EFEE NEWSLETTER

In this edition:

Fines Reduction and Its Impact on the Economics of Aggregate Operations

The Fragmentation-energy Fan, a Universal Behavior of Blasted Rock?

...and much more!

September 2017

NEWSLETTER

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We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in November 2017. Please feel free to contact the EFEE secretariat in case:

- You have a story you want to bring in the Newsletter
- You have a future event for the next EFEE Newsletter upcoming events list
- You want to advertise in a future Newsletter

Or any other matter.

Jari Honkanen, Chairman of the Newsletter Committee and the Vice President of EFEE and Teele Tuuna, Editor of EFEE Newsletter - newsletter@efee.eu

Dear EFEE members, the President´s voice

I am very delighted to be able to write a few words of introduction to the first professionally printed EFEE Newsletter. It is published at a very important time and at the most important event for our federation, the 9th EFEE World Conference on Explosives and Blasting which takes place in Stockholm - the capital of Sweden from 10th to 12th September 2017. Regular readers of the EFEE Newsletter will note that this is easily one of the most volumnious issue published so far. Nevertheless, as those of you who will decide to attend the conference will know, a single Newsletter volume can provide only a sample of what will be presented there. In spite of that I assure all of you that this issue of EFEE Newsletter contains really outstanding articles that shed light on contemporary topics related to blasting and explosives.

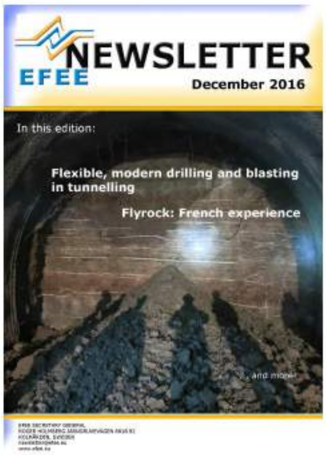
The EFEE World Conference on Explosives and Blasting has established itself as one of the most important international blasting events. It all started in year 2000 with 1st EFEE World Conference in Munich and after Prague 2003 it continues on a regular basis within 2 years period. All eight of our previous EFEE World Conferences, with great success, have proved to be really important events where we can mutually share our different experiences and skills. We expect the EFEE 9th World Conference on Explosives and Blasting to be as successful as our previous World Conferences and that it will attract participants and delegates not only from Europe but also from all over the World. The Conference is organized in cooperation with the Swedish national association - Swedish Rock Engineering Association.

The 9th EFEE World Conference on Explosives and Blasting 2017 will take place at the Brewery - Conference Centre Stockholm, a short walking distance from the city centre. The Conference will start on Sunday 10th September with registration, workshop and welcomeing reception and will continue on Monday 11th September and on Tuesday 12th September with technical sessions and exhibition. The Gala dinner is planned for Monday evening and will take place at Winterviken in former Alfred Nobel's factory. In accordance with experiences from our previous eight Conferences we expect attendance to over 450 delegates and professionals from over 50 different countries with a large industry exhibition. This will enable us to create a really unique forum for meetings and discussions of professionals from tunnelling, construction, demolition, quarring and mining industry. We have to mutually share all new and good experiences, as well as bad experiences to avoid mistakes in the future and improve our techniques.

It applies to all of us - explosives end-users, manufactures, drilling and blasting operators, consultants, contractors, university people and state authorities. We can all mutually benefit from the development of thinking and mutual dialogue inside our community about all aspects of our important and dangerous work. I believe that for us, as practitioners, and also for all our members is absolutely essential to share our experiences for continuous improvment of actions and procedures. I´m really looking forward to our meeting with all of you in Stockholm from 10th - 12th September 2017.

Finally please do not finish reading our September Newsletter edition with my foreword but kindly continue to read all the interesting articles prepared especially for you in this Newsletter. Special thanks we have to address to the article contributors for their work, trust and patience. We continue welcoming article submissions in our area of expertise.

Igor Kopal, President of EFEE



The EFEE Newsletter was first issued in 2008, thanks to the Newsletter Committee chairman Johan Finsteen Gjødvad, who was also the president of EFEE later on.

Since then, the Newsletter has grown and positively changed with time.

Now the Newsletter comes out quarterly, filled with interesting and useful topics from the explosives industry.

It is issued electronically as a PDF document and sent out via e-mail as a web magazine, it is easy to read on any tablet, smartphone or laptop. The Newsletter archive can be found on www.efee.eu/newsletter

The Newsletter is received by 25 National Associations, more than 1 000 corporations, institutions and universities and accessible to more than 20 000 individuals

We warmly welcome you to read the EFEE Newsletter regularly, you you can make a subscription on www.efee.eu or contact the Newsletter Committee directly - newsletter@efee.eu

Please, do not hesitate to contact the Newsletter also if you wish to publish a technical article or an advertisement aimed at the explosives industry.

Sincerely yours, the Newsletter editor, Teele Tuuna

Fines Reduction and Its Impact on the Economics of Aggregate Operations

Abstract

Previous work indicated that the annual per-capita consumption of raw aggregate material averages about 10 tons; half of which is produced by blasting. Given a population of approximately 320 million in the United States alone, this amounts to 1.6 billion tons of blasted material annually. It was also estimated that up to 20% of the blasted material in aggregate operations is smaller than 6.35 mm (1/4 inch) in size. Thus, about 320 million tons (i.e. 1 ton per capita) of byproduct is produced annually and sold at significantly lower prices or potentially discarded in waste dumps.

Therefore, aggregate producers are twice-penalized for the generation of such fines. Not only does it diminish the saleable volume of premium product, but it often ties up real estate wherever such material is placed. Operators often have taken a 'fatalistic' view, believing that economic blasting restraints and geologic constraints inevitably conspire to preclude a solution. This fatalistic view can lead to sub- optimal drill and blast procedures. The odds of maximized economic returns are worst in those cases where rock-on-ground contracts are bid without quantitative and objective blast performance indicators in place.

Several techniques to reduce blast-induced fines in aggregate operations have been suggested over the years. Some of such techniques included the use of: smaller hole diameter, air decks, low VOD explosives, short delay timing, etc. The use of numerical modeling and sophisticated computer codes has also been recommended. However, some of the suggested methods have shown to be unpractical or unfeasible in some cases. The current work is an attempt to critically review some of the practical methods to reduce blast-induced fines in aggregate operations. The current study also attempts to quantify the impact of fines reduction on the economics and profitability of such operations.

Introduction

Fines are an inevitable byproduct of any mining process. Blast-generated fines are assumed to originate mainly from the annular crushed zone around a blast hole with sizes less than 1 mm. The amount of fines from such crushed zone as well as the compacted zone behind it may constitute up to 5% of fines found in a muckpile. Crack branching and merging, joint filling and breakage is another significant source of fines during blasting and may contribute up to 10% more fines. Additional sources of -1 mm material may be attributed to loading, haulage and dumping prior to crushing (Ouchterlony & Moser, 2012).

Depending on the application, fines may or may not be considered a byproduct depending on the operation. In quarry applications, fines are considered an undesirable product as it does not typically constitute a sellable product and cost the operation in disposal expenses. In operations adopting leaching as the main ore processing method, the generation of excessive fines may hinder recovery as certain fines tend to affect the permeability of leaching pads. Minimizing or eliminating fines in such applications is appealing (Tawadrous, 2012).

On the other hand, in some metal mines fines may be advantageous as the ore has to be crushed and ground after blasting and excavation. Therefore, fines generated from blasting in such operations may reduce the energy consumed in downstream operations and can increase mill throughput. Over the years, a consensus between practitioners has developed that the vast majority offines generated in a blast are produced due to compressional damage around the blasthole (Hustrulid, 1999,(Whittaker, Singh & Sun, 1992).

Previous work indicated that the annual per-capita consumption of raw aggregate material averages about 10 tons; half of which is produced by blasting. Given a population of approximately 320 million in the United States alone, this amounts to 1.6 billion tons of blasted material annually. It was also estimated that up to 20% of the blasted material in aggregate operations is smaller than 6.35 mm (1/4 inch) in size (Moser, 2004).

Thus, about 320 million tons (i.e. 1 ton per capita) of byproduct is produced annually and sold at significantly lower prices or potentially discarded in waste dumps.

Therefore, aggregate producers are twice-penalized for the generation of such fines. Not only does it diminish the saleable volume of premium product, but it often ties up space wherever such material is stockpiled. Operators often have taken a 'fatalistic' view, believing that economic blasting restraints and geologic constraints inevitably conspire to preclude a solution. This fatalistic view can lead to sub-optimal drill and blast procedures. The odds of maximized economic returns are worst in those cases where rock-on-ground contracts are bid without quantitative and objective blast performance indicators in place.

Extensive research efforts over the last several decades were dedicated to understanding generation of fines in mining and quarrying operations. Hustrulid (1999) credits Favreau (1969) with establishing the fundamental relationships for borehole pressures. He cites Il'yushin (1971) for work in understanding mechanisms of crushing around a borehole. The USBM predictive model (Atchison, 1964) considered three zones of fragmentation around a blasthole: 1) source zone, 2) transition zone & 3) seismic zone.

The Swedish Rock Blasting Research Organization (SveDeFo) described fragmentation around a borehole using different explosives in efforts to reduce damage in adjacent rock (Olsson, 1996). An excellent case history by Oriard (1993) describes efforts to reduce fines in a large dam project. Esen et al. (2003) reviewed the work of five researchers to calculate the volume of the crushed zone and presents an additional fines predictor. A comprehensive "Less Fines" project was undertaken in Europe. Moser (2004), Oucterlony (2005), Sanchidrian (2002) and Grasedieck (2002) all reported on this work. The less fines project included full- scale quarry shots as well as laboratory tests using rubber lined chambers. Ouchterlony and Moser (2012) have proposed a "branching and merging" mechanism to account for the large amount of fines produced beyond the crushed zone.

Definition of Fines

In order to effectively influence the amount of fines, it is of high importance to quantitatively define what sizes fines encompass. **Figure 1** depicts three zones of fragmentation in a muckpile: 1) coarse material originating in the collar and face, 2) gradational fragmentation throughout much of muckpile and 3) fines due to compressional failure adjacent to the powder column.

In an attempt to minimize the amount of blast-generated fines during a dam construction project, Oriard (1993) defines fines as the material of sizes less than 4.69 mm (Mesh #4). Muñoz et al. (2010) use sizes less than 150 microns to define the portion of fines in their attempt to increase the recovery of heap leaching pads in a copper operation. Onederra et al. (2004) proposed a modified engineering model to predict fragmentation due to blasting. In their work, the authors applied the model to quarry operations and suggested that the fines inflection point is best defined at 1 mm.

Ochterlony & Moser (2012) point out that the choice of 1 mm as an upper limit in that case has no direct physical background, but may only be related to the grain size of the rock. Moser et al. (2003) use sizes between 100 microns and 1 mm to define the sizes of fines in quarry operations.

It can be concluded that the literature does not have a clear definition of the sizes within the fines range. It is the authors opinion that an industry-wide definition of fines should be established to eliminate confusion between practitioners and align the attempts of predictive modeling. If one definition is unachievable several definition of fines can be established such that each one serves a segment of the industry. For the purpose of the current study, fines are defined as sizes less than 6.68 mm (Mesh #3).

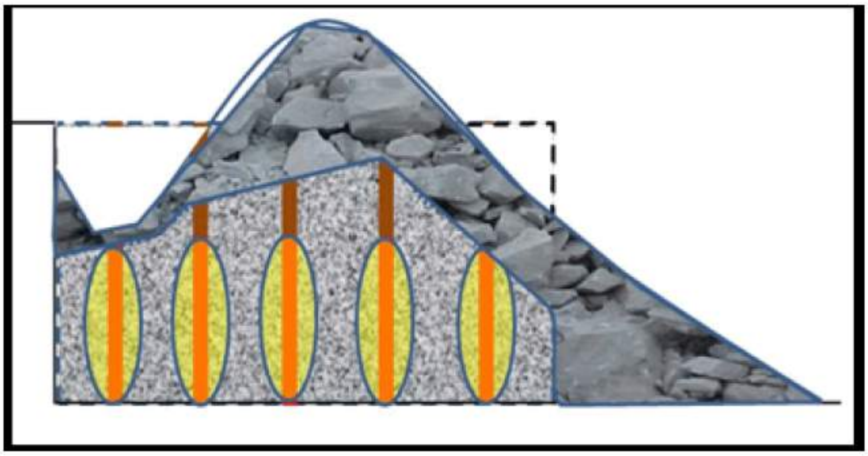


Fig. 1. Different zones of fragmentation in a muckpile

properties and the behavior of the rock under static and dynamic loading conditions. The results of the testing program can be used further to predict the response of the rock due to blasting using different explosive products, hole diameters, air decks, etc.

Techniques of Fines Reduction

Several techniques to reduce blast-induced fines in aggregate operations have been suggested over the years. Some of such techniques included the use of: smaller hole diameter, air decks, low VOD explosives, short delay timing, etc. The use of numerical modeling and sophisticated computer codes has also been recommended. However, some of the suggested methods have shown to be unpractical or unfeasible in some cases. Moreover, understanding the physical and mechanical properties of the rock being blasted as well as its response to explosive loading is imperative to fines reduction. Oriard (1993) indicates that more fines are generated when blasting high-strength brittle lime-stone which is counter intuitive. Vovk et al. (1973) show experimental results indicating a relationship between extent of rock fracturing and its strength, Figure 2. Tawadrous (2010) proposed a testing methodology to characterize rock layers. The procedure uses detailed testing techniques to define the mechanical

Estimation of Fines

Over the years, several empirical models have been introduced to predict blast-induced fragment size distribution. One of the commonly used models in the mining industry to predict size distribution from blasting is the Kuz-Ram model proposed by Cunningham (1983). The model makes use of the following:

- the Kuznetsov equation that predicts the mean fragment size from blasting;

- the Rosin-Rammler equation which has long been established as approximating the size distribution not only of crushed coal (its original application) but also of rock in blast muck piles;

- an empirical equation using blast pattern geometry parameters which gives a value for n in the Rosin-Rammler equation (Cunningham, 1987).

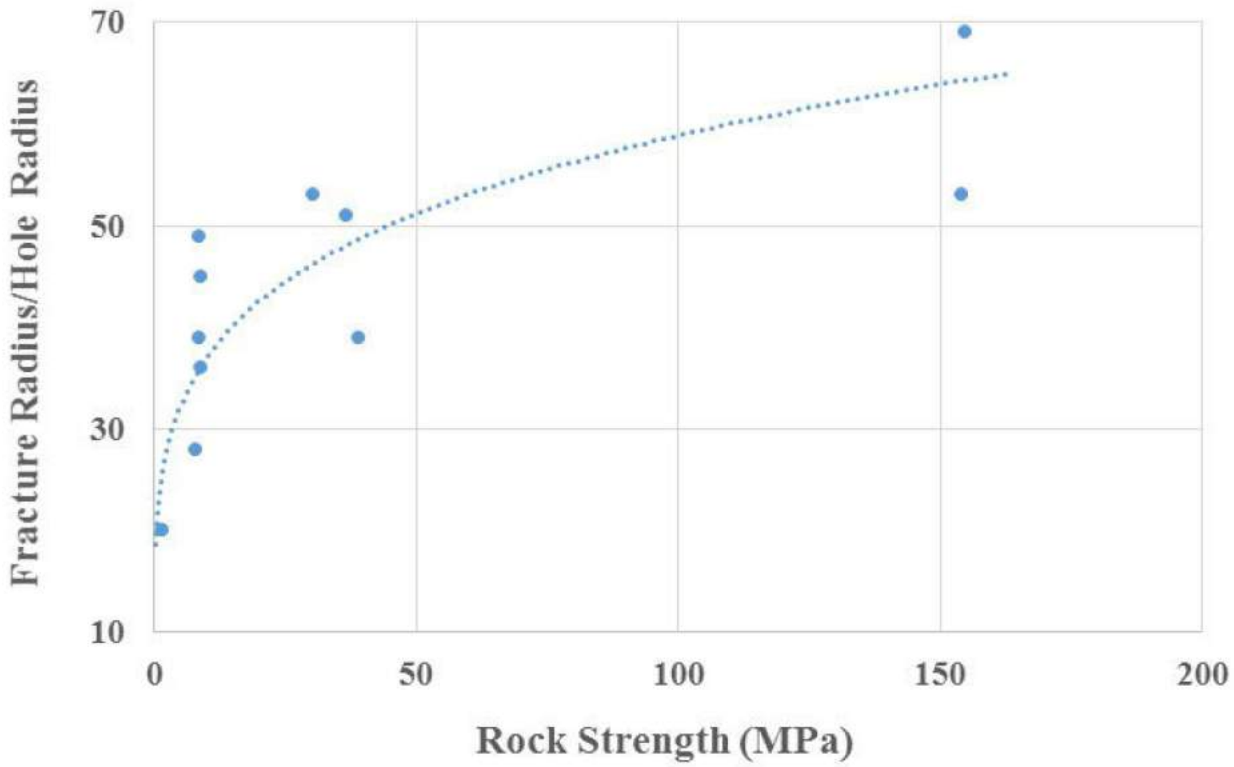


Fig. 2. Extent of rock fracture as a function of rock strength (Vovk et al., 1973)

Although the original model, as proposed by Cunningham (1987), is still used extensively in practice, it has some known drawbacks such as insensitivity to delay timing (Chung & Katsabanis, 2000) and the poor ability to predict fines unless detailed sieve or high-resolution image analysis data are available for calibration (Gheibie et al., 2009). However, detailed sieve analysis is scarce and high-resolution image analysis is expensive to acquire. This constitutes a major hurdle in calibrating the model and accurately estimating fines. Some attempts have been made to incorporate the effect of delay timing between holes as well as the effect of detonator scatter on fragmentation into the model (Cunningham, 2005).

