EFEE

NEWSLETTER

Explosion disaster in Beirut - EFEE report

Detonation characteristics of a NOx-free mining explosive based on sensitized mixtures of low concentration hydrogen peroxide and fuel

A guide to use Relevant Good Practice for explosive demolition of structures, II

Use of explosives for Reflection Seismic Survey Application

And much more!

May 2021

May 2021 edition

We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in August 2021. Please feel free to contact the EFEE secretariat or write to newsletter@efee.eu 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 an upcoming Newsletter edition

or any other matter.

Viive Tuuna, Chairman of the Newsletter Committee and the Vice President of EFEE and

Teele Tuuna, Editor of EFEE Newsletter - newsletter@efee.eu

Dear friends,

A beautiful life, then and now.

In the past year, I have spent a lot of time thinking about what it means to have a good life, a state of wellbeing, if you will.

Specifically, I have been wondering whether my personal definition of a good life has changed in light of the situation we have been facing for over a year now. *I feel like it was the longest year.*

Before the pandemic, I used to define my state of wellbeing by reference to having love, family, friends, as well as the fulfilment given by a thing done well.

It meant having beautiful, innovative, spectacular, impossible projects that turn, as if miraculously, into happy clients and colleagues.

It meant having the faith to move forward, even when the road ahead was very difficult. It meant being grateful for every moment you are alive, healthy, surrounded by love and care.

It meant "stubbornness" to not give up your principles, even if it meant losing out at that moment, but eventually winning your soul, the greatest treasure.

What else did having a state of wellbeing mean for me? It meant enjoying my time in nature, strolling through Cismigiu Park.

It meant the joy of having a cup of coffee with my partner while discussing serious matters, after which we would make our way to the libraries.

It meant the joy of receiving a caring message or listening to my daughters telling me about their work (we are past school age!) or that I am a cool dad.

It meant having the opportunities to see new places.

Has any of this changed? No. I feel the same way, only that I am infinitely more grateful for having them in my life. I am trying to be more present and wiser - I hope for that with all my heart. I try to talk less and listen more. I try to count my blessings, as the Englishmen say.

I want us to be happier this year. The reasons for being joyful are already in our lives, we just have to open our eyes to see them.

Switching gears from these personal reflections, I am happy to see continuous interest and active participation in EFEE life. The 66th EFFE Council Meeting and the 20th EFEE Annual General Meeting have just taken place before the incoming weekend of week 22.

EFEE is a living body and through its members will continue to develop and bring more added value and feasible projects to the explosives industry. I was also happy to see that new people have joined both our online meetings, which gives me hope that future ideas will come to life as a result.

The decision to move the Maastricht EFEE World Conference to Spring 2022 was, predictably, a wise one. We are all missing our real-life interactions, but hopefully soon we can hug each other warmly and enjoy a glass of beer or wine together ...

Nowadays, EFFE is in a good financial position and will continue to deliver to its members a platform where we can discuss innovative ideas and good practices in the explosives industry. To tie this in with my previous reflections, I hope to see EFEE as a contributing factor to our members state of wellbeing.

Doru Anghelache,
President of EFEE

AGM, the Annual General Meeting

Friday 28th May EFEE had the AGM Meeting over Internet. 27 Members attended.

President Doru Anghelache was appointed to be the Chairman.

The previous AGM meeting was also held over Internet 20th November 2020 and the MoM was approved anonymously.

It was mentioned that since the last Council Meeting EFEE has one corporate member joined. It is Irish Industrial Explosives Ltd., Ireland. Also 6 new Individual Members joined.

AGM approved the Board Annual Report 2020 which has been communicated to all EFEE Members.

The **Financial report for 2020** was shown and the Auditor Donald Jonson and the Proxy Auditor have scrutinized the report and AGM approved the Audit Report.

The **2021 Budget** was presented and was approved.

The **Election Committee** was unanimously chosen: José Gois (Chairman), Mark Hatt and Anne Charline Sauvage

The **Election of the Board** was unanimously approved;
Doru Anghelache as President. Viive Tuuna as Vice-President.
Jörg Rennert as Treasurer.
Board Members; Johan Gjødvad, Igor Kopal, Mathias Jern and Espen Hugaas.

Jari Honkanen is Immediate Past President according to Constitution.

The **Audit Committee** was unanimously chosen; Donald Jonson as Chairman and Walter Werner as Proxy Auditor.

Election of **Council Members representing Companies and Individuals**
Mark Hatt, UK was re-elected for two years for representing EFEE Individual Members 2021-2023. Robert Laszlo, Mathias Jern and Tomi Kouvonen are Council Members representing Corporate Members 2020-2022. Teele Tuuna is representing Individual Members for the two years 2020-2022.

The AGM decided that the **Membership Fees** should be the same for 2021 as for 2020.

