "differing site condition" claim against the owner. The claim was unsuccessful because the owner's engineers had carefully explored and reported the site's geological conditions to the contractor. Extensive rock borings were made and they clearly showed the locations of mud seams and other zones where low RQD (Rock Quality Designation) values indicated the rock was very weathered.

In retrospect, it is quite obvious that the blaster was not qualified for this type of project. When the experience of the blaster is critical to the success of the work, the blasting specifications should clearly define the necessary experience requirements of the blaster-in-charge. Most blasting professionals would agree that the blaster, more than anyone else involved in the work, has more influence on the results and impacts of blasting. Having adequate experience in one industry clearly does not qualify a blaster for work in other disciplines. Mining companies or contractors have an obligation to ensure that their blasters have proper experience and training for the **specific** type of blasting work they perform or supervise. Moreover, project planners can also help avoid this problem by spelling out precise experience requirements for the blasters-in-charge in project specifications. The project inspectors and managers also play a role in evaluating the capabilities of blasters. At another high-risk dam construction project, inspectors representing a government owner found that the capabilities of several blasters were inadequate, and as allowed by the contract provisions, the contractor was directed replace them with qualified blasters.

DETERMINING POTENTIAL BLASTING IMPACTS

Before blasting begins in new areas, it is wise to define how the blasting might impact neighbors, animals, structures, utilities and the environment in general. Obviously, the degree of risk and impacts will vary depending on the nature of the blasting work. For instance, a downtown building implosion project will have very different risks from a proposed mining project in a national forest. Blasting programs in urban areas must control flyrock, vibration and air overpressure, whereas, the project in the national forest will likely have strict environmental controls on water quality and animal impacts. For example, work might be suspended during time periods when birds are nesting or fish are spawning. Blasting projects often have unique risks. In one case, it was feared that blasting in an urban area would cause rats to migrate from abandoned buildings into nearby homes. At other urban blasting projects, blasting was restricted when doctors performed sensitive laser surgery and when researchers conducted sensitive experiments with electron microscopes. When blasting occurred near an urban zoo, biologists concerned with blasting impacts on animals measured stress hormone levels in five control species. Due to the growing involvement of governmental agencies in the permitting process for new projects, especially large ones, potential environmental impacts are usually identified beforehand and mitigation measures are explained in environmental impact studies.

As shown in the previous case histories and examples, the risks associated with blasting are wide ranging and some are quite unique. The following table, although not complete, can be used as a general aid for identifying and developing measures to manage blasting risks.

TABLE 1. Blasting Risk Evaluation Guide

Concern	Primary Impacts	Controls
Flyrock	Damage and Injury	Pre-qualification requirements, blasting controls (blast mats—burden requirements—stemming requirements), blast plan submittals and reviews, and careful inspection of work.
Structural damage to buildings	Damage claims, work delays or suspension	Pre-qualification requirements, blasting controls, blast plan submittals and reviews, careful inspection of work, public education, effects monitoring and pre-blast condition surveys.
Damage to rock slopes and final excavation walls	Rock falls, remedial slope repairs and work disruption	Evaluate in situ condition of slopes and install additional support is needed. Develop blasting controls and carefully monitor the work.
Damage to buried pipes and utilities	Unrealistic restrictions on blasting or total ban on blasting	Pre-qualification requirements, blasting controls, blast plan submittals and reviews, careful inspection of work, effects monitoring and blasting effects evaluation study by expert.
Startled or scared people	Complaints	Inform neighbors before each blast.
Damaged water wells or aquifers	Blasting prohibition or project delays	Blasting controls, pre-blast and/or post-blast inspections, effects monitoring and blasting effects evaluation study by expert.
Environmental Impacts or other Animal Effects	Disapproved EIS, blasting prohibition or project delays	Blasting controls, pre-blast and/or post-blast inspections, and blasting impacts and mitigation study by expert.
Work or business disruption	Financial damage claims and/or organized opposition to the work	Public education, blasting controls, monitoring and schedule blasting during non-working hours.
Contractual Claims and Legal Actions	Financial damages	*Owners and Engineers:* Have appropriate experts review contract documents and specifications. Prepare pre-qualification requirements that ensure contractor and personnel are capable of performing the work, and carefully inspect and document all non-conforming work. *Contractors:* Carefully evaluate all available pre-bid documents—including all geotechnical information, attend pre-construction meetings, document all efforts to conform and barriers to conformance.

SUMMARY

Managing the risk of blasting starts well before the blaster shows up to do the work. Regulators develop blasting and explosive handling laws intended to improve blasting safety and minimize impacts on neighbors and nearby structures. Engineers develop blasting contract documents and specifications defining blasting performance goals and limitations. When the work is underway, the blaster-in-charge is clearly responsible for ensuring it is done safely and in compliance with regulations, specifications and rules. In construction work, inspectors also play a role in ensuring it is done properly. As illustrated in the case histories, the blaster or blasting contractor does not control all aspects of the risk-management process. The overall responsibility of managing blasting risk is shared with regulators, specification writers or rule makers and with managers and inspectors overseeing the work.

Our ongoing challenge is to improve blasting safety by understanding the principles of blasting risk management and by properly applying them at all projects. If successful, our reward will be fewer incidents and ongoing viability for blasting methods that are a valuable tool for the construction industry and society.

APPENDIX. REFERENCES

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