The Two-Component Model (TCM) was proposed to improve the accuracy of the Kuz-Ram model to predict fines. It employs two Rosin-Rammler distributions to predict the entire size distribution. The TCM is a five-parameter model in which two of the parameters are related to the coarse fraction of the distribution and three are related to the fines part (Djordjevic, 1999). It was observed that the TCM frequently underestimates the amount of fines found in the muckpile even when half-barrels on the bench face are visible after the blast (Ouchterlony & Moser, 2012).

Spathis showed that the original Kuz-Ram model contained an error that skewed the predicted size distribution to the larger size fractions.

The corrections enhanced the fines predicted by the Kuz-Ram model (Spathis, 2004). Given that the TCM utilizes two Rosin-Rammler distributions it inherently contains the same error and requires similar corrections. Another recently-developed model to predict size distribution is the Swebrec function (Ouchterlony, 2005).

Astrom (2006) showed that the instability of fast propagating crack plays a fundamental role in the size distribution curve specially in the small size regime. He indicates that unstable cracks leave behind a trace of small-size fragments along their propagation paths. These fragments follow a universal power- law. Grasedieck (2006) was able to relate the points of minimum slope along the size distribution curves of shot cylindrical specimens, i.e. the inflection points, to the points where the fragments go from being composed of multi-mineral, possibly polycrystalline, fragments to single-mineral grains.

Sophisticated numerical modeling is increasingly used as a tool to analyze high loading rate type problems. Due to the advancement of the computational power, it has become possible to carry out large-scale numerical simulations that could reproduce many complex physical processes to great details. Tawadrous (2012) used hydrodynamic modeling and a calibrated material model to estimate the amount of fines produced around a blasthole due to the detonation of ANFO and emulsion, Figure 3. The model indicated that fines produced due to an emulsion charge are over twice the amount of fines produced by an ANFO charge occupying the same hole.

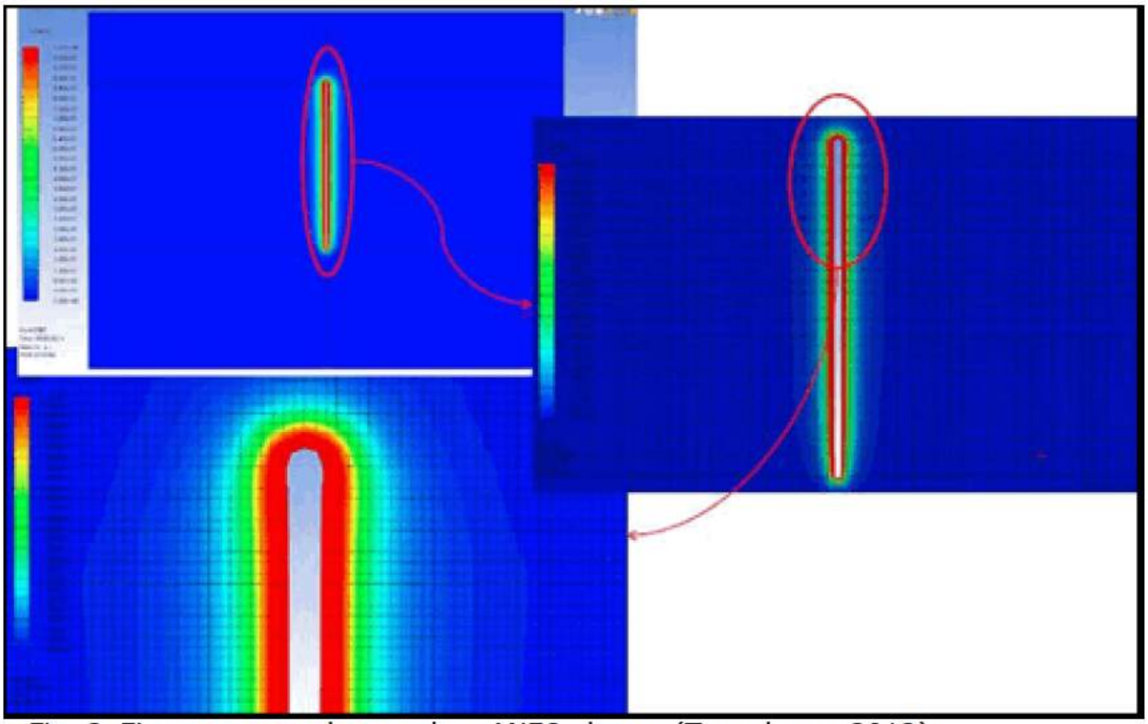


Fig. 3. Fines generated around an ANFO charge (Tawadrous, 2012)

Several engineering models to predict the extent of crushing around a blasthole have been suggested. The model presented by Esen et al. (2003) shows that the ratio between the crushing zone radius and borehole radius is a function of explosive type, rock properties and blasthole diameter. Even though there was no clear definition of the sizes included in the crushing zone predicted by the model, its results came in very close agreement with those predicted by Tawadrous (2012). This indicates that the crushed zone entails sizes in the micron range of the size distribution curve.

ECONOMIC IMPACT OF THE AMOUNT FINES GENERATED

Given the significant economic implications, it's not surprising that a great deal of research has gone into efforts to reduce fines induced by blasting. Strategies for fines reduction fall into three categories: reduced velocity of detonation, reduced powder factor and decoupling. The crushed zone that results from compressive failure near the borehole is most often cited as the principal source of fine material. This zone is thought to be very fine; generally, in the micron range. This definition of fines is order of magnitudes smaller than what aggregate producers consider as fine material where sizes under 25.4 mm (1 inch) have a reduced value and sizes below 6.35 mm (1/4 inch) are often on economic.

The authors originally set a seemingly modest goal of creating an economic model to guide efforts to reduce fines and encourage the advances of Esen et al (2003) and the observation by Vovk et al. (1973). However, during the literature review, Oriard (1993) and Ouchterlony et al. (2012) have shed light on the complex mechanisms involved. Therefore, a somewhat anecdotal offering follows which may serve as a practical yardstick to guide cost optimization efforts.

An optimization scheme for aggregate production has the potential of becoming quite complex. A reduction in powder factor could hypothetically yield an increase in the percentage of the high-value size fraction. However, high costs may result from unanticipated productivity losses in areas such as secondary breakage, low loading speeds or crusher hangups. Optimization of blasting with regard to fines demands a firm commitment. Experienced operators have developed a list of do's and don'ts to manage fines. However, for effective optimization, data-driven decision making is essential. This section looks at a few hypothetical scenarios that may help to illuminate available opportunities. The scenarios assume a 10,000,000 tons per year operation with an average selling price of $6/ton and a 15% unsellable fines. The reduction of 1% in fines therefore nested additional 100,000 tons per year. The gain is then estimated to be $600,000 less additional costs incurred.

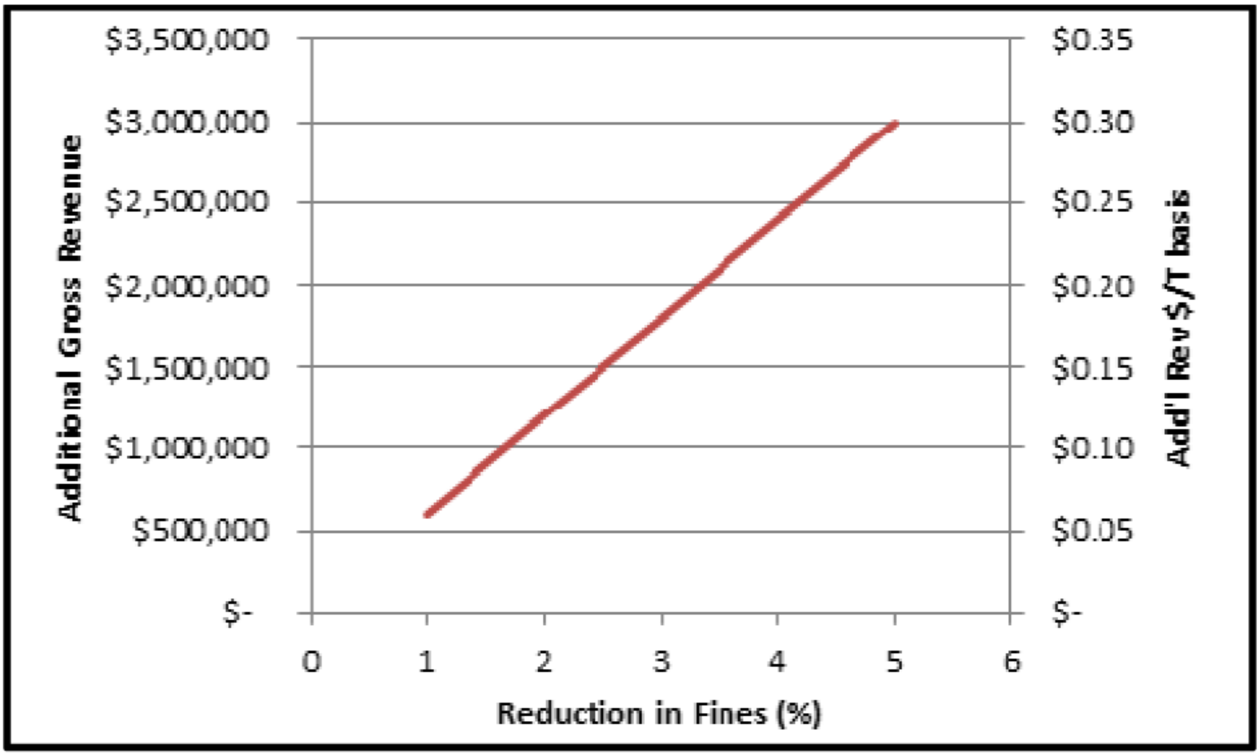


Fig. 4. Additional gross revenue and revenue per ton as a function of fines reduced

Table 1 summarizes the geometrical design parameters used in the modelled scenarios. Figure 4 shows the estimated increase in gross revenue and revenue per ton as a function of percentage of fines reduced.

Case One: A quarry attempts to reduce fines generation from blasting by having a better control over the delay timing of the blast pattern. This is achieved by converting from the use of non-electric detonators to electronic initiation.

Geometry	
Diameter (mm) (in)	(127) (5)
Bench Height (m) (ft)	(10.7) (35)
Spacing (m) (ft)	(4.27) (14)
Burden (m) (ft)	(4.27) (14)
Subdrill (m) (ft)	(0.91) (3)
Stemming (m) (ft)	(3.05) (10)
Explosives Density (g/cm^3)	(1.25)
Rock Density (kg/m^3) (lb/ft^3)	(2723) (170)

Table 1. Geometrical parameters assumed for economic modeling

Table 2 shows the unit costs when using non-electric detonators and electronic detonators while Table 3 compares the cost per ton in both cases. The additional annual cost amounts to $300,000.

Unit	Non-Electric Detonators	Electronic Detonators
Booster	$4.00	$4.00
Downhole Cap	$6.00	$25.00
Surface Cap	$4.00	N/A
Drilling ($/ft)	$2.00	$2.00
Explosives Cost ($/lb)	$0.25	$0.25
Primers in Hole	1	1

Table 2. Unit cost in the case of non-electric detonators vs. electronic detonators

	Non-Electric Detonators			Electronic Detonators		
Item	$/Hole	$/Yd	$/ton	$/Hole	$/Yd	$/ton
Drilling	$75.60	$0.30	$0.14	$75.60	$0.30	$0.14
Explosives	$74.45	$0.29	$0.14	$74.45	$0.29	$0.14
Primer	$14.00	$0.06	$0.03	$29.00	$0.11	$0.06
Total	$164.05	$0.65	$0.31	$179.05	$0.70	$0.34

Table 3. Cost per ton in the case of non-electric detonators vs. electronic detonators

Case Two: A quarry has multiple rock types and uses a standardized blast design. Comprehensive sampling and rock testing reveals areas needing special drill and blast procedures. The comprehensive testing program for a rock type may cost approximately $100,000. In the long run, expedient field tests such as drop weight test or measured while drilling parameters can replace expensive lab testing.

Case Three: A quarry reduces the powder factor by expanding pattern sizes and realizes a reduction in fines. However, the practices subsequently abandoned due to excess toll in extra oversize which hampers productivity. The solution may be to add stab holes to the new expanded pattern.

The same unit cost assumed in case one is used for case two. **Table 4** compares the cost per ton in the case of the base pattern to the expanded pattern when adding stab holes. The pattern expansion with added stab holes yields an annual savings of $300,000.

Case Four: A quarry reduces the powder factor by expanding pattern sizes and realizes a reduction in fines and some increase in oversize. The initiative is subsequently hampered due to reduction in loader availability and increase in cycle time. **Table 5** compares the cost per ton in the two cases. A reduction of 1% in fines ($600,000 increased revenue) will significantly overcome the cost of deteriorated cycle time and loader availability ($200,000).

	Base Pattern		Expanded Pattern with Stab Holes	
Item	$/Yd	$/ton	$/Yd	$/ton
Drilling	$0.30	$0.14	$0.28	$0.13
Explosives	$0.29	$0.14	$0.27	$0.13
Primer	$0.06	$0.03	$0.04	$0.02
Total	$0.65	$0.31	$0.59	$0.28

Table 4. Unit cost in the case of expanded pattern with stab holes

	Base Case (Finer Fragmentation)	Expanded Pattern (Coarser Fragmentation)
Loader Availability (%)	85	80
Fill Factor (%)	90	85
Cycle Time (min.)	10.9	11.8
Productivity (tons/hr)	1519	1322
Cost ($/ton)	$0.73	$0.75

Table 5. Unit cost in the case of deteriorated loader availability & cycle time

It can be observed that a strong case can be made in support of fines reduction economics. If achieved, the goal of gaining 1% reduction in unsaleable rock would net $600,000 in additional revenue. None of the figures provided can be considered engineered values nor are the tactics assured of providing any fines reduction. The purpose of this exercise is to unify a complex problem into a simple set of numbers for consideration. Some may consider this a best case scenario; others may feel that a goal of 1% is modest. Some operations may be sensitive to storage space for excess fines and the costs associated with reclamation of waste dumps.

DISCUSSION

Experienced operators are keenly aware of bottlenecks in the flowsheet. A hierarchal summary of bottlenecks is a necessary first step. The most commonly cited critical bottleneck is the primary crusher. Where production is crusher-limited, it may be unwise to coarsen crusher feed. In these cases, improved sorting at the face, adding a grizzly or very selective coarsening by rock type could be considered. Successful implementation of a reduced fines program will rest upon heightened awareness of field controls. The margin for errors will shrink.

Misidentification of rock types, drilling errors, product performance or imprecise hole loading could shift the economic balance unfavorably, thus raising the probability of an overly coarse muckpile with low digging rates and unacceptable crusher throughput. A single bad blast could sour management's view and hinder future efforts to reduce fines.

Unlike a fixed installation (e.g. the primary crusher), there may be some flexibility in loading. Additional loaders may not be necessary if longer shifts or an additional shift can be used. While lower productivity is often considered heresy, this cost is easily and accurately modeled and should not be discounted out of hand.

Final pit walls often receive special attention. However, it is uncommon to employ pre-splitting in routine production blasts. The objective would be to create a reliably uniform new face with minimal damage. The potential for oversize in the front row would be reduced and could potentially allow a lower powder factor for the entire blast.

Much has been published in regard to consistent timing and its effect on uniformity in fragmentation. The additional costs for electronic timing are straightforward and predictable. The additional control afforded by precise timing has been shown to increase uniformity of fragmentation.

CONCLUSIONS

Fines are an inevitable byproduct of any mining process. Blast-generated fines are assumed to originate mainly from the annular crushed zone around a blast hole. Crack branching and merging, joint filling and breakage is another significant source of fines during blasting. Additional sources of fines may be attributed to loading, haulage and dumping prior to crushing. In quarry applications, fines are considered an undesirable product as it does not constitute a sellable product and cost the operation in disposal expenses. Aggregate producers are twice-penalized for the generation of such fines. Not only does it diminish the saleable volume of premium product, but it often ties up space wherever such material is stockpiled.

Several techniques to reduce blast-induced fines in aggregate operations have been suggested over the years. Some of these techniques included the use of: smaller hole diameter, air decks, low VOD explosives, short delay timing, etc. Understanding the physical and mechanical properties of the rock being blasted as well as its response to explosive loading is imperative to fines reduction. Testing methodologies have been proposed to characterize rock layers. The methodologies detailed procedures to define the mechanical properties and the behavior of the rock under static and dynamic loading conditions.

The results of the proposed testing program can be used further to predict the response of the rock due to blasting using different explosive products, hole diameters, air decks, delay timing, etc. Much has been published in regard to consistent timing and its effect on uniformity in fragmentation. The additional costs for electronic timing are straightforward and predictable. The additional control offered by precise timing has been shown to increase uniformity of fragmentation.

Successful implementation of a reduced fines program will rest upon heightened awareness of field controls. The margin for errors will shrink. Misidentification of rock types, drilling errors, product performance or imprecise hole loading could shift the economic balance unfavorably, thus raising the probability of an overly coarse muckpile with low digging rates and unacceptable crusher throughput.