Next AGM meeting will be held in Maastricht 14th May 2022.

EFEE

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Explosion disaster in Beirut on August 4, 2020

Connecting to the explosion accident in Beirut which caused 210 deaths, 7,500 injuries and 12.6 € billion in property damage, investigation results have been published in the last couple of weeks.

After extensive examination of these reports, it has to be assessed that some of the presented findings have come to conclusions that, from a professional point of view, cannot be shared and endorsed by EFEE. That is why EFEE issued a statement concerning this inquiry report and delivered it to the UNIDIR which you can find here.

The IME (Institute of Makers of Explosives) and the AEISG (Australasian Explosives Industry Safety Group Inc.) delivered statements with contentual similar results. To prevent serious accidents as this in the future, it is implicitly necessary to examine the true reasons that lead to this incident.

Only if this is given, the right conclusions can be found and subsequently the right measures can be met, and actions can be taken.

Jörg Rennert

EFEE representative in the EU Directives

8 February 2021

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To
Dr Pieter S J Halliday
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c/o Societe Suisse Des Explosifs
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Re. Beirut Report by UNIDIR

Dear Piet,

Thank you for sending us the Beirut Report; Compiled by United Nations Institute for Disarmament Research (UNIDIR).
EFEE have read the report with great interest. Especially the recommendations of the authors of this report was studied carefully by us.

In summary, EFEE would like to strongly express that we do not share the opinion of the authors of the study in their conclusions from the incident.

From our technical background and our understanding of the typical chemical reaction of explosives AN is not a burning material; it is rather an oxidizer. This means that AN cannot burn by itself and that the explosion that occurred in Beirut was based factually on more components than pure AN. According to the report of New Times from the 10 th of September 2020 the AN was stored together with fuel, fuses and pyrotechnics. We therefore believe that there is overwhelming probability that the fire started with the pyrotechnics. This is also supported by the first seconds of the videos of the whole catastrophical incident, which strongly supports a pyrotechnical initiation.

From our point of view the combination of AN, fuel, fuse and pyrotechnic is the obvious reason for the explosion. Therefore, we regard it as an unnecessary action to move AN from class 5.1 to class 1.1.

EFEE is ready to answer any questions raised, should there be any need for further elaboration or clarification of our standpoint.

On behalf of the EFEE board

Doru Anghelache and Jörg Rennert
EFEE President EFEE representative in the EU Directives

11th WORLD CONFERENCE
Maastricht
MECC, Maastricht, Netherlands

Important Date Change: 15th - 17th May 2022

CONFERENCE ANNOUNCEMENT

EFEE 11th World Conference | Sunday, 15th to Tuesday, 17th May 2022.
After careful consideration the EFEE Board has decided to postpone the 11th World Conference in Maastricht to Sunday 15th to Tuesday 17th May 2022. This difficult decision has been taken as many countries are now experiencing further waves and lockdowns, creating significant uncertainty regarding travel restrictions and consequently impacting the feasibility of hosting the conference in September.

With the phenomenal progress globally of vaccination programmes and our hope is that by delaying the conference until May 2022 we will ensure a safer and far more accessible conference for all parties.

It is EFEE's intention to run an educational webinar during September 2021, details will be made available in due course.

Please find below the updated timetable:

Abstracts & Papers

Friday 29th October 2021 - Abstract Deadline
Friday 26th November 2021 - Abstract Notification
Monday 6th December 2021 - Distribution Preliminary Programme
Friday 28th January 2022 - Submission Papers
Friday 25th February 2022 - Paper Notification