It can be concluded that even a 1% reduction in unsaleable product in an aggregate operation would net significant additional revenue. Some may consider this a best case scenario; others may feel that a goal of 1% is modest. Some operations may be sensitive to storage space for excess fines and the costs associated with reclamation of waste dumps. Nonetheless, the increase in revenue may justify the cost of additional personnel or loader productivity losses.

J. Eloranta and A. Tawadrous

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Progress in blasting through digital solutions

Digital solutions and innovations are playing an important part in the development of the excavation and mining industries in the near future. Being able to gather real-time data from every step of the blasting process and analyzing it, in order to optimize blasts and getting better and cost-effective results, is the direction to which the development seems to be heading. We might not be there quite yet, but it is a realistic goal that is not that far away.

Co-operation between different fields and organizations is essential in reaching this next level of digitalization with automated signals, data gathering and having machines communicating seamlessly to improve results as well as the overall safety on the blasting site. When bright minds with different competences work together for a common goal, progress is inevitable.

Benefits of a modern blast design software

O-Pitblast is one example of a relatively new blast design software, that represents the previously mentioned new wave of digital solutions that are likely to impact our field. Lead developers of O-Pitblast,

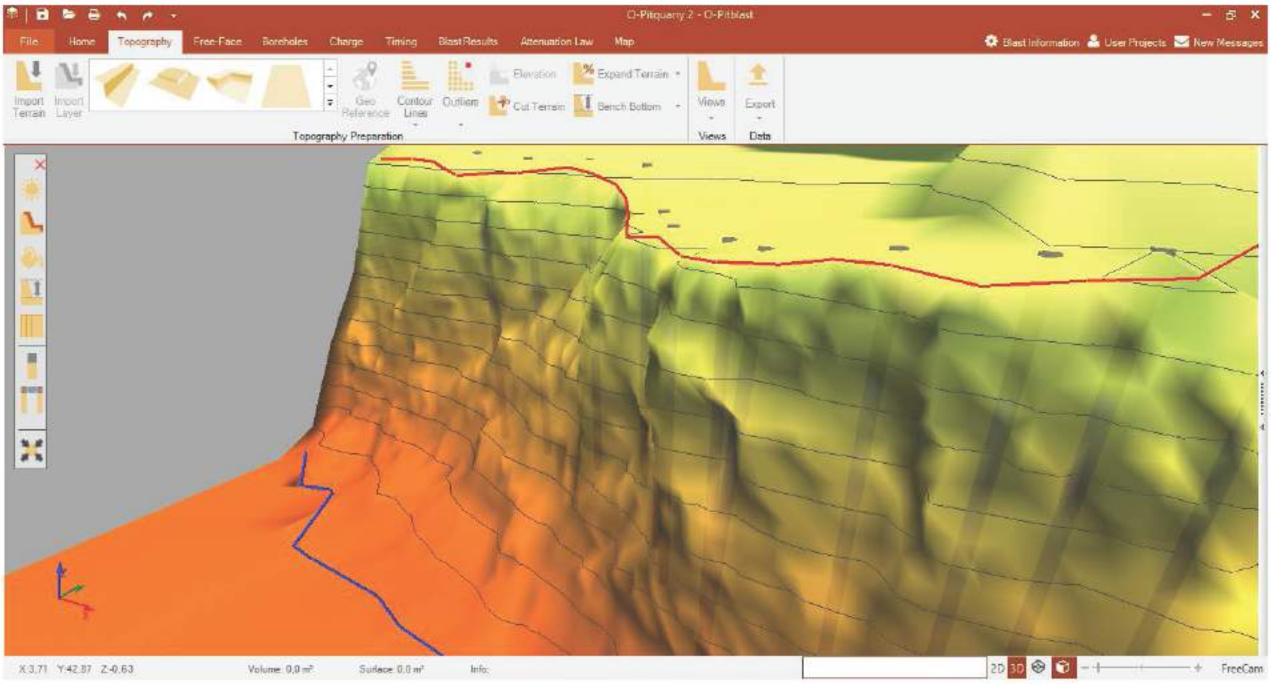


Image 1.

Francisco Leite and Vinicius Gouveia, set out to develop a platform to serve as a complete toolkit for blast design and optimization.

Jarkko Manninen, from the Finnish aggregate producing company Rudus (part of international CRH group), was among the first Nordic users of O-Pitblast. Jarkko is an experienced blast engineer and he uses the software on a daily basis. Currently Jarkko uses the software mainly for scanning his blasting sites and designing blasts using the Free Face, Borehole and Charge modules. He acknowledges that there still is work to be done with the software, but he also points out that extensive testing and continuous communication with the developers is the best way to improve software and implementing new features.

Existing features of the system include following modules:

Topography module is a tool that allows the import of XYZ point clouds into the software and begin designing the blast field using an actual model. The Topography module also allows for the creation of different types of standard models, which allows blast planning to be completed with a theoretical model without actual location data.

Free Face module allows the import of blast location data obtained using different types of laser scanners and creating a 3D model based on their XYZ coordinates. The model is created on the coordinate system to which the scanner is linked during scanning. This menu allows, for example, the import of measurement results from MDL, Renishaw and Pulsar borehole deviation sensors, which allows the analysis of the situation in the field as realistically as possible.

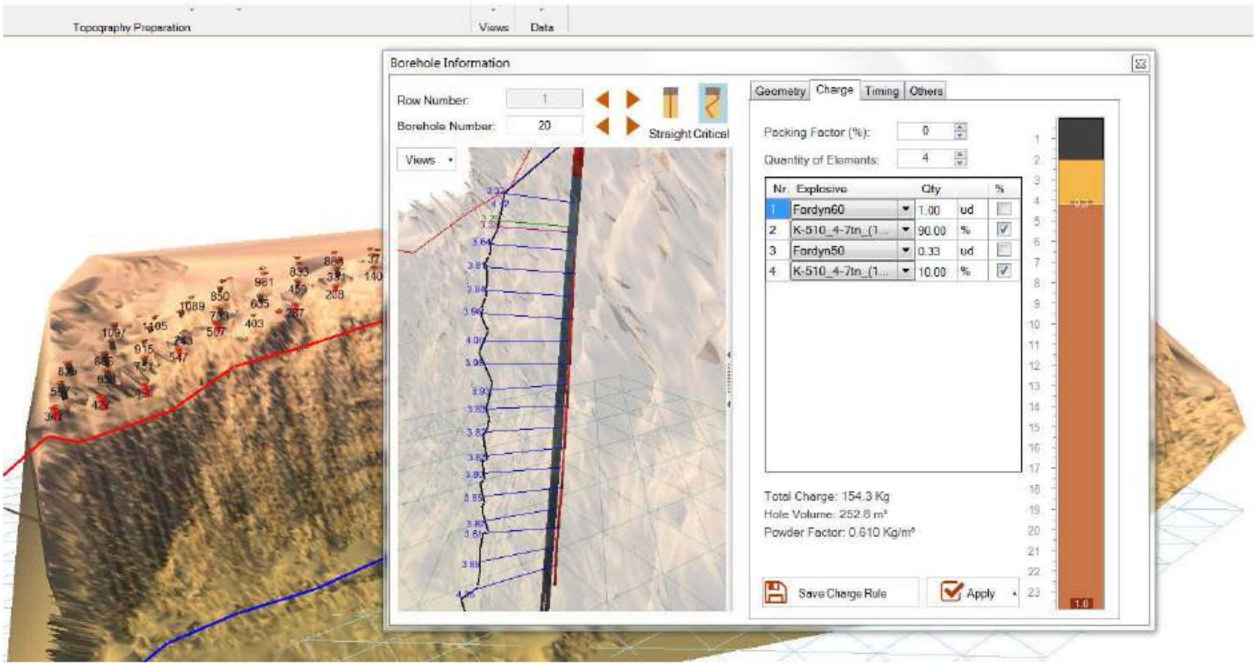


Image 2.

Borehole and Charge module can be used to import and design drill patterns and charges for blasting. The file is imported as a XYZ text file (.txt or .CSV, in the future also in e.g. .xml) and the plan can be exported to devices that support data drilling in .CSV format. Boreholes can be reviewed individually or as a pattern in relation to the total benefit when an actual 3D model has been created for use. Boreholes can be charged using a single, standard charging rule. Then, the front row can be reviewed one borehole at a time, for example, and the loading adjusted according to the requirements of the actual conditions.

Timing module allows detonator planning using electric detonators, tube impulse detonators and electronic detonators. O-Pitblast allows timing to be simulated and blast directions and simultaneously igniting boreholes to be reviewed. When using electronic detonators in the planned field, the calculations in the software can be used to ensure that a single borehole is ignited at a time in the desired time window.

Image 3.

Blast optimization

Analytical tools of a modern blast design software allow prediction of fragmentation patterns as well as vibration effects from a blast. The data from the analyses can be utilized in the optimization of blast plans, which contributes to better and more cost-effective blasts.

The Blasting result module menu can be used to estimate the fragmentation of the blast field and optimize future blasts to better suit the fragmentation range requirements or to be more cost-effective.

O-Pitblast also allows the consideration of blast vibrations when designing the field, which provides a warning if the load being designed is too instantaneous for the conditions.

Cloud services

Today's advanced blast design softwares allow managing and organizing of blast plans in their respective cloud services, which means that you'll have access to your blast plans wherever you are as long as you are connected to the internet. O-Pitblast's cloud service, for example, allows the user to download a specific design to a PC or share it with another user. Furthermore, an additional iOS mobile application is provided, which can be used to review blast designs on smartphones and make changes to borehole-specific loads on the field.

Blast design software demonstrations at EFEE 2017 in Stockholm

Francisco Leite, one of the lead developers of O-Pitblast, will be at Forcit's exhibition booth (25 & 26) during EFEE 2017 in Stockholm, demonstrating O-Pitblast and its features.

Jesper Nyström, Tomi Kouvonen
OY FORCIT AB

A report from the Technical Committee of the 9th EFEE World Conference of Explosives and Blasting

During the spring of 2017, many abstracts from all over the world has been sent to EFEE. The abstracts cover many subjects like:

- Blast Vibration and Seismology
- Blasting Work Experiences
- EU Directives and Harmonisation Work
- Construction Blasting
- Health, Safety and Environment
- Blast Design Management
- New Applications and Training
- Quarry Experience
- Technical Development

A total of 80 abstracts was sent in. The quality of the papers differed but in general they were well written well and the Technical Committee had a lot of work to do in order to select the most interesting ones.

This task is as difficult as there is much hard work involved in the projects described by the contributors, and they are of course very eager to communicate what their interesting projects has resulted in.

It is also a fact that some of the contributors may not be able to participate in the conference if their papers have been rejected.

On the conference, which will be run in parallel sessions, will only be possible to have less than 50 papers, with half an hour for presentation.

The conference starts with a Workshop on Sunday, 10th of September, 2017. For the first time in EFEE Conference history the workshop will include a site visit to the biggest road construction project in Sweden - the E4 Stockholm bypass – Förbifart Stockholm. This essential new section of Stockholm network is 21 km long with over 18 km being routed underground, to reduce the impact on Stockholm's natural and cultural environment. Therefore it requires a huge amount of drilling and blasting work for tunnels, using the very latest research and technology.

After this superb visit, the participants will have the unique opportunity to discuss the project with the client, contractors and consultants, including the key areas of the design, environmental impacts, challenges in blasting and much more. Further information surrounding the project is available on the following web site. www.trafkverket.se/en/thestockholmbypass

On Monday and Tuesday, 11th and 12th September 2017, there will be parallel sessions for the paper presentations.

The Technical Committee warmly welcomes all of you to a great conference with a very large exhibition, held right in the middle of the city of Stockholm, overlooking the lake Mälaren. We are sure you all will have a wonderful time!

The Technical Committee members

Roger Holmberg, Sweden – (Chairman)

After graduation 1972 he was working as Blasting Research Engineer for the Swedish Detonic Research Foundation (SveDeFo), performed research in many quarry and mining operations and wrote computer codes for bench, tunnel blasting and thermodynamic codes for explosives performance calculations. Roger was President for SveDeFo 1982-86. Roger has been involved as a blasting consultant in many parts of the world, for construction and mining companies and for governmental bodies. He was one of the founders of the International Society of Rock Fragmentation by Blasting. He paid four years' service as a Board of Directors of the Int. Society of Explosives Engineers (ISEE) and two years as President for the European Federation of Explosives Engineers (EFEE). Roger has had various positions at Nitro Nobel, Dyno Nobel, Orica and Nitro Sibir. Today he is working as Secretary General for EFEE. Roger is author and co-author of over 100 publications.

Robert Farnfield, UK

After graduating from Leeds University with a degree in Mining, Rob carried out research into the environmental impact of surface coal mine blasting for more than 10 years with funding from the UK's National Coal Board Opencast Executive. Rob then moved on to become a lecturer in Mining Engineering at Leeds and completed a Ph.D. in the environmental impact of surface mine blasting. For the last 17 years he has worked for EPC-UK, initially as Technical Services Manager dealing with all aspects of the use of explosives. In 2007 he was appointed Technical Services Manager for EPC Group Area B with a watching brief over technical matters in Northern and Eastern Europe. He is now Head of Explosives Engineering for EPC-UK. Rob is a Member of the UK's Institute of Explosives Engineers and The International Society of Explosives Engineers. Rob has published many papers relating to explosives engineering and is a well-known speaker throughout the industry.

Finn Ouchterlony, Sweden

Finn Ouchterlony graduated from the Royal Institute of Technology in Stockholm, Sweden in 1980 (Tekn.Doktor) and received his honorary degree from Montan-universität Leoben (Dr.mont.h.c.) in 2007. His skills include fracture mechanics, blast damage and blast fragmentation. From 1967 to 1984 he was employed by Atlas Copco and worked mainly at the Swedish Detonic Research (SveDeFo) labs in Vinterviken. During 1987-1993 he was head of the SveDeFo labs, during 1993- 2003 head of the blasting research at SveBeFo and 2003-2010 head of the Swedish Blasting Research Centre, Swebrec. He has held academic positions at Luleå Univ. Technology (1985-88), Yamaguchi Univ., Ube, Japan (1991-92), Luleå Univ. Techn. (2003-2010) and Montanuniversität Leoben, Austria (2011-2014.

Finn Ouchterlony was co-author of the EU funded projects "Downhole Abrasive Jet Cutting Operations in Quarrying, Mining and Civil Engineering" (BE-1671; 1996-99) and together with Prof Peter Moser of "Less Fines Production in Aggregate and Industrial Minerals Industry " (GRD-2000-00438; 2001- 2004). He has a long experience of working with industry related explosives and blasting projects.

He was the co-ordinator of the ISRM working group WG on Fracture Toughness Testing of rock, which led to suggested methods in 1988. He is a member of the editorial boards of the journals: i) Blasting and Fragmentation (ISEE), ii) Int. J. Rock Mechanics and Mining Sciences and iii) Rock Mechanics and Rock Engineering. He is a member of the int. organizing committee of the triennial Fragblast symposia. He discovered the Swebrec distribution during the Less Fines project. This led to the Douglas Hay award in 2005.

Jörg Rennert, Germany

Jörg Rennert (Dipl. –Ing. –Päd) is a German Citizen, born May 22, 1965, in Roßlau, Germany. His educational achievements include a high-school graduate in steel working for metallurgical engineering and a diploma: Dipl.-Ing.-Päd. from the Technical University of Dresden. Jörg's professional career includes being a steelworker for metallurgical engineering in the steelwork in 1985. A scientific employee of the Technical University of Dresden in 1991. Assistant professor at Sprengschule Dresden GmbH from 1992 to 1998. Jörg progressed to managing director of The Dresdner Sprengschule GmbH and leader of business fields Blasting Technology and Pyrotechnics in 1998.

In 2001 Jörg became president of the German Blasting Association (Deutscher Sprengverband e.V.). In 2010 he was elected as vice president of EFEE and was the president of EFEE between 2012 and 2014. Since 2008 Jörg is also the Chairman of the EU-Directives in EFEE.

Jerry Wallace, USA

Jerry R. Wallace came into blasting naturally – as a 5th-generation logger in the U.S. Pacific Northwest. A licensed professional blaster for over 35 years, Jerry founded Wallace Technical Blasting, Inc. in 1992. The firm specializes in close-in civil construction blasting, and now includes Jerry's two sons who are earning their own stripes in the industry.

Jerry studied Forest Engineering at Oregon State University, including coursework in explosives engineering. He has taught numerous professional blasting courses including within the University of Washington (Seattle) Professional Engineering Program. An active ISEE member since 1984, Jerry served on the ISEE Board for 12 years including a two-year stint as president.

Jerry is one of the many co-authors of the 17th and 18th editions of the ISEE Blasters Handbook. Jerry has served on several governmental advisory committees dealing with explosives and industrial safety laws and regulations in the U.S. Jerry has been active in EFEE since the first conference in Munich in 2000, has attended each of the 8 previous EFEE conferences and presented papers at 3 of them.

Roger Holmberg
Secretary General EFEE

EFEE Membership

<u>**Become an EFEE member and take use on the following benefits:**</u>

Reduced fee for attending EFEE Conferences.

Reduced fees on workshops in conjunction with EFEE conferences.

On-line access to proceedings from all earlier EFEE Conferences except 2000 and 2003.

Access to the EFEE web page with information and possibilities to interact with members.

Gain access to list of European standards on vibrations and air blast through the member section of the EFEE website.

Gain information of and possibilities to influence the EU shot firing procedures and attend standing committees like EU-directives, Environmental and Newsletter.

Supporting of the professional explosives engineers.