Registration

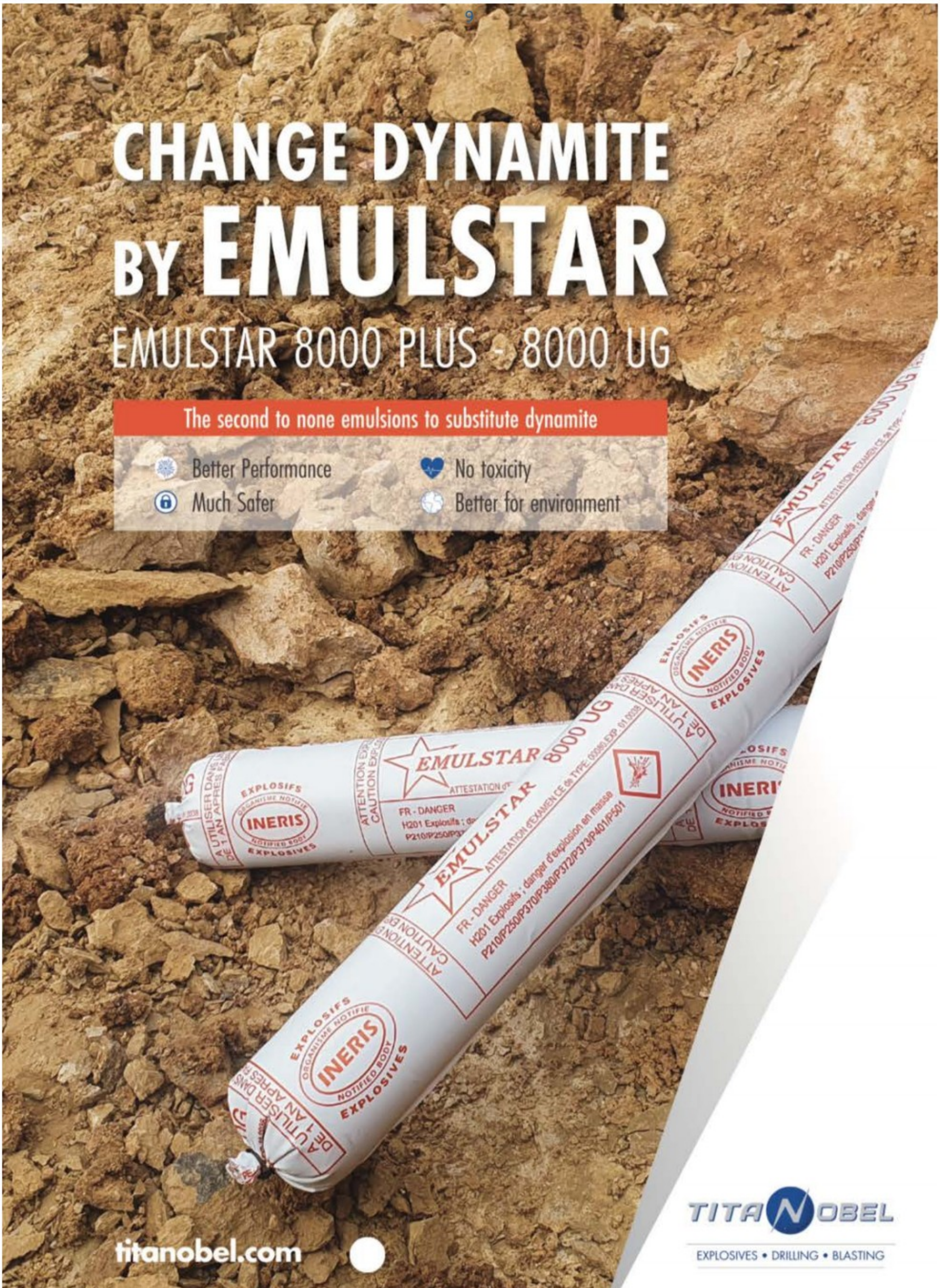
January – March 2022: Early Bird Registration
April – May 2022: Standard Registration

We would like to take this opportunity to thank the authors who have submitted abstracts for the 11th World Conference. Abstracts will be carried over to the 2022 programme and authors will have the ability to submit amendments and additions from now until the revised deadline **Friday, 29th October 2021**.

We look forward to welcoming you to the 11th World Conference in the Spring of 2022. We will be updating the conference website in the coming weeks, however, if you have any immediate queries please contact info@efee2022.com

Igor Kopal, Conference Committee Chair and James Tyler, Tyler Events

www.efee2022.com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Detonation Characteristics of a NOx-Free Mining Explosive Based on Sensitised Mixtures of Low Concentration Hydrogen Peroxide and Fuel

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Abstract:

Mining explosives based on ammonium nitrate(V) are safe and effective, however, the risk of NOx fume production during blasting is still present. In 2013, a project to eliminate NOx fumes from blasting began and hydrogen peroxide was chosen to replace ammonium nitrate(V) as the oxidiser. Previous work in this area demonstrated that hydrogen peroxide/fuel- based mixtures were able to detonate, provided that they are initiated under a situation of high confinement and also using hydrogen peroxide at relatively high concentrations. In contrast, a comprehensive study was conducted to determine the detonation properties of hydrogen peroxide/fuel- based mixtures that used hydrogen peroxide at lower concentrations (below 50 wt.%), detonated in unconfined conditions and used void sensitisation to achieve an efficient detonation reaction. This article presents the results of the influence of the density, water content, critical diameter and type of void sensitisation on the velocity of detonation (VOD) of hydrogen peroxide/ fuel- based explosive mixtures. The results indicate that the mixtures can achieve a different VOD which depends on the size of the sensitising voids and more importantly, the mixtures behave as non-ideal explosive, similarly to ammonium nitrate- based explosives, but with the advantage of being a NOx-free explosive.

1 Introduction

Currently most of the commercial explosives used in mining and civil blasting applications are based on mixtures of ammonium nitrate(V) (AN) with fuel.