Network of professional explosives engineers.

A possibility to be part of the EFEE Council and influence the EU explosives society.

Four electronic Newsletters per year.
Information on conferences and professional courses.

SAFEX information on incident matters in the explosives industry.

Corporate Members also have the benefit of a 25% discount on ads in the EFEE Newsletters

Visibility on the EFEE website.

There are different types of membership in EFEE: National Association membership, Corporate membership and Individual membership and Student membership - more information info@efee.eu.

The fragmentation-energy fan, a universal behavior of blasted rock?

Abstract

Blast fragmentation data in the form of percentile fragment sizes as function of specific charge often form a set of straight lines in log(size)-log(energy) space that tend to converge on a common focal point. Single-hole shots in specimens of virgin material clearly show this and the phenomenon is called the fragmentation-energy fan. Field data from bench blasting in rock scatter much more but may be interpreted to form such fans. The slopes values of the fan lines depend primarily on the percentile level.

This property can be derived from sieving functions of the form $P[\ln(x/x_{max})/\ln(x_{max}/x_{50})]$. An example is the Swebrec function when the parameter b is constant.

The fragmentation-energy fan and associated sieving function contradict two basic assumptions of the Kuz-Ram model; i) that the Rosin-Rammler function reproduces the sieving data well and ii) that the uniformity index n = constant and independent of q.

This favors formulating fragmentation prediction formulas instead of the Kuz-Ram way as a set of percentile fragment sizes, parameters that by definition are independent of the size distribution. A generalization of the fan behavior to include non-dimensional fragment sizes and an energy term with implicit size dependence seems possible to make.

Introduction

Most blast engineers know of the Kuz-Ram model for bench blasting (Cunningham 1983, 1987 & 2005). Over 30 years it has helped them estimate the fragmentation outcome of changes in blasting pattern, rock conditions and explosives. Cunningham adapted earlier Soviet work (Koshelev et al. 1971, Kuznetsov 1973) in which a prediction eqn for the mean fragment size $x_m = A/q^{\alpha}$ was presented with q being the specific charge (powder factor, kg/m^3).

The Soviet work showed that the Rosin-Rammler function $P_{RR}(x;x_c,n)$ (Rosin & Rammler 1933) was an adequate description of the cumulative fragment size distribution in many blasting cases yet it didn't produce a prediction equation for the function parameter called uniformity index n. In the Soviet work the normally close agreement between the parameter characteristic fragment size x_c and the mean, $x_m = \langle x \rangle$, was used to express their final prediction equation in terms of x_m.

Cunningham (1983, 1987) made the Soviet work useful to engineers by supplying prediction equations both for the median fragment size x_{50} and for n. The fact that $x_{50} \neq x_m$ has caused some controversy, see Ouchterlony (2015, 2016) for details, but as of 1987, the Kuz-Ram model contains a prediction equation for x_{50} adjusted to data for the 50% passing sizes of the muck piles. The Kuz-Ram n-equation is a more theoretical construct in that no explicit tests of its predictions seem to have been published. Some recent work (Sellers et al. 2013, Ivanova et al. 2015) on the effect of drill hole deviations even contradict it e.g.

Since the Kuz-Ram model was published in 1983, much sieving data from different kinds of blasts of different sizes in different materials have been published. It has become clear that the three-parameter Swebrec function PSwebrec(x; x50, xmax, b), see Ouchterlony (2005, 2009a) usually fits the sieving data much better and over a much larger size range than the Rosin-Rammler function (Sanchidrián et al. 2014).

A first suggestion how to use the Swebrec function instead of the Rosin-Rammler one in the Kuz-Ram was called the KCO model (Ouchterlony 2005) but the model was incomplete in that only tentative prediction equations for the maximum fragment size xmax and the undulation exponent b were given.

Later, a theoretical, dimensional analysis supported the use of the Swebrec function instead of the Rosin-Rammler function (Ouchterlony 2009b) and it became clear that its parameter triplet (x_{50}, x_{max}, b) could be replaced by triplets like (x_{50}, x_{80}/x_{50}, x_{50}/x_{20}) or more generally by (x_{50}, x_P/x_{50}, x_{50}/x_{100-P}) where P > 50% (Ouchterlony & Paley 2013). While (x_{50}, x_P/x_{50}, x_{50}/x_{100-P}) thus are parameters of a transformed Swebrec function they are also distribution free in the sense that their determination from the sieving data requires no knowledge about an underlying distribution function.

Full-scale quarry blasting tests of the effect of changing specific charge on fragmentation had confirmed the efficacy of the Swebrec function (Ouchterlony et al. 2006, 2015) and that b ought to be constant to avoid that blasting harder (higher specific charge) produces less fines. Furthermore, an equation like $x_{max} = x_{100} = A/q^{\alpha}$ described the maximum fragment size well with values of A and α that were different than those for x_{50}, i.e. for P = 50%. This was in line with results of the dimensional analysis.

Extensive studies of x50 and x80 and how they varied with the blasting parameters in 1/10 scale bench blasting had been made by Otterness et al. (1991) and their x80 data were used by Chung and Katsabanis (2001) to derive a Kuz-Ram-like equation

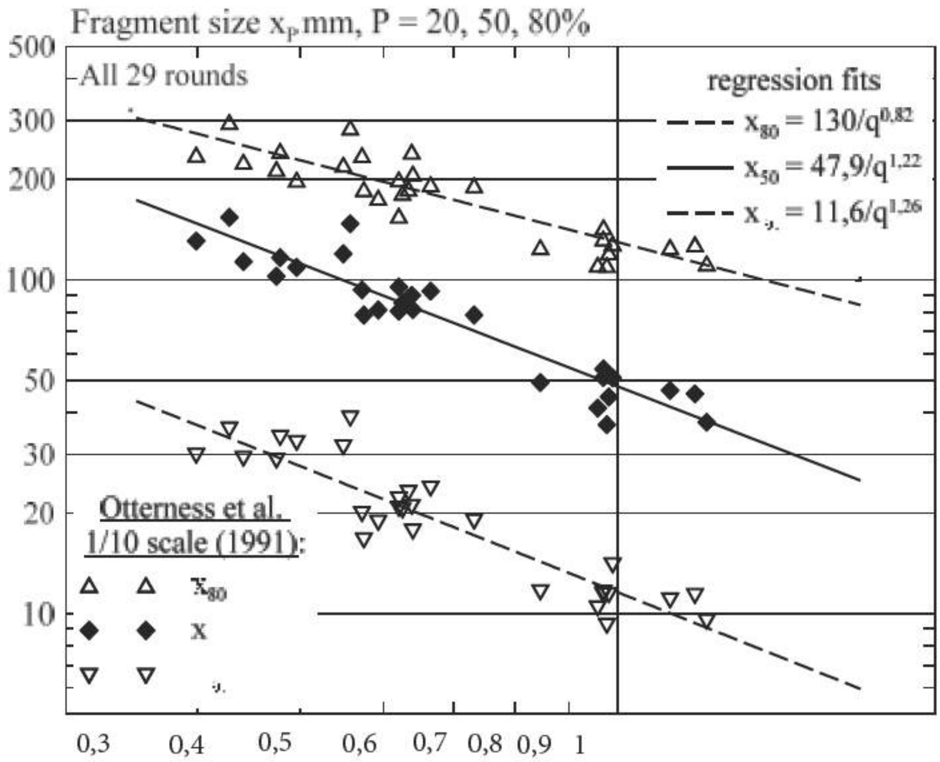
x80 = A/q^{α} in addition to the standard one for x50.

Figure 1. shows log(xP) vs log(q) plots of the data from Otterness et al. (1991) for
P = 20, 50 and 80%.

In Figure 1. the data are well reproduced by straight lines,
log(xP) = log(A)-α·log(q) where the slope factor α > 0 decreases with increasing values of P.

In Ouchterlony (2015, 2016) it was pointed out that the only behavior consistent with the Kuz-Ram model's statement that n is independent of q is that α = constant. Clearly the x80(q) data in Figure 1. have a different fitted slope than the x50 and x20 data.

This introduction explains that there were several reasons, theoretical and practical ones, to make a wider study of how blasting data in distribution-free form, xP for



Specific charge q=Q//BSH), kg/m³

Figure 1. Plots of x50, x80 and x20 vs specific charge, data from Otterness et al. (1991)

arbitrary values of P, depend on specific charge. An extensive analysis of such data was made by Ouchterlony et al. (2016) and the findings are summarized in this paper. The consequences for improved blast prediction equations are explored in the companion paper Sanchidrián & Ouchterlony (2016, 2017).

The Percentile Passing Fragment Size Data

Blasting data from relatively well defined sets of blasting tests with different values of specific charge q_i, $i = 1, 2, 3, \dots$ were collected. All tests but one were made by Luleå University of Technology (LUT), Montanuniversitaet Leoben (MUL), the Swedish Rock Engineering Foundation (SveBeFo) and the Swedish Blasting Research Centre (Swebrec). The cumulative passing sieving data have been reanalyzed with log-log interpolation, or sometimes extrapolation, to determine values $x_P(q_i)$ and linear regression in log-log space made to determine the values of log(A) and α for each chosen P-value. To begin with a large set of P-values was used; P = 5, 10, 15, 20, …, 95, 100%. It quickly became clear that $x_P(q)$ was usually well described by straight lines in the log-log diagram except for very small or very large value of specific charge. Thus the analysis was then reduced to the values P = 20, 35, 50, 65, 80%.

The following sets of sieving data were analyzed in Ouchterlony et al. (2016).

1. Mortar cylinders, 140 mm diam., shot with 3-40 g/m PETN cord in a central through going hole; six free and six confined ones with q in the range 0.20-2.6 kg/m^3. Johansson (2008, 2011).

2. Free cylinders of rock, 100-300 mm diam., shot with granular PETN during the Less Fines project; 61 cylinders of six rock types, five limestones and an amphibolite with q in the range 0.33-4.0 kg/m^3. Grasedieck (2006).

3. Free cylinders of granites, 100-300 mm diam., from full-scale quarrying tests, shot with granular PETN; seven from the Bårarp quarry (Grasedieck 2006) and eight from the Vändle quarry (Paulitsch 2005) with q in the range 0.36-2.9 kg/m^3.

4. Free cubes of sandstone, 100-200 mm side, shot with granular PETN; 13 cubes with q in the range 0.52-2.5 kg/m^3. Reichholf (2003).

5. Model scale slabs, 100 mm thick and varying burden, shot with PETN cord; 14 shots with an equivalent q in the range 2.5-100 kg/m^3. Nie (1988).

6. One tenth scale bench blasts in dolomite; 29 blasts with 2-4 holes each shot with Ø11-25 mm dynamite charges and q in the range 0.40-1.22 kg/m^3. Otterness et al. (1991).

7. Small size rounds shot in 5 m bench with 4-8, Ø38-76 mm holes in Bårarp granite quarry; seven rounds with packaged emulsion explosive and q in the range 0.27-0.39 kg/m^3. Olsson et al. (2003).

8. Full scale rounds in Vändle granite quarry, 30-40, Ø90 mm holes in 11-13 m benches; four rounds shot with gassed bulk emulsion and q in the range 0.49-0.68 kg/m^3. Ouchterlony et al. (2005).

9. Full scale rounds in Långåsen granite quarry with 45-67, Ø 89 mm holes in 14-19 m benches; four rounds shot with gassed bulk emulsion and q in the range 0.71-1.04 kg/m^3. Ouchterlony et al.(2015).

Figure 2 to Figure 4 give examples of plots of xP(q) for data sets 1-9. Triangles and diamonds denote data used in regression fits and inserts give the fitted equations xP(q). The symbol × denotes data not used in fits. Figure 2b and Figure 3b give examples of where data for low q-values were excluded from the fits. There is obviously an upper limit in fragment size determined by the size of the specimen size or by the blasting pattern and a lower limit in specific charge where the specimen or the bench doesn't break open. For q-values just above the latter limit the fragmentation is one of dust and boulders, i.e. a sieving curve of a few large blocks and a tail of fine material (Ouchterlony & Moser 2013). In turn, Figure 3a gives an example of where data for large q-values have been excluded from the fits. Here the fragmentation may start to be influenced by other fracture modes, e.g. spalling.

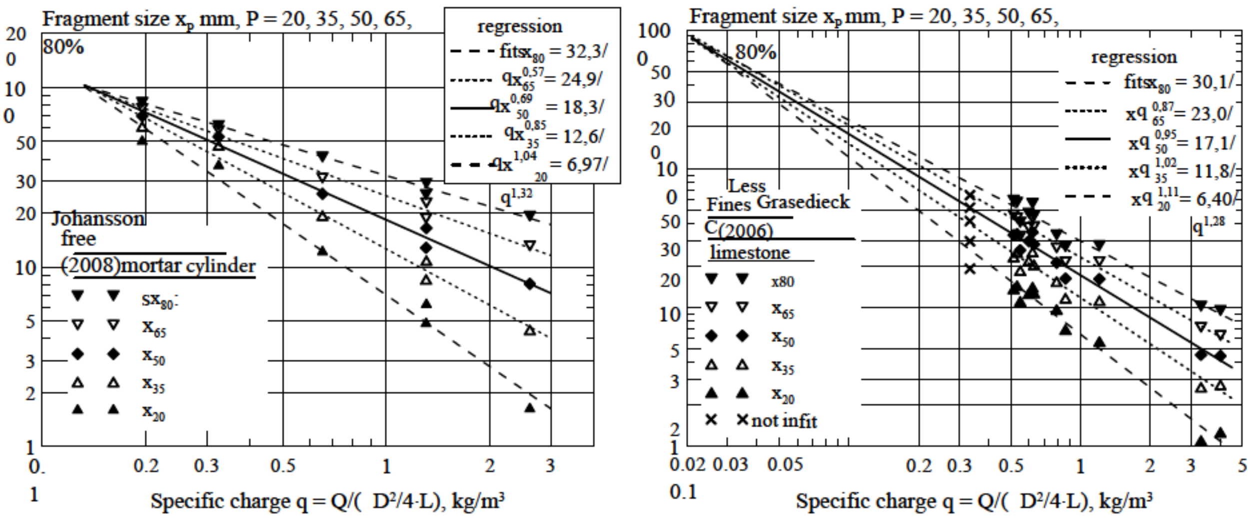


Fig. 2a, b: xP(q) for sets 1 and 2, Ouchterlony et al. (2016) figures 2 and 7

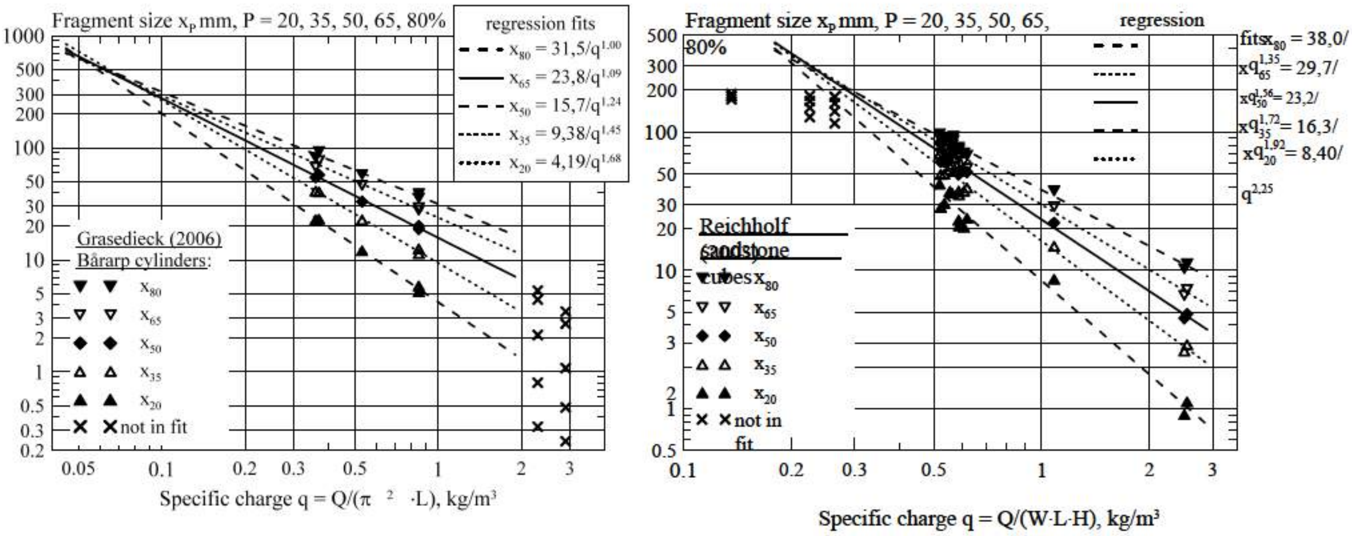


Fig. 3a, b: xP(q) for sets 3 and 5, Ouchterlony et al. (2016) figures 9 and 12

In between these limits is a range of q-values where the fitted lines tend to converge on a common focal point or tend to be parallel.

An example of the A and values plus the quality of the fits is given in Table 1. A and depend on P and also on the rock properties. The r2 values lie in the range 0.937-0.996, typical of the cylinders, cubes and slabs of sets 1-5 except the Vändle granite cylinders for which r^2 ≈ 0.88-0.91. For bench blasting data sets 6, 8 and 9 r^2 is roughly 0.8 or larger. For set 7, see Figure 4a, r^2 is as low as 0.43-0.66 because of the concentration of the data around q = 0.6 kg/m^3.

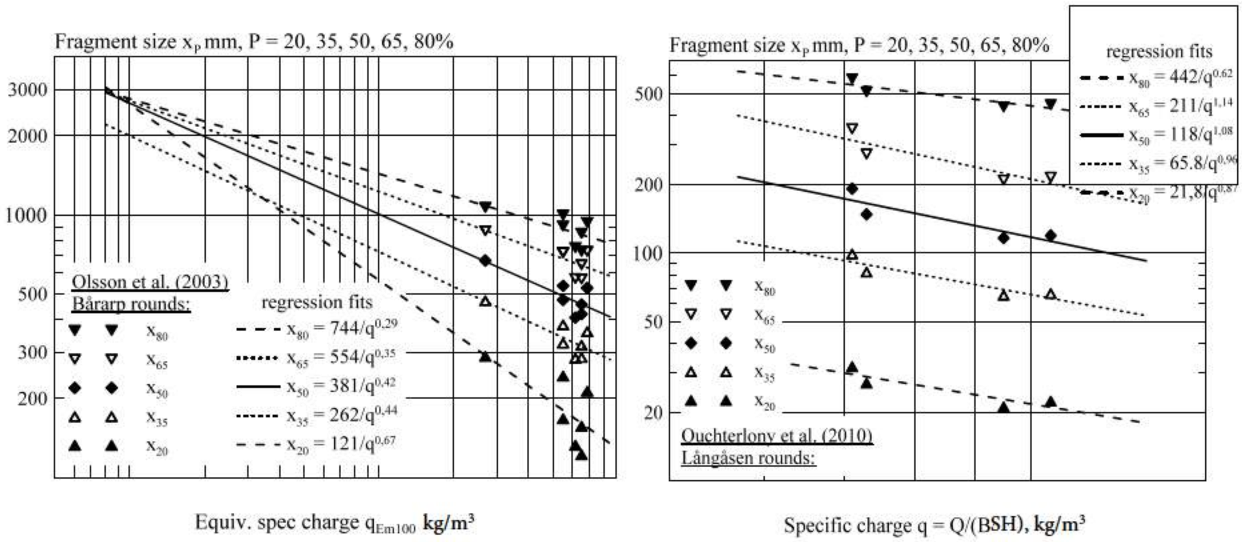


Fig. 4a, b: xP(q) for sets 7 and 9, Ouchterlony et al. (2016) figures 14 and 16

	BIT[1]			CP			NK-F			NK-K			NK-R			NK- S		
	A	α_P	r^2	A	α_P	r^2	A	α_P	r^2	A	α_P	r^2	A	α_P	r^2	A	α_P	r^2
x_{80}	40.8	0.87	0.937	30.1	0.87	0.957	26.7	1.01	0.950	27.3	0.86	0.986	26.7	0.94	0.985	28.0	0.83	0.983
x_{65}	33.0	0.93	0.969	23.0	0.95	0.967	20.6	1.12	0.955	21.7	0.91	0.992	20.9	0.96	0.986	22.2	0.88	0.990
x_{50}	26.6	0.99	0.984	17.1	1.02	0.970	15.4	1.22	0.957	16.9	0.99	0.991	16.0	1.00	0.984	17.4	0.95	0.993
x_{35}	20.2	1.06	0.992	11.8	1.11	0.971	10.5	1.39	0.959	12.4	1.10	0.988	11.4	1.04	0.980	12.4	1.04	0.996
x_{20}	12.9	1.19	0.984	6.40	1.28	0.976	5.14	1.64	0.946	7.76	1.16	0.979	6.78	1.10	0.952	7.12	1.20	0.993

Note 1: BIT denotes an amphibolite, CP a limestone and NK a suite of limestones qualities from the same quarry

Table 1. $x_P(q)$ lines for cylinders in data set 2, expressed as $x_P(q) = A/q^{\alpha_P}$. Note subscript P on **α**

Data set 6 (Otterness et al. 1991) was the only one with a slightly different behavior, see Figure 5. It seems to be a combination of the two extremes, $x_P(q)$ lines that converge to a common focal point when $50 \leq P \leq 80\%$ and $x_P(q)$ lines that are parallel when $20 \leq P \leq 50\%$. This data set is also the only one where we didn't control the work ourselves and one in which more factors than the effect of specific charge were investigated. As far as can be judged though, the work of Otterness et al. (1991) was extremely thorough and a analyzing a subset of the data in which other factors than q were kept as constant as possible didn't change the character of the $x_P(q)$ diagram so an explanation is wanting.

The tendency for the $x_P(q)$ lines to meet at a common focal point is much clearer for the simple specimens than for the bench blasts. There are several reasons for this; variations in material properties and testing conditions are much larger in the field and the range of q-value possible to test smaller.

In the development of their general fragmentation model, Sanchidrián and Ouchterlony (2016) used sieving data from 169 bench blasts in different sites and rock types, different bench geometries and different delay times, for which the design data for the blasts and the size distributions of the muck piles obtained by sieving were available. These blasts include the data from sets 6-9 above and the data are plotted in Figure 6 together with the best fit lines $x_P = f(q \cdot e)$. Here e (J/kg) is the heat of explosion of the explosive and the use of q·e instead of q gives a common basis of comparison for different explosives.

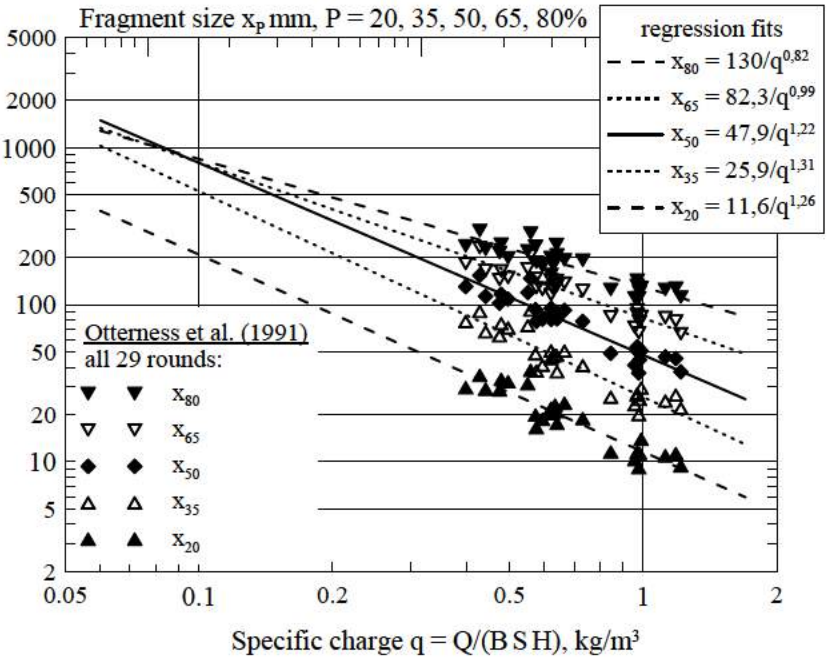


Fig. 5. xP(q) for set 6, Ouchterlony et al. (2016) figure 13.

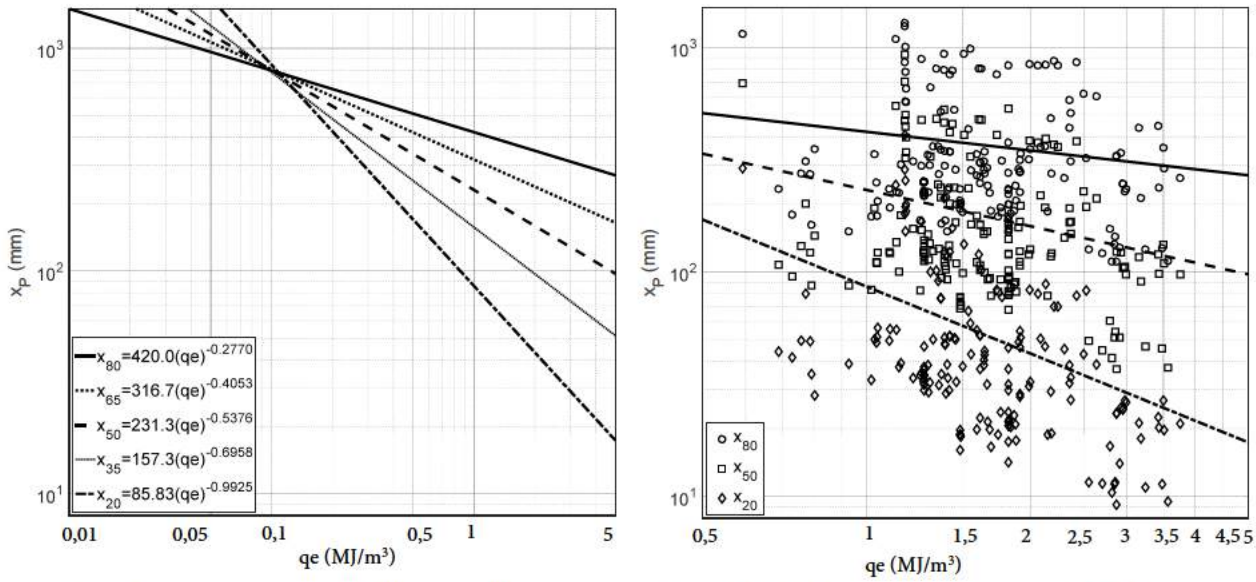


Fig. 6. Fragment sizes xP for bench blasts vs. qe, Sanchidrián and Ouchterlony (2016) figure 13

The data in Figure 6 scatter enormously because of the wide span in blasting conditions. Even so the average behavior of the fragmentation data with specific charge is a convergence of the xP(q) lines, which is not as clear in the individual cases data sets 6-9 . We may take this as a further indication that in general the xP-lines for bench blasting rounds tend to meet at a common focal point in log(xP) vs. log(qe) space, or that in some cases they may be parallel.

The fragmentation-energy fan

The material above makes it possible to state the following hypothesis: *When blasting in a given geometry and changing the specific charge, either through changing the charge size (hole diameter) or through a change in geometry through the breakage burden e.g., then the fragmentation can be described by percentile mass passing xP vs. specific charge relationships of power-law type that for different P-values converge to a common focal point (x0, q0).*

This behavior is called the *fragmentation-energy fan*, a focal point with diverging xP(q) rays (lines). It is valid within a limited range of q-values. The focal point lies outside the region in xP vs. q space where breakage actually occurs. It may, practically seen, lie at infinity for parallel lines. For blast damaged and jointed material this convergence of the xP-lines on a common focal point is subject to substantial scatter in the individual cases but not so for the average overall behavior, see Figure 6.

The fragmentation-energy fan behavior may be written:

Equation 1

$$xP/x0 = (q0/q)^{\alpha(P)} \text{ or } \alpha(P) = \ln(xP/x0)/\ln(q0/q) = \ln(x0/xP)/\ln(q/q0)$$

It follows from an inversion of α(P) that for P a suitable monotonically decreasing function of the argument

Equation 2

$$P = \alpha^{-1}(P) = P[\ln(x0/x)/\ln(q/q0)] \text{ for } x < x0 \text{ and } q > q0.$$

where the general notation x is now used for the sieve size, instead of xP, as the actual P value for a couple (q, x) is now determined by the function P itself. A geometric interpretation follows immediately from the proportionality of side lengths in similar triangles since ln(x0/x) = ln(x0)-ln(x) and ln(q/q0) = ln(q)-ln(q0), see Figure 7.

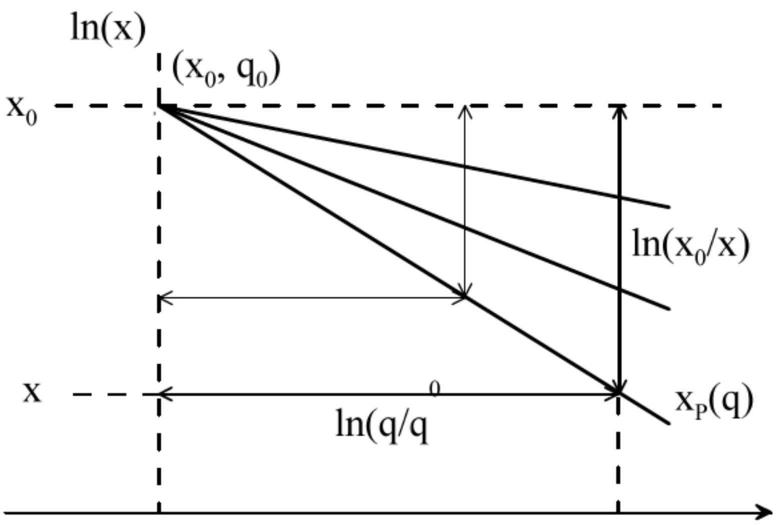


Figure 7. Fragmentation-energy fan with similar triangles

Choose two specific percentile size values, P = 50 and 100%, i.e. the median and maximum fragment sizes x_{50} and x_{100} = x_{max}. From Eqn 1 and some manipulation, it follows:

Equation 3

$$\ln(x_0/x)/\ln(q/q_0) = \alpha_{100} + (\alpha_{50}-\alpha_{100})\cdot\{\ln[x_{max}(q)/x]/\ln[x_{max}(q)/x_{50}(q)]\}$$

This represents a linear transformation of the argument of the function in Eqn 2. The logarithm ratios in the right hand member of Eqn 3 also translate to distances for similar triangles as in Figure 7. Substituting Eqn 3 into Eqn 2, this becomes, with P being a different function

Equation 4

$$P(x, q) = P[\ln(x_{max}/x)/\ln(x_{max}/x_{50})]$$

Here the dependence on q is 'hidden' in the values of x_{50} and x_{max}, which makes this form of P(x, q) useful for describing the sieving curve of a specific test, i.e. to describe P(x, q = const.). Thus, if the form of Eqn 4 is determined by curve fitting to fragmentation data that show fragmentation-energy fan behavior with the focal point (x_0, q_0) then there follows that P(x, q) may be written, using Eqn 3:

Equation 5

$$P(x, q) = P\{[\ln(x_0/x)/\ln(q/q_0)-\alpha_{100}]/(\alpha_{50}-\alpha_{100})\}$$

The properties of P(x, q) are such that when x increases then the value P(x, q = const.) must increase monotonically because when the sieve size increases, the mass passing must increase. At the same time P(x = const., q) must increase monotonically with increasing q because when one blasts harder in the same geometry, more fine material of a given size must be produced. The latter argument means that even if there were no common focal point for the percentile size lines $x_P(q)$, these lines cannot cross in the q-range where they are valid.

The three-parameter Swebrec function (Ouchterlony 2005, 2009a) is a special case of Eqn 4, where the q-dependence is confined to the logarithm ration if b = constant

Equation 6

$$P(x) = 1/\{1+[\ln(x_{max}/x)/\ln(x_{max}/x_{50})]^b\}$$
$$\text{when } x < x_{max}$$

Thus this version of the Swebrec function is commensurate with the fragmentation-energy fan. Inserting Eqn 1 into Eqn 6 for P = 50 and 100% and solving for α yields

Equation 7

$$\alpha(P) = \alpha_{100} + (\alpha_{50}-\alpha_{100})\cdot[1/P-1]^{1/b}$$

This underscores that for α to be a function only of P in a given testing set-up, as with the fragmentation-energy fan, b must be constant for the given material and blast configuration in question. Eqn 7 fits the b values of the Swebrec distributions fitted to the sieve data of set 1 with a high determination coefficient (Ouchterlony et al. 2016); this form is also used in the new fragmentation model derived by Sanchidrián & Ouchterlony (2016).

It may further be shown (Ouchterlony et al. 2016) that for the Swebrec function
b(q) = constant, independent of the specific charge is the only b-value consistent with the statement that blasting harder cannot produce less fine material, or blasting with less intensity cannot produce more fine material. This supports the judgment made with the KCO model design curves for blasting in the Vändle and Långåsen quarries (Ouchterlony et al. 2006, 2010 and 2015), that
b(q) = constant is an appropriate description of the sieving curves for blasts with different q-values.

In the Kuz-Ram model $x_{50} = A/q^{\alpha}$ with $\alpha = 0.8$ and n is a function of blast geometry and rock conditions but not on specific charge q. With the Rosin-Rammler function in the form

Equation 8

$$P(x) = 1 - e^{-(x/x_c)^n} = 1 - e^{-\ln 2 \cdot (x/x_{50})^n}$$

one may derive that

Equations 9

$$n = \ln[\ln(5)/\ln(2)]/\ln(x_{80}/x_{50}) = 0.842/\ln(x_{80}/x_{50}) \text{ and } n = 1.133/\ln(x_{50}/x_{20})$$

For n to be independent of q it follows first that α(P) in Eqn 1 must be constant, but it generally isn't. Figure 4b is an exception. In it the xP(q) lines are roughly parallel. So we have a situation in which the Kuz-Ram model with the Rosin-Rammler function with a constant n-value might be consistent with the special case of parallel xP(q) lines if the ratios x_{80}/x_{50} and x_{50}/x_{20} meet Eqns 9. In a broader perspective with large variations in q and fragment sizes, the Kuz-Ram model is definitely inconsistent with the fragmentation-energy fan behavior. As previously shown, using the Swebrec function with the exponent b independent of q is consistent with the fragmentation-energy fan, including the parallel lines case; we may determine the constant b from a triplet of percentiles, e.g. 20, 50 and 80 (Ouchterlony & Paley 2013).