These mixtures are commonly known as ammonium nitrate(V)/fuel oil (ANFO), emulsion and watergel explosives. Literature describing formulations, detonation properties, applications, *etc*. is given elsewhere [1- 5].

Despite being safe and excellent explosives, one of the disadvantages of AN-based explosives is that they may produce NOx fumes from inefficient reactions caused by the complex interaction of unpredictable ground conditions and/or poor implementation practices. These fumes can cause health issues and in some countries, government regulators have intervened in the matter. The evolution of NOx fumes has been investigated by various researchers in the past [6, 7]. Additionally, documents addressing the management of NOx fumes before and after blasting have been issued by government regulators and industry in Australia [8, 9]. To address this problem, work was undertaken to find potential oxidiser materials that could substitute the AN present in current mining explosives, and thus truly eliminate the chances of producing NOx fumes. In order to achieve this objective, the potential AN replacements should have no nitrogen in the molecule and be mass produced. One of these potential substitutes is hydrogen peroxide (HP).

This material is an oxidiser, mass manufactured, which has shown in past studies that when mixed with fuel, it can detonate under certain conditions of high concentrations and confinement [10-12]. However, those detonation studies of HP/fuel-based mixture did not consider relatively low HP concentrations (*i.e.* 40 wt.% -50 wt.%) with void sensitisation.

Although mixtures made with low concentration of HP would be insensitive to initiation, void sensitisation can confer sensitivity of the mixtures. Void sensitisation is a standard process used with AN- based mining explosives and the process is applied at the point of loading (which increases the safety when handling, transporting, storing and using mining explosives).

Detonation tests were conducted using lower HP concentration and sensitising methods to determine if mixtures were able to detonate. Results of these detonation tests were published in 2013 [13, 14] and studied the influence of both density and the diameter of the charge on the VOD. That study revealed that HP/fuel-based mixtures were able to detonate when sensitised with glass microballoons (GMB) and more importantly, that HP/fuel-based explosives, similarly to AN- based explosives, belong to the group II of explosives, where VOD depends on the density, as defined by Price [15].

Due to the success of this early study, more comprehensive work was conducted to determine the influence of variables such as density, type of sensitisation, water content and combination thereof on the VOD of HP/fuel- based mixtures. Results from these are discussed in this article.

2 Experimental section

2.1 Formula

Table 1 displays the formula studied in this work. HP/fuel-based mixtures were prepared with HP 35 wt.%, 40 wt.% and 50 wt.%. As fuel, a mixture made up of glycerine and xanthan gum was used. The fuel phase content varied between 14.0 wt.% - 17.0 wt.%. The total water content varied between 41.5 wt.% and 56.6 wt.%.

The types of sensitising voids used in this study were:

- GMB Q-cel 5020, not sieved, with a particle size of 20-120 µm;
- chemical gas bubbles, with a particle size of 100-400 µm;
- Expanded polystyrene (EPS) voids, with a particle size of 5500-7500 microns.

Table 1.

Formulas tested

HP concentration [wt.%]	35	40	50
Component			
HP [wt.%]	30.45	34.40	41.50
Water [wt.%]	56.55	51.60	41.50
Fuel [wt.%]	13.00	14.00	17.00
Density [g/mL]	1.14	1.16	1.20
OB	−1.04	−0.42	−0.56

The sensitising voids were hand-mixed into the HP/fuel-based mixtures using a plastic spatula and a 5-Litre plastic container. In this way the potential of any friction event that could initiate the explosive was lowered. In order to chemically gas the mixtures, a solution of NaOH (13.0 g/L) and NaHClO (52.5 g/L) was used to decompose the hydrogen peroxide and produce gas bubbles. The amount of HP decomposed for gassing was minimal and did not affect the total strength of the HP as oxidiser in the oxidiser solution.

The lowest density achieved when using GMB for sensitisation was 0.75 g/mL. At this density, due to the GMB load, the mixtures become too thick and there was too much friction when mixing. For safety reason no more incorporation of GMB was tried.

EPS was sourced from the supermarket and then sieved.

2.2 Detonation tests

The HP/fuel-based mixtures were loaded into PVC tubes (mostly 102 mm inner diameter, 1 mm wall thickness and 600 mm in length). The charges were initiated with a 50 g pentolite booster.

Conical charges were also used to determine critical diameter. Pipes/cones with the explosive were loaded and fired the same day. A small 25-gram booster and an electric detonator were used to initiate the charges. The VOD was continuously measured using the MREL- Microtrap data acquisition system. The VODcable was externally attached to the PVC pipe.

3 Results and Discussion

3.1 Range of formulas tested

Previous work by Shanley *et al.* [10] showed that HP/fuel mixtures (where acetone, ethanol, glycerine, *etc*. were used as fuel) were able to detonate in a wide range of proportions under confined conditions and no sensitisation. Most of the mixtures are inefficient from a mining application perspective as they were not oxygen balanced. More specifically one of the components of the mixture is in excess (either oxidiser or fuel) and this excess will not react during the detonation process and therefore will not contribute to the release energy to sustain the detonation. This excess will only absorb energy and hence their unsuitability for practical blasting applications. Excess fuel will also produce unwanted reaction by-products (CO).

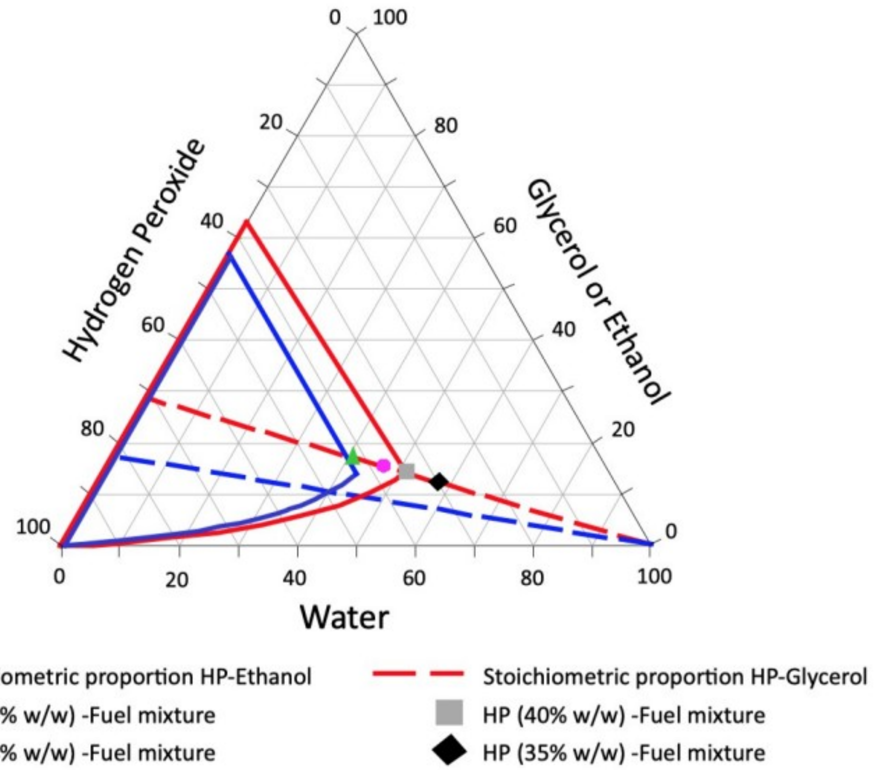


Figure 1.

Ternary diagram displaying the detonation ranges of HP/fuel mixture according to Shanley et al. The plot also displays the formulas investigated in this research

In this work, only HP/fuel-based mixtures that were oxygen balanced were studied. These compositions are displayed in the ternary diagram in Figure 1 (along the dotted red line, which correspond to the HP/glycerol mixtures).