Equation 10

$$b = \ln(4)/\ln[\ln(x_{50}/x_{20})/\ln(x_{80}/x_{50})]$$

Generalization of the fragmentation-energy fan

In the log(x_P) vs log(q) plots shown above both quantities are dimensional. Yet the dimensional analysis in Ouchterlony (2009b) and the Kuz-Ram equation for x_{50} suggest a generalization in which there is a more general blast energy descriptor than q or q·e and a non-dimensional response variable, fragment size x_{50}/length, see the eqns 27 and 30a for cylinders and bench blasts respectively in that paper. In slightly different forms these equations read

Equations 11

$$x_{50}/D = A\cdot[\pi/k\cdot(L/D)]^{1/3}/(q\cdot e\cdot D^{0.400})^{\alpha} \text{ or } x_{50}/B = A\cdot[(H/B)\cdot(S/B)/k]^{1/3}/(q\cdot e\cdot B^{0.400})^{\alpha}$$

Here L and D denote the length and diameter of the cylinder specimens and B, S the burden and spacing of the blast pattern in a bench of height H. A is a prefactor involving effect of rock properties, like the Kuz-Ram model's rock mass factor A. k is a factor related to fragment shape. Note that the quantities in the square brackets in Eqns 11 are non-dimensional but that the factors $q\cdot e\cdot D^{0.4}$ and $q\cdot e\cdot B^{0.4}$ in the denominator are not. Eqns 11 are a starting point for generalized prediction equations for x_P where P is arbitrary and $\alpha = \alpha(P)$ etc.

When plotted x_P/D vs. q, the data in set 1 still form a fragmentation-energy fan since all specimens shot had the same diameters and lengths. Dividing by D simply shifts the position of the fan vertically by log(D) but doesn't change the angles α. The data in sets 2-4 were almost all obtained by keeping Q/L (kg/m), the linear charge concentration, essentially the same in each set but varying the specimen diameter D to change q. Take the data for amphibolite from set 2 as an example. The dimensional and non-dimensional data are compared in Figures 8a and 8b. The fitting data are compared in Table 2.

The diagrams in Figures 8a and 8b look principally the same except that the slopes of the x_P/D-lines are flatter than the slopes of the x_P-lines, all by the same amount $\alpha_P - \alpha_P' = 0.496$ and the ratio A/A' ≈ 167 is constant too where primed quantities refer to the x_P/D data. The constant difference between α_P and α_P' occurs because the specific charge for the cylinders is $q = (Q/L)/[\pi/4\cdot D^2]$, where Q/L is roughly constant. Thus the inverse $D = \text{const.}/\sqrt{q}$ and a division of x by D amounts to a division of $A/q^{\alpha P}$ by $q^{-0.5}$, i.e. a lowering of the exponent by about 0.5. Checking the other seven cylinder test series in data sets 2 and 3 (Ouchterlony et al. 2016) shows that $\alpha_P - \alpha_P'$ is constant for each test but lies in the range 0.45- 0.59, i.e. differs somewhat from set to set.

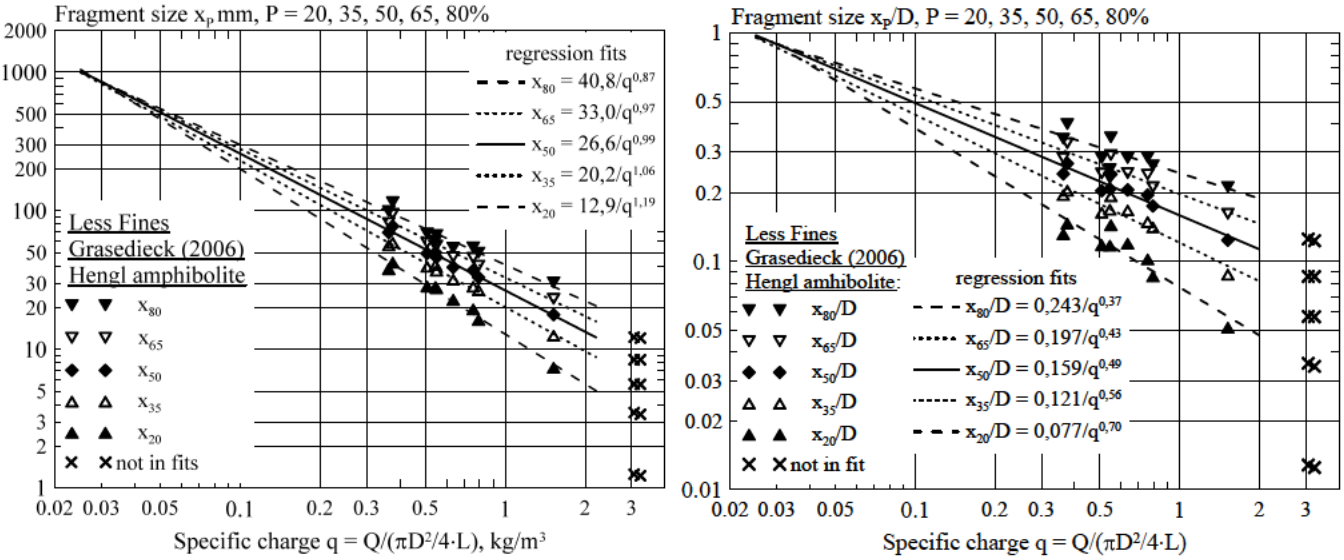


Fig. 8a, b. xP(q) and xP(q)/D for set 2, Ouchterlony et al. (2016) figures 14 and 23

Table 2. Fitted xP-lines data for cylinders of amphibolite, set 2

	xP (Table 1)				Non-dimensional, xP/D			
	A	α_P	r^2		A'	α_P'	r^2	α_P - α_P'
x_{80}	40.8	0.867	0.937	x_{80}/D	0.243	0.371	0.709	0.496
x_{65}	33.0	0.928	0.969	x_{65}/D	0.197	0.432	0.833	0.496
x_{50}	26.6	0.988	0.984	x_{50}/D	0.159	0.492	0.904	0.496
x_{35}	20.2	1.057	0.992	x_{35}/D	0.121	0.561	0.909	0.496
x_{20}	12.9	1.193	0.984	x_{20}/D	0.077	0.697	0.864	0.496
x_0 = 945 mm, q_0 = 0.0278 kg/m³				x_0/D = 0.932, q_0' = 0.0278 kg/m³				

The correlation coefficients of the fitted xP/D lines are lower than those of the corresponding xP-lines. The data in Figure 8b clearly deviate more from the fitting lines than the data in Figure 8a. Yet the fragmentation-energy fan character of the data hasn't really changed by the transformation since firstly the slope difference between two adjacent fan lines doesn't change, e.g. $\alpha35 - \alpha20 = \alpha35' - \alpha20'$. Secondly the position of the focus point q_0 as determined by the average position from the 10 possible line intersection point hasn't changed either, see Table 2.

In Ouchterlony et al. (2016) it was also tried to replace the blast energy descriptor from q or q·e to $q \cdot e \cdot D^{\beta}$ or $q \cdot e \cdot B^{\beta}$ as in Eqns 11 where β is a constant exponent for each data set. This comes from the dimensional analysis and a generalization of Eqns 11 to arbitrary values of P.

Equations 12

$$x_P/D = A\cdot[\pi/k\cdot(L/D)]^{1/3}/(q\cdot e\cdot D^{\beta})^{\alpha} \text{ or } x_P/B = A\cdot[(H/B)\cdot(S/B)/k]^{1/3}/(q\cdot e\cdot B^{\beta})^{\alpha}$$

There are however very few data sets where both specimen size (B or D) and linear charge concentration Q/L have been varied independently. One such set is the model scale slab blasting tests of Rustan and Naarttijärvi (1983); however, the amount of their data was insufficient to substantiate the generalization. In Sanchidrián and Ouchterlony (2016) a much larger amount of data has been used to find a suitable generalization of Eqns 12.

Conclusions

Blast fragmentation data in the form of percentile fragment sizes x_P as function of specific charge q tend to form a set of straight lines in a log-log diagram that converge on a common focal point (q_0, x_0). This phenomenon is quite clear for single hole shots in specimens of virgin material and it is called the *fragmentation-energy fan*. Low specific charge values, which give a dust and boulders fragmentation and high specific charge values for which fragmentation mechanisms like spalling occur give data that do not fall on the fan lines.

The fan behavior has several consequences. Firstly the slopes of the fan lines, $-\alpha_P$ in log(x_P) vs. log(q) space depend only on the P-value; $\alpha_P = \alpha(P)$ for a given test set-up. Secondly an inversion of α(P) gives a direct, linear transformation between the specific charge (powder factor), or explosive specific energy dependence of x_P and the sieving curve function P(x) at a given energy level and vice versa. This sieving function is of a preferred type in which two dimensionless size ratios are used; i.e. P[ln(x/x_{max})/ln(x_{max}/x_{50})]. The Swebrec function is of this type and it has the fan behavior; it is further shown that consistency with Physics requires the undulation parameter b not to depend on q. The constancy of b is not obvious, even when working under well controlled experimental conditions. In this sense the fragmentation-energy fan represents an idealized, scatter free fragmentation behavior.

The existence of the fragmentation-energy fan contradicts two basic assumptions of the Kuz-Ram model; i) that the Rosin-Rammler function reproduces the sieving data well and ii) that the uniformity index n = constant and independent of q. This rather supports the view that the two issues of deriving fragment size prediction formulas and choosing the form of the size distribution function should be separated. The best way to solve the first issue is to formulate the prediction formulas in terms of a sufficient number of percentile fragment sizes x_P.

It was found that the focal point value q_0 is quite insensitive to simple data transformations.

This supports the use of non-dimensional fragment sizes by dividing the size by a characteristic length. This has been done successfully, the non-dimensional fragment sizes also displaying the fan-like pattern. To include an energy term with an explicit size scaling factor dependence in the generalization requires a larger amount of data, with independent variations of specific charge and breakage dimension. Such an analysis of extensive bench blasting data is made by Sanchidrián and Ouchterlony (2016, 2017) and it supports the generalized fan behavior.

Data and derivations that support and explain the material in this paper in greater detail may be found in Ouchterlony et al. (2016).

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The authors would like to acknowledge PhD Gunnar Sjödin, Enebyberg, Sweden for valuable help with discussions about the inversion of the fragmentation-energy fan equations and Claude Cunningham of Knysna, RSA for his willingness to always engage in serious discussions and to share his expertise and data about blast fragmentation.

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Annual Meeting of the Notified Bodies for Explosives 2017

This year's annual meeting of the Notified Bodies for Explosives took place on 12th May 2017 in Krakow, Poland. It was the 26th meeting and it was hosted by GIG (Główny Instytut Górnictwa, Central Mining Institute) which is the Notified Body for explosives in Poland.

The debate agenda of the meeting covered the following points:

- Results of the consultation of the Group of Experts on Explosives on harmonised standards for explosives. In connection with this point, on 18th October 2016 the EU Commission sent out a questionnaire within the Group of Experts on Explosives on the need to update the existing harmonised standards and/or develop new harmonised standards for civil explosives. Replies from 18 Member States, EEA/EFTA countries, Notified Bodies and stakeholders were received.

- AdCo Group's report on explosives. On 28th October 2016 the AdCo meeting for explosives took place in Buxton. The content (Market surveillance under 2014/28/EU) as well as the outcomes of this meeting were presented.

- Updates from the European Commission

  - Update on the re-notification process of NBs and on the transposition of Directive 2014/28/EU into national legislation
  - Update on the last meeting of the Group of Experts on Explosives
  - Update on the amendment of the UN Model Regulations for an international harmonised security marking for explosives
  - Challenges posed by Mobile Explosives Manufacturing Units (MEMUs)

In the course of this meeting the current state of implementing Directive 2014/28/EU in national legislation of the Member States as well as the related re-notification or re-appointment of the Notified Bodies for explosives were presented. It was announced that Finland's previous Notified Body for explosives will not be re-appointed. In this case it is important that any type examination certificates issued by this Body remain accessible in the future. The Finnish state is in charge of that which is crucial in terms of market surveillance.

In this context the developments expected in the UK were also looked at. In case the UK exits the EU, the Notified Body HSL (Health and Safety - Executive Health and Safety Laboratory) will not be able to function as such any more. Due to the fact that any EU legislation will not apply any longer, it cannot be guaranteed that certificates issued by the HSL will be available any longer. A suitable solution must be found. Another point of the agenda covered the MEMU topic. Given the accident in Norway on 18th January 2014 (a MEMU on fire causing a detonation), it was discussed whether specific legal regulations for Notified Bodies using and operating MEMUs are necessary. The answer was negative. Instead it was recommended to prepare a code of best practice.

As part of the so-called round-robin test, previously determined tests on explosives or detonators are carried out by different Notified Bodies. This is done in order to share experiences and also to ensure that all required tests are done in a comparable manner. This is the only way to guarantee that comparable values are obtained which play an essential role in type approval (CE certification). The current test covered the examination of shock tube ignition systems. By running this test, the following points were analysed:

- Amount of explosive in the shock tube.

- Reaction rate of the reaction front expanding in the shock tube.

- Abrasion resistance of the shock tube material.

- Stability/Resistance towards impact and compression load.

Test results are expected by the end of 2017.

As a stakeholder for users and partly also for manufacturers of explosives, EFEE plays an immediate transferring role in both directions. We will endeavor to continually use and expand this role and opportunity. If you have any questions or comments in connection with this or the upcoming meeting, please do not hesitate to contact us at: Joerg.Rennert@Sprengschule-Dresden.de (Chairman of the EU-Directives in EFEE).

EFEE influence for individual and cooperate members

Election of individual and cooperate delegates with voting rights.

The purpose of this article is to describe the objectives and targets of EFEE and its basic operation procedures. The focus is on the election procedure of voting delegates from Corporate and Individual membership. Hereby we expect to encourage Corporate and Individual members to contribute to the work and operation of EFEE. Equally it the article emphasizes the benefits from influence in EFEE. Which rapidly is becoming an important organisation in the industry. We look forward to welcome new members in our growing federation.

The European Federation of Explosives Engineers (EFEE) was founded in 1988 and has National Association members, Corporate members, Individual members, Student members as well as Honorary members and Associate members. The primary objectives of EFEE is the development of good practise, harmonisation of rules and regulations in Europe for the use of explosives in the civil sector.

The training of staff and labour is of utmost importance with a focus on the required qualifications and training programmes of the shortfirer. The objectives of EFEE include:

- promotion of safety, health, environment and security in the field of explosives;
- promotion and standardisation and harmonisation of explosives training in Europe;
- promotion of explosives technology in all fields related to this technology;
- the fostering of the image of profession as well as good relations and cooperation with related associations;
- collaboration on the development of laws and regulations within the EFEE field of activities.

EU have and will also in the future introduce many new directives and regulations which directly or indirectly effect the use of explosives in the civil sector. This is influencing the daily work of EFEEs members as their activities as producers, blasters and end users. This therefore adds additional importance to the role of EFEE and also adds additional goals for, which are defined as:

- Active cooperation with EU working bodies e.g. meetings of explosives working group and meetings of Notified bodies for explosives.

- Transfer the response from EFEE members to the EU working bodies on how the new directives and regulations are operated and used.

- Gather, communicate and advocate the initiatives, ideas and goals coming from EFEE members to EU working bodies

In order to ensure input and representation of as large an audience as possible EFEE have strategy in ensuring the voice of the members as well as the and would like to welcome new members in our growing organization. Their efforts and contributions are really essential for success of our mutual work in the presence as well as in the future of European field of explosives in civil sector.