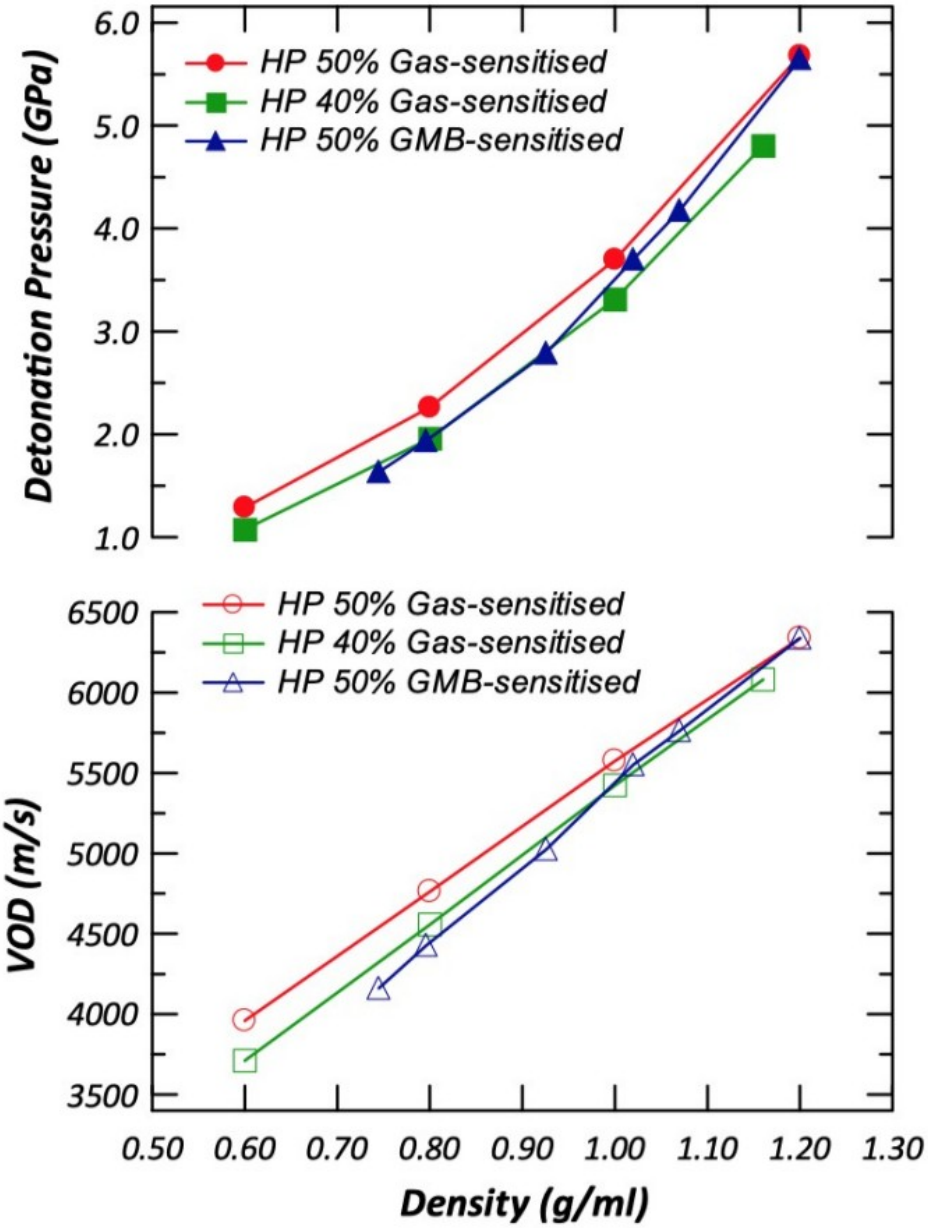
The HP/fuel-based mixtures were sensitised by incorporating physical voids (GMB or EPS) or by generating in-situ bubbles (chemical gassing). The incorporation of the sensitising voids caused of course, a drop in the density of the HP/fuel based mixtures.

3.2 Thermodynamic calculations

It is observed that formula prepared with 50 wt.% of HP has an energy of 4.66 MJ/kg. This energy is higher than ANFO, which is 3.60 MJ/лg. The other two formulations have a lower energetic content than ANFO (2.90 MJ/лg and 3.48 MJ/лg for 35 wt.% and 40 wt.% respectively). Plots from the thermodynamic calculations for the HP/fuel- based mixtures prepared with HP of different strength (40 wt.% and 50 wt.%) are presented in Figure 2. The plots show both the ideal VOD and ideal detonation pressure) when using different sensitisation.

Figure 2.

Thermodynamic calculations of HP/fuel-based mixtures, with different densities, sensitisation type and water content



The thermodynamics properties were calculated using an ideal detonation code. It is seen that the VOD and detonation pressure drops with the density. It is also interesting to see that there is not significant difference in VOD or detonation pressure between samples made with HP 50 wt.% or HP 40 wt.%.

3.3 Influence of the type and size of the void on the detonation properties

The relationship between the density of the HP/ fuel- based mixture (in the range 0.30 g/mL - 1.2 g/mL and prepared with HP 50 wt.%) and the VOD, when using different void size, is displayed in Figure 3.

It has been noted that the VOD of the HP/ fuel- based mixtures drops considerably in the density range 0.3 g/mL - 1.00 g/mL when EPS is used as sensitising voids. This behaviour has also been found in previous work [16], however no hypothesis was presented to explain the mechanism by which the VOD drops when using large voids for sensitisation.

The shape of the Density Vs VOD curve shown in Figure 3, which shows a peak on the VOD, is characteristic of an explosive from Group II [15].