Presently the EFEE membership base includes 25 National Association members, 35 Corporate members, 91 Individual members, 1 Student member and 2 Honorary members. The primary body of the EFEE is the Annual General Meeting. Other bodies are:

- The Council

- The Board

- Standing committees and Ad Hoc project committees

- Secretariat

All the meetings are open to EFEE members but voting is limited only to the delegates with voting rights. The Annual General Meeting is held once a year, generally in the spring time. The Council Meetings are organized twice a year with the same participants and procedures as for the Annual General Meeting. The agenda reflects the aim of federation, technical ongoing work, the committee reports, the establishing of new projects, receiving final reports and establishing and/or dissolving committees. Our federation operates following standing committees:

1. Constitution
2. Conference
3. Newsletter
4. Marketing and Membership
5. Environmental
6. Shotfiring
7. EU Directives
8. Election
9. Finance and Audit

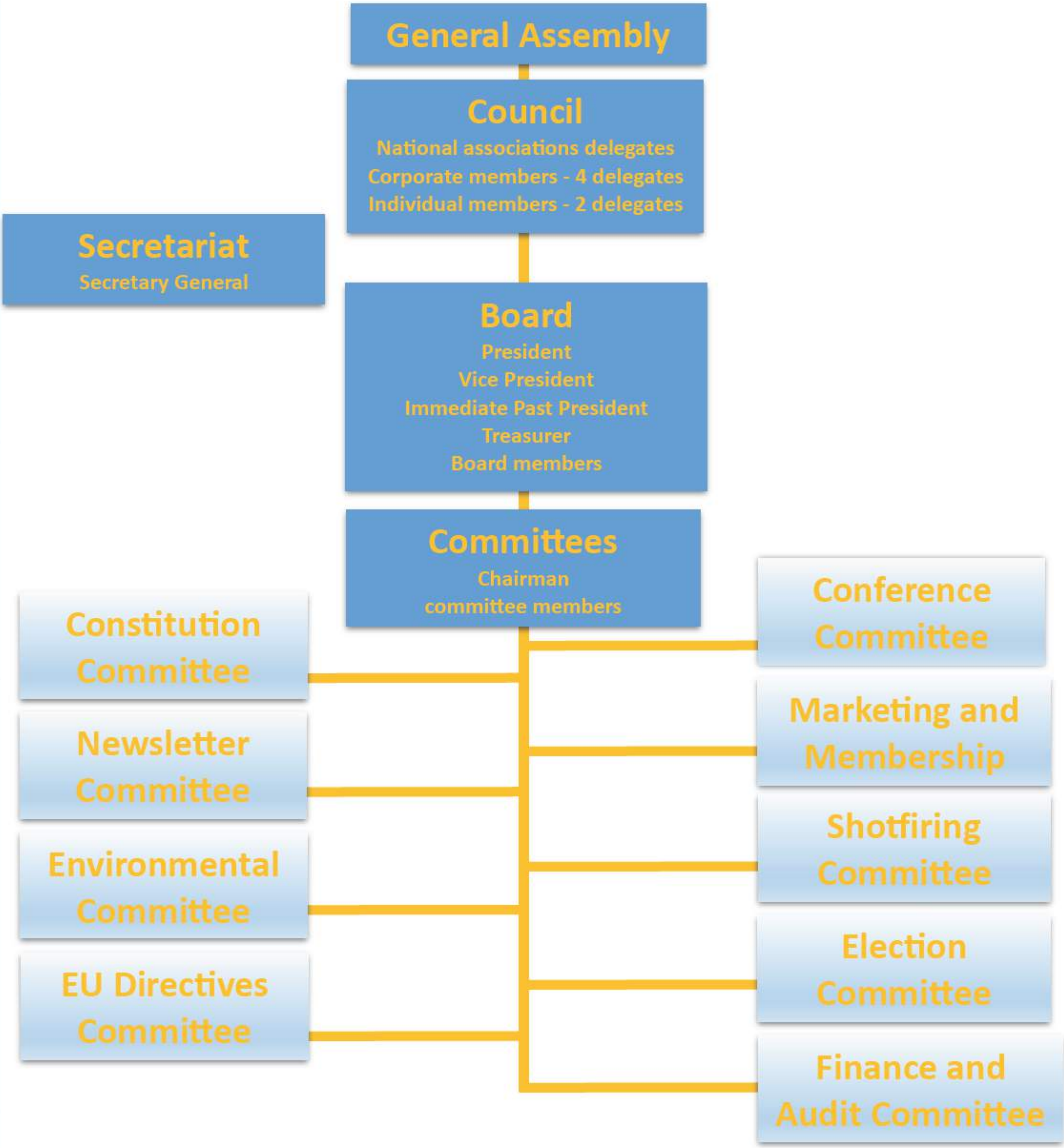
The EFEE standing committees can be divided into two essential groups. The committees of general operation of EFEE (Election, Audit and Constitution) and the committees covering the aims of our Federation (the rest of the committees). All the committees are open to EFEE members. EFEE also participates at the meetings of the Notified Bodies for Explosives as well as at the meetings of the Explosives Working Group. EFEE is presently represented in both types of meetings by Mr. Jörg Rennert who makes a great work for our federation in this area.

The voting delegates in the Annual General Meetings and the Council Meetings are the delegates representing National Association Members and the delegates elected by the Corporate and Individual membership classes.

The voting system is designed to give preference to the National Associations, which represents the professionals of their respective countries. The national associations each have a **"Single vote"** each, limited to a single per country. Where the first national or paying association gets the single vote. **"Additional voting rights"** are given to the Corporate and Individual members. There are up to 6 places on council, 4 delegates from Corporate members and 2 delegates from Individual members.

Election of delegates with additional voting right (Corporate and Individual membership classes) takes place every second year. Elected delegates are then voting delegates for the following two years and may be repeatedly re-elected. To maintain the desire of the EFEE for a geographic spread "Additional voting delegates" are limited to two from any single country. Practical processing of the "Additional voting delegates" election is organized by EFEE by means of internet. The delegates are elected by and between members of the same two type of members (Corporate and Individual). The Board requests the Corporate and Individual members to nominate candidates within a specific date. The soonest and subsequent to this specific date a list with nominated candidates for the following voting is distributed to the actual members. The votes is processed in cooperation with Election committee. The results are announced immediately when approved.

Organisation and voting



EFEE are on regular basis organising its biannual conferences. The EFEE World Conference on Explosives and Blasting has established itself as one of the most important international blasting events. The past EFEE world conference on Explosives and Blasting, are:

- Munich, Germany, 2000.
- Prague, Czech Republic. 2003.
- Brighton, UK, 2005.
- Vienna, Austria, 2007.
- Budapest, Hungary, 2009.
- Lisbon, Portugal, 2011.
- Moscow, Russia, 2013.
- Lyon, France, 2015.

The previous eight EFEE World Conferences have all had great success and have repeatedly proved how important events are where professionals share our experiences and skills. We equally expect that the EFEE 9th World Conference on Explosives and Blasting in Stockholm to be as successful as our previous World Conferences and that it again will attract participants and delegates not only from Europe but also from all over the World. The Conference is organized in cooperation with the Swedish national association - Swedish Rock Engineering Association. In accordance with experiences from our previous eight Conferences we expect attendance over 450 delegates and professionals from over 50 different countries with a large industry exhibition. This enables EFEE to create an unique forum for meetings and discussions of professionals from tunnelling, construction, demolition, quarry as well as the mining industry. To promote the industry EFEE is of the opinion that we have to share mutually new knowledge and good experiences - as well as bad experiences to avoid mistakes in the future and improve the techniques and herof the efficiency and lowering the cost. This applies to all of us - explosives end-users, manufactures, drilling and blasting operators, consultants and contractors.

EFEE issues its own Newsletter minimum four times per year. The EFEE Newsletter aims to publish information on:

- Technical articles
- EFEE work and involvement
- Blasting incidents/accident articles
- Other related business
- News from members

The EFEE Newsletter is issued electronically as a PDF document in order to send it out over the e-mail. We also create a web magazine version based on a PDF document which will be easy usable in any tablet, smartphone or laptop. The EFEE Newsletter is received by:

- 25 National Associations
- More than 1 000 corporations and institutions
- More than 20 000 individuals

Igor Kopal,
President of EFEE

Johan Finsteen Gjødvad,
Immediate Past President of EFEE

Rockefeller University Project

Monitoring Construction on a Historic Campus Amid Cutting Edge Research

The new Kravis Research Building and platform structure, which are part of the River Campus Project, are now taking shape on the East River side of New York's Rockefeller University campus.

The new facility is part of an extensive program that also involves the urgently needed repair of the portion of the East River seawall adjacent to the campus.

Image 1.

The new building, which will be developed on a platform structure, was designed to provide state-of-the-art research facilities and other amenities for the University. By 2019 the new development will horizontally extend the campus out over the FDR Drive for the length of almost four city blocks.

Importantly, it will also feature a green roof that will provide the campus with almost two acres of additional landscaped green space overlooking the river.

The northern portion of the Rockefeller University campus is within the Rockefeller University Historic District (New York City Landmark-eligible, State/National Register-eligible). It is protected by restrictions on vibration produced by construction by New York City Department of Buildings regulations. The eastern boundary of the existing campus, beyond which the new facility is being constructed, is established by an approximately 45-foot-tall schist retaining wall that extends along the west side of the FDR Drive.

Critical research and experiments

Additionally, as part of the university's research facilities, the existing campus buildings contain several types of vibration-sensitive equipment used for critical research and experiments. With these factors, all present on the Rockefeller University campus, keeping a handle on vibration produced by the construction of the new research facility and platform structure is essential for the project team.

AKRF Inc., a leading provider of environmental services in New York City and the eastern seaboard of the United States, was tasked with myriad responsibilities on the project. These include securing environmental approvals, pre-construction survey work, and hazardous materials monitoring – creating and implementing a Construction Protection Plan (CPP) for the project. The CPP was developed in consultation with the New York City Landmarks Preservation Commission (LPC) to protect the sensitive research buildings and historic architectural resources on the campus. Vibration monitoring was a key tool specified by the CPP to protect these structures. The planning of the River Campus Project was initiated in 2011 and the actual construction work commenced in October 2015.

Daniel Abatemarco is AKRF's lead on the vibration-monitoring task for this prestigious project at the heart of Manhattan. The primary goal of the monitoring program, as specified in the CPP, is to protect structures on the campus from potential damage caused by construction activity. However, the vibration-monitoring program also presents an opportunity to keep tabs on the construction-generated vibration to aid in communications with the faculty and students concerned about construction adjacent to their workplaces.

Image 2.

Consequently, Daniel needs to maintain the typical scheduled monitoring and reporting, as well as respond to inquiries from University staff in a timely and detailed manner.

The convenient and flexibility of a fully integrated remote monitoring solution like the Sigicom INFRA system and other similar systems allows in-depth information to be at Daniel's fingertips when questions come in from the campus. AKRF is known for its responsiveness to clients, delivering efficient and effective solutions with very fast turn-around. To maintain this reputation for responsiveness, AKRF depends on real time information provided in a clear and concise manner from the web application.

Implementing a vibration monitoring program for the buildings that could be affected by construction-related vibration on Rockefeller University's 14-acre campus containing 26 buildings without disturbing or getting in the way of the University's ongoing activities, presents unique challenges for AKRF. The structures to be monitored include buildings as well as outdoor structures including walls and a formal landscaped garden.

The available selection of devices allows AKRF to effectively implement its monitoring program in such a way as to be integrated into the University's campus environment without interference.

Construction of the platform over the FDR Drive, due to restrictions on FDR during over-night hours, and as such, the Drive lane closures, primarily occurs vibration-monitoring program must cover these over-night shifts and ensure that information reaches the over-night shift site superintendents quickly and reliably.

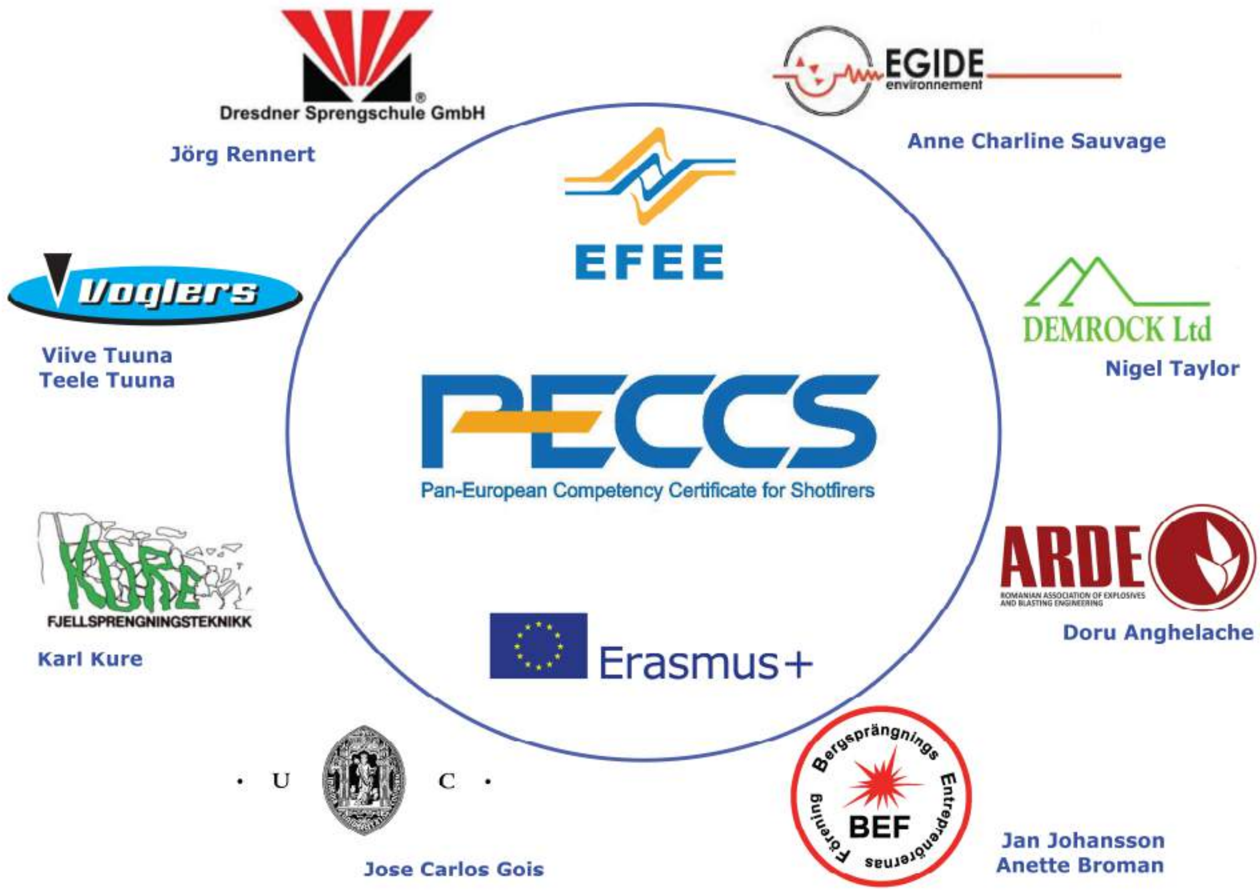
The messaging system allows for the over-night construction management and University staff to receive email and SMS alerts when vibration reaches designated thresholds so that they are always on top of the construction vibration, no matter the time of day or night.

Pan- European Competency Certificate for Shot firers/ blast designers

Most of the EFEE Newsletter readers are already familiar with the letter combination PECCS – the Pan-European Competency Certificate for Shot firers / Blast designers by EFEE. Most of these readers are also familiar with the problems we face in the explosive industry – no mobility in between countries, not enough young people interested in this profession, not enough or good enough means to study to become a shot firer/blast designer.

Well, PECCS was designed to tackle these problems. A Project made for enhancing the educational possibilities and mobility of shot firers and blast designers in Europe. Funded by the European Commission.

For now, the Project has been active for almost a year and a lot has been done already. The main goal is to create a certificate course in order to give out universal certificates, which would be accepted in all EFEE Member countries. The Project already has well composed materials from earlier stages, which will be the base of the certificate course (please visit our web page http://www.shotfirer.eu/peccs-by-efee/ for more information).



PECCS Project partners from the left: Anette Broman, Jan Johansson, Anne Charline Sauvage, Doru Anghelache, Teele Tuuna, Nigel Taylor, Viive Tuuna, Fredrik Viking, Jose Carlos Gois, Jörg Rennert, Karl Kure

Within the first year of the Project, the materials have been overlooked with a critical eye by the 8 project partners in different countries and necessary changes has been done in order to have modern and well composed knowledge.

The next step is to start with the test courses of the certificate. There will be all together three stages for test courses, in three different countries – Sweden, Germany, France. These test courses are designed to gather feedback from participants and through this feedback we will enhance the course even further

The teachers of these courses are the latest co-authors of the materials and the partners of the project. The participants are people who would be possible future teachers and also people, who could give actual feedback from a shot firer point of view. The first test course will take place from the 11^{th} of December until to the 15^{th} of December 2017 in Stockholm, Sweden. More information about this course and also for the registration for the participation, please do not hesitate to write info@shotfirer.eu

Project managers Viive Tuuna and Anette Broman

In 2016 December edition of EFEE Newsletter we also invited people to participate in the project as critics, to look at the existing materials and suggest necessary changes. As the materials are available on a web page www.shotfirer.eu and will stay there also after modifications, we still invite people to visit and comment if they see necessary changes as PECCS is beneficial for everyone in this field of expertise.

Through creating additional learning opportunities and a more universal certificate we hope to attract more young people to the profession, solve problems with workforce in different countries and provide better knowledge for safer and more modern industry of explosives engineering.

PECCS materials and courses will be evaluated by specialists and introduced to authorities. The goal is to have the certificate in use already by the end of 2019. In order to be able to do that in full expected quality, we hope to have good participation on our test courses, our Multiplier Event in Germany and also in the last evaluation processes. These events will be held for everyone interested, and the information for these events will be public on the project home page on www.shotfirer.eu or through EFEE board members.

We will do our best to change the shot firer's world for the better. Just hop on board and join us!

Teele Tuuna, project technician

It all began in Vinterviken!

Ascanio Sobrero had managed to produce nitro-glycerine in 1847 in his laboratory in Turin and in 1853, a former teacher (Russian Professor Nikolay Zinin) to Alfred, draw his attention to nitroglycerine, which he thought could be used for military purposes. During the Crimean War in 1853-56 Alfred's father Immanuel Nobel together with his sons were doing work with naval mines for the Russian military. The tests, Immanuel performed, showed that it was not difficult to produce nitroglycerine in small scale but the trick was to initiate it properly.

Image 1. Alfred Nobel. Painting by A. Österman.

Back in Sweden, Alfred together with his father Immanuel and his younger brother Emil had been experimenting, with various mixtures of nitroglycerine and black powder which was ignited with a black powder fuse and in 1863 Alfred took a patent on mixtures for blasting and artillery. However, Alfred was not satisfied and he continued experimenting with pure nitroglycerine. He invented a wooden capsule, filled with black powder and a fuse, which properly ignited the pure nitroglycerine in a drill hole. Production and sales of nitroglycerine started at their small production facility in Heleneborg, some 2 km from Vinterviken. Many Swedish users became strongly interested in the use of the explosives and the volumes increased.