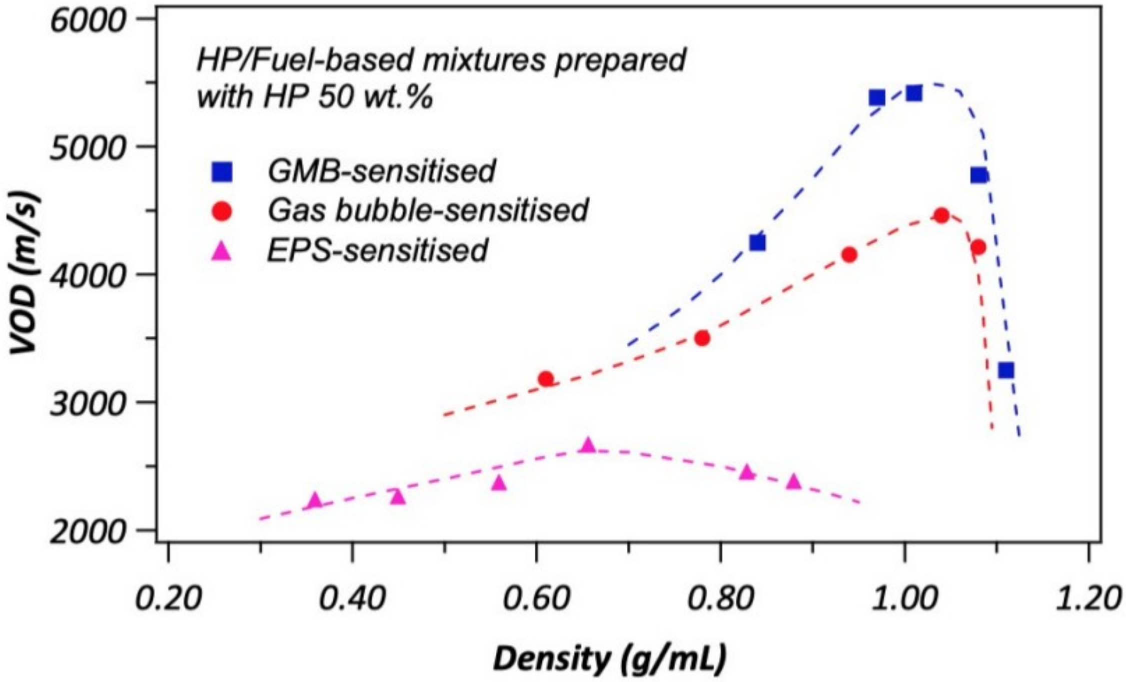


Figure 3.
Relationship between density and VOD, using different sensitising voids

However, a few interesting features are seen when the size of the void increases. Firstly, the VOD peak for the GMB- sensitised mixture is at a density of around 1.00 g/mL versus 0.65 g/mL, when compared to the EPS- sensitised mixture. This shift of the VOD peak of the mixtures towards higher densities when the sensitisation void's size decreases is in line with previous published results [17, 18]. Secondly, for the same product, different densities could achieve the same VOD. For example, he gas-sensitised products (at density of 0.90 g/mL or density 1.04 g/mL) can achieve VODs of approximately 4000 m/s. However, the product at density 0.90 g/mL has between 2-3 times as much GMB (by volume) than the product at density 1.04 g/mL.

This high amount of GMB is diluting the HP/Fuel-based mixture (less energy release per unit of volume) which causes a low VOD and in turn a lower detonation pressure. This would also translate into a different blasting result at a mine scale.

We also hypothesized that there are two factors to consider in the decomposition and ignition of the energetic material along the VOD curve:

- heat produced by the hot spot;
- heat released by the shocked and ignited material.

In the high density of the curve, hots spots decompose the material they are in contact with but after that, the heat released by the decomposed material is the main factor to continue the ignition and sustain the detonating process. However, at low densities (left hand side of the VOD curve), the amount of heat released is quite low mainly due to the low amount of energetic material being shocked and decomposed. The heat released may not be sufficient to decompose and ignite the unreacted material to continue sustaining the detonation reaction. Therefore, hot spots, which are abundant in the low density section, are the main factor that influences the ignition of the energetic material.

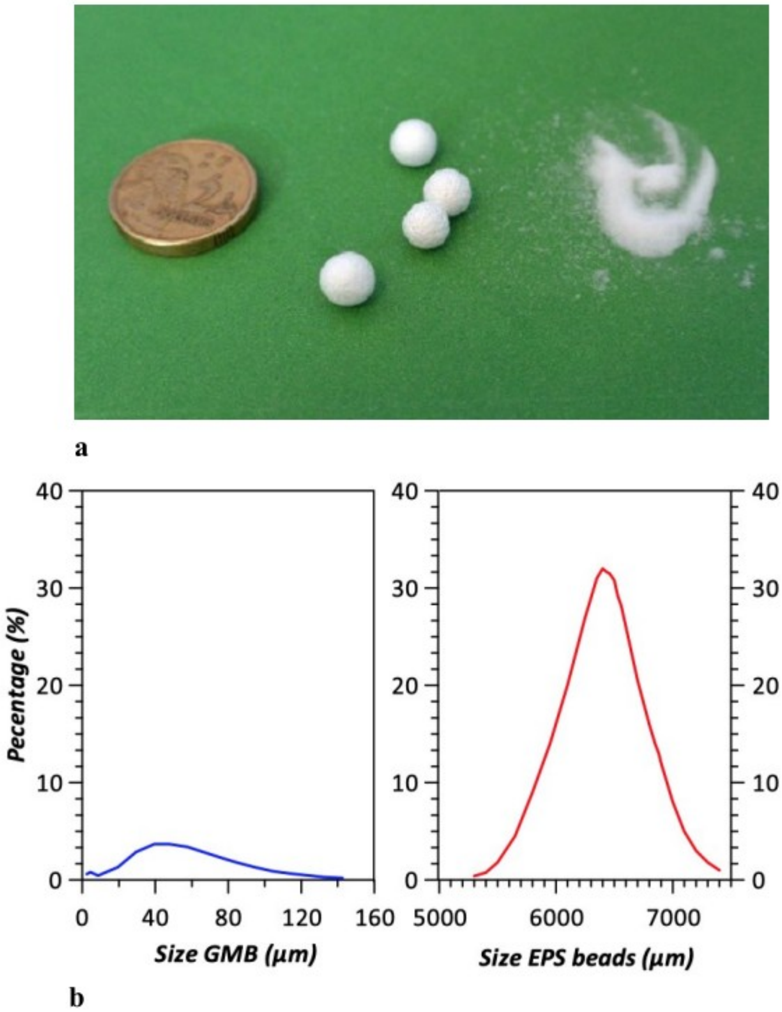
Regarding the void size influence on the VOD, a picture showing the size for both EPS and GMB is displayed in Figure 4. The distribution size is also shown [19].