But on 3rd September, 1864, the production facility was destroyed by a large explosion and six people died. One of them was Alfred's youngest brother Emil. The demand for nitroglycerine had increased with mines and construction work, so Alfred immediately started up the production on a barge, anchored at Bockholmssundet, west of Stockholm. Alfred also began to search for a land based site where the production could continue after necessary approvals were received by the authorities.

On November 28, 1864, Alfred Nobel together with two partners established a Nitroglycerin Aktiebolaget. He sold his patent of nitroglycerine production and use, which he aqcuired in July the same year, to the company. Nitroglycerin Aktiebolaget was not only his first company, but also became the first company in the world to produce nitroglycerine commercially. The company erected its explosives plant at Vinterviken, situated at the isolated inlet of Lake Mälaren.

The manufacture of nitro-glycerine, on an industrial scale, started in Vinterviken as early as 1865. For more than fifty years, the Vinterviken factory delivered Nobel explosives and blasting devices of various kinds for civil engineering, with a steadily expanding capacity. Alfred started up plants first in Krümmel, Germany and in Lysaker, Norway, then Finland and thereafter Alfred Nobel´s expansion of his dynamite business empire continued worldwide.

The nitroglycerine was a product welcomed by the users, but from the safety point of view, it was a product that intrinsically differed from the black powder, used in blasting since the 17th century.

Image 2. The production area in Vinterviken can be seen behind the ship.

If the product not was pure enough the probability for accidents was extremely high when exposed to any impact. The nitroglycerine was delivered from Vinterviken in cans and transported to the user on bad, bumpy roads. Thereafter, it was to be carried on ladders down to the blasting site. From the can, it was poured into the drill holes with a risk of spill and unintentional initiation. All over the world tragical accidents were reported and the authorities banned the sales and transportation of nitroglycerine in July 1868. This was however about the same time as Alfred Nobel had invented the dynamite, by using kieselguhr to absorb the nitroglycerine.

Vinterviken was not spared from several severe accidents. The worst one occurred in april 1860 when some 700 kg of explosives was unintendedly initiated and resulted in 14 fatalities of which were 5 women and 2 children. The cause was never confirmed but it was thought that nitroglycerine spill on the floor was initiated when earthenware vessels, filled with nitroglycerine, were pushed over the spill.

Alfred Nobel's revolutionary inventions - the blasting cap and the dynamite, patented in 1863 and 1867, respectively - formed the basis for operations at Vinterviken. In 1865 Alfred improved the cap and used a copper shell filled with mercury fulminate.

Records show that in the early stages, Alfred Nobel was not only the company's president, but also its chief engineer, secretary, travelling salesman, advertising manager and treasurer. Very soon, in order to be able to channel his energy into building of what would become a world-wide industrial empire, he appointed his eldest brother Robert for a managing director in Vinterviken. Then soon after, the day-to-day operations at Vinterviken were turned over to his childhood friend, the engineer Alarik Liedbeck. This was the beginning of a fruitful collaboration, which later led to the establishment of many important factories in other parts of the world. Alfred Nobel often visited Vinterviken. He saw to it that world-wide improvements in manufacturing techniques as well as new inventions were immediately made available to Nitroglycerin Aktiebolaget.

In 1915 Nitroglycerin Aktiebolaget acquired Gyttorps Sprängämnes AB, its toughest competitor in the Swedish explosives industry. This made it possible to move the explosive production from Vinterviken to Gyttorp, a village belonging to the county of Nora, north of Örebro. Imposed limits on the quantity of dynamite produced at Vinterviken made it necessary to move the production and in the summer of 1921, dynamite production at Vinterviken ceased. For many years, the buildings were used as warehouses, storing explosives produced in Gyttorp and later transported to blasting sites in the vicinity of Stockholm. In 1965 the name Nitroglycerin Aktiebolaget was changed to Nitro Nobel. Dyno Nobel ASA, which also originates from an early Nobel company, acquired by Nitro Nobel in 1986 and since 2006 the operations have been taken over by the Australian company Orica Ltd.

From 1946 to 1987 the company housed its Nitro Nobel Detonics Research Laboratory in some of the buildings. Together with the Swedish Detonic Research Foundation (established 1953) fundamental research were carried out and many new ideas in blasting technique, vibration monitoring, high speed photography, testing of explosives strength through underwater testing and cylinder expansion testing, charging techniques, safety testing of explosives, rock fracture toughness testing, shaped charges, software for blast calculations and strength, metal cladding by explosives and advanced explosives and high precision initiation systems.

Novosibirsk-Russia, Inbri- India and many other universities/research organisations world-wide like Luleå University of Technology-Sweden, Colorado School of Mines-USA, New Mexico Tec-USA, University of

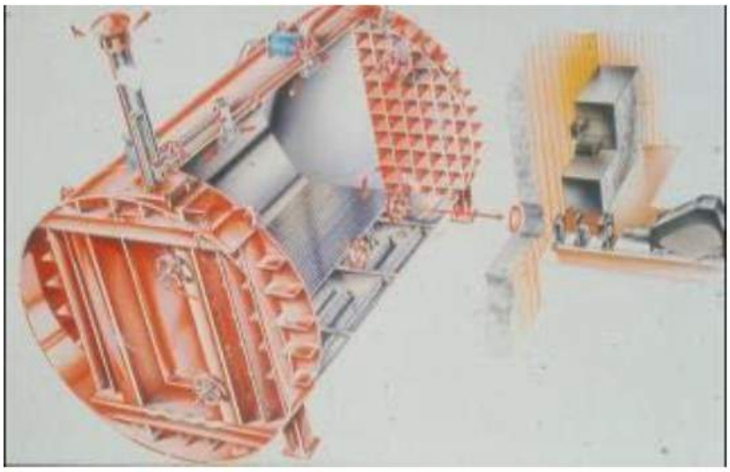


Image 3. Blasting chamber for maximum 5 kg explosives.

Maryland-USA, Yokohama National University-Japan, AMIRA-Australia to mention some of them.

It was indeed a truely stimulating and interesting research work, carried out at Vinterviken. I had the privilege to work at Vinterviken as researcher from 1972 and later as a managing director 1982-86.

A blasting chamber, managing 5 kg, was built in 1982 and installed in Vinterviken where we carried out tests with channel effects and high speed photography of detonations. A Cordin 116, a high speed camera that could take 25 pictures with a speed of maximum 1,3 million frames per second, was of great help for studying various phenomena.

The Swedish Detonic Research Foundation had interesting collaboration with many international mines, construction companies, explosives companies and drill rig producers as well as creative collaboration with foreign laboratories like Los Alamos -USA, Stanford Research Laboratories-USA,

Image 4. Decoupled charge. The decoupling air gap causes an air shock precursor, the "Channel Effect" which may dead press the explosive and stop the detonation.

I also lived at the Vinterviken idyllic place during 1982 to 1986. Also, Professor Finn Ouchterlony in the Technical Committee for the 9th EFEE World Conference on Explosives and Blasting lived and worked in Vinterviken many years and took over as managing director for the Swedish Detonic Research Foundation in 1986.

A major reconstruction took place at Vinterviken in the beginning of the 1990s and a sculpture park was established as well as recreation areas, café, restaurant and small gardens for growing flowers and vegetables.

Image 5. The old acid plant built 1891.

when sulphuric acid was needed for the production of nitroglycerine, a new plant was built in 1891. This is the building in which the Gala Dinner will be held at the 9th EFEE World Conference on Explosives and Blasting. Today it is renovated and a beautiful building with wooden beams in the ceilings housing a café, restaurant and a fantastic banquet room for 500 people named "Winterviken".

References

Nitroglycerin Aktiebolaget 1864-1964, - Nordisk Rotogravyr, Stockholm, Sweden, 1964.

R. Holmberg, *"From Black Powder Fuse to High Precision Detonators." - Discussion Meeting of the Rock Blasting Committee, Stockholm, pp 99-106, 1994. (In Swedish).*

Photos. From Nitro Nobel's and Swedish Detonic Research Foundation´s archives.

Roger Holmberg,
Secretary General EFEE

Helsinki, Finland will host the 10th EFEE World Conference on Explosives and Blasting in 2019

On behalf of EFEE and Finnish INFRA contractors' association I would like to warmly welcome all explosives engineers to Helsinki in September 2018 to join the 10th EFEE World Conference on Explosives and Blasting! Finland is a great country to visit and we are working hard to make it the best EFEE conference ever!

Helsinki and Finland in a nutshell

- Helsinki is easy to reach, it has excellent flight connections and public transportation
- Finland has been evaluated the safest country and Helsinki the safest capital in the world
- Helsinki is highly international, innovative, friendly and modern city - Beautiful archipelago and unspoiled nature within easy reach - Great accommodation and food everywhere
- Long traditions in blasting engineering and underground rock construction
- Helsinki was the first capital to introduce an underground general plan
- Innovative and leading technology development - many of the leading technology and equipment manufacturers for Mining and Construction come from Finland

Conference venue - Scandic Marina Congress Center

Scandic Marina Congress Center is located right in the heart of Helsinki, right by the sea. Overlooking the harbor, market square, City hall and Presidential palace.

This modern congress venue can offer exceptionally flexible facilities with the very latest technology for up to 2 500 delegates. All rooms are equipped with modern technique, air conditioning and free Wi-Fi

Accommodation - Scandic Grand Marina Hotel

The Scandic Grand Marina Hotel just next to the Marina Congress Center will be the main accommodation hotel. The hotel is a 4-star property and is a 5 minute walk from the city center. Half of the bedrooms are facing sea. This 7 floor hotel has 450 well equipped guestrooms and 20 suites

Educational Tours

Pre and post conference tours are planned to include
- Visit to a tunneling / underground construction project
- Guided walk through underground city center of Helsinki
- Visit to Forcit Explosives factory and a mine museum
- City Tour

See you in Finland in 2019 – we will have a blast!

Jari Honkanen
Vice President, EFEE
National EFEE Council member of Finland

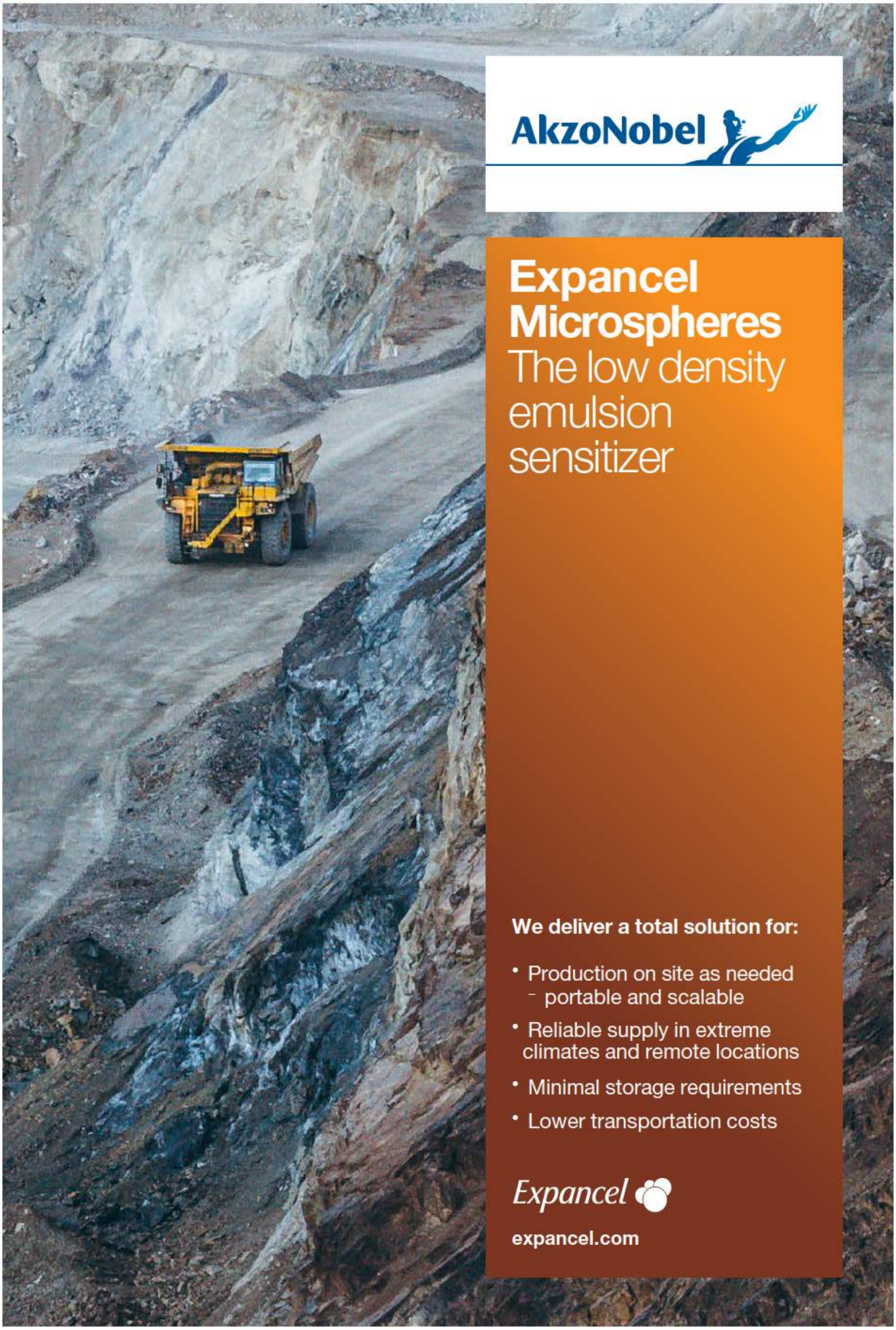
New EFEE members

EFEE likes to welcome the following Members who recently have joined EFEE

Individual Members

Immacilada Álvarez Fernández, University of Oviedo, SPAIN

Adam Garrod, Greater Manchester Police, UK


AkzoNobel
Expancel Microspheres
The low density emulsion sensitizer
We deliver a total solution for:
• Production on site as needed – portable and scalable
• Reliable supply in extreme climates and remote locations
• Minimal storage requirements
• Lower transportation costs
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Upcoming Events

MPES 2017
26th INTERNATIONAL SYMPOSIUM ON MINE PLANNING & EQUIPMENT SELECTION
August 29.-31. 2017
Luleå, Sweden
http://www.ltu.se/research/subjects/Mining-and-Rock-Engineering/Konferenser/MPES-2017?l=en

EFEE 9th World Conference on Explosives and Blasting
September 10.-12. 2017
Stockholm, Sweden
www.efee.eu and http://efee2017.com/

44th Annual Conference on Explosives and Blasting Technique, ISEE
January 28.-31. 2018
San Antonio, TX, USA
https://www.isee.org/conferences/2018-conference

Fragblast 12
June 09.-15. 2018
Luleå,Sweden
http://www.ltu.se/research/subjects/Mining-and-Rock-Engineering/Nyheter/FRAGBLAST-to-Lulea-2018-1.143098?l=en

25th WORLD MINING CONGRESS
June 19.-22. 2018
Astana, Kazakhstan
www.wmc2018.org

HILLHEAD
June 26.-28. 2018
Derbyshire, UK
www.hillhead.com

EFEE 10th World Conference on Explosives and Blasting
September 15.-17. 2019
Helsinki, Finland


INFRA
A complete solution for remote construction site monitoring
Blast application available
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Sigicom
Project: Blasting Stockholm
sigicom.com
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The art of successful blasting
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ORICA
SHOTPlus5

44TH ANNUAL CONFERENCE ON EXPLOSIVES & BLASTING TECHNIQUE

January 28 – 31, 2018
San Antonio, Texas USA

Grand Hyatt San Antonio

River Walk, San Antonio, Texas

Call For Papers

ISEE Conference 2018

Call for Papers

The International Society of Explosives Engineers' Conference Program Committee is issuing an industry wide Call for Papers to be presented at the 44th Annual Conference and published in the Conference Proceedings.

Here's your chance to share your techniques, strategies, solutions, product innovations, and research discoveries with your peers.

Ideas should be submitted in the form of a 200-400 word abstract (summary) highlighting the major points of your 8 to 10 page paper. Papers may not be commercial in nature.

Abstracts must be submitted by completing the online abstract submission information by May 12, 2017. The submission site, guidelines, instructions and deadlines can be viewed at www.isee.org. Please contact us if you do not receive confirmation within two weeks of submitting your abstract. Chapter sponsored papers must be submitted by the deadline.

Suggested Topics

Papers addressing all explosives, vibration, blasting and drilling related topics are requested. Papers addressing the following topics are specifically invited:

- Explosives Safety/Security
- Environmental Improvement
- Drill o Mill Optimization
- Blasting Research
- Digital Imaging on the Jo
- Blast Vibration and Seismology
- ast Blasting and Open Pit
- Explosives for Oil Extraction
- Explosives Analysis
- Explosives Chemistry
- Fragmentation Modeling/Measurement
- Base Histories: Problems and Solutions
- Risk Assessment/Legal
- Urban Blasting
- Demolition Blasting
- Quarry Blasting
- Underground Blasting
- Electronic Detonators
- Underwater Blasting
- Construction Blasting
- Public and Media Relations
- Driller/Blaster Communication
- Basic Drilling Practices
- Blast design

Deadlines

May 12, 2017
Last day for submission of abstracts.

June 15, 2017
Notification of abstract acceptance.

August 15, 2017
Last day to submit completed papers.

November 1, 2017
Notification of final acceptance of papers.

November 30, 2017
Conference registration deadline for authors.

January 28 - 31, 2018
Annual Conference - presentation of papers.

Abstract Deadline May 12, 2017

International Society of Explosives Engineers
www.isee.org | 440.349.4400