It can be observed that the size distributions for EPS and GMB differ greatly. The size distribution of gas bubbles is slightly higher than GMB ones, so it will not be included in this comparison.

The drop in the VOD of the EPS sensitised mixtures might depend on both the large size of the voids and the area of the HP/fuel-based mixtures that is exposed to the voids.

The area of the HP/fuel-based mixtures exposed to the GMB voids is around 120-130 times larger than the area exposed when using EPS. This exposed area difference and the high number of hot spots generated when the shock wave passes, may be the cause of the high VOD for GMB sensitised mixtures. To explain the low VOD, in a wide range of densities for the EPS sensitised mixtures, is a more difficult task. The number of hot spots is very low, and so is the surface area exposed to the voids but the HP/fuel-based mixtures still detonate.

Figure 4



Pictures of EPS (middle) and GMB (a). The coin at the left hand side is 20.5 mm in diameter. The plots for the distribution size are also shown (b)

It is postulated that other detonation mechanisms are manifested when EPS(or, in general, large sensitising voids) is used. For example, Field suggested that for large cavities, void collapse is relatively slow and adiabatic heating of the gas is important.

However, if very high shock pressures are involved, then the "hot spot" produced by jet impact could be significant [20]. Mader also suggested this jet impact mechanism for the decomposition of energetic materials [21, 22]. In this case, the shock pressure for the EPS-sensitised HP/fuel based mixtures may be between 1-3 GPa (according to Figure 2), which would fit with Field's and Mader's theory.

It is believed that the time taken for the EPS voids to collapse could be longer than the time for the formed jet to hit the material and start decomposing it by friction or any other mechanism. Thus, jet impact is the predominant factor rather than adiabatic heating in the low density section when using large voids.

Another interesting theory has been given by Menikoff's simulation [23].

When the shock wave passes through the large voids, the jet starts forming, but at the same time, and a lot faster, the shock waves start bouncing back at the other side of the voids. This causes further interaction between the multiple shock waves bouncing which assist with the explosive decomposition. These collisions of bouncing shock waves might not happen when the voids are smaller like GMB or chemical gassing bubbles.

For smaller cavities down to 1-micron diameter, viscous and plastic heating mechanisms dominate [24], however in the current study that small size of void was not used. Finally, the mixtures, especially those sensitised with EPS, are far from the ideal VOD.

3.4 High speed video footage

High speed video footage (90,000 frames per second) was taken from the detonation process of the HP/fuel-based mixtures sensitised with gas bubbles and detonated in 102 mm diameter PVC pipes. Figure 5 displays still pictures taken from the high speed video. Points at densities 0.60 g/mL, 0.78 g/mL, 1.04 g/mL and 1.09 g/mL are shown. The individual frames are at 11 μs, 55 μs, 132 μs and 176 μs (only for density 0.60 g/mL).

The VOD obtained from the still frames match the VOD measured with the VOD instrument. It was observed that for density 0.60 g/mL, the expanding gases show a different color if compared with high densities' gases. This is likely to be related to the temperature generated by the detonation process. From the still images, the length of a "reaction region", for the product at density 0.60 g/mL, can be calculated. Each mark in the pipe is 50 mm apart, hence a rough calculation shows that the length of this "reaction region" is around 30 mm. This appears to be at least 300 times longer than the reaction zone of high explosives such as PBX 9494 or composition B, which shows reaction zones of about 0.01-0.1 mm [25]. From the footage it was also seen that for different densities the expanding gases form a slightly different angle with the side of the pipe; and that the reaction regions appear to be different. Further analysis is being conducted to determine the causes for these differences.

Density of samples [g/mL]			
0.60	**0.78**	**1.04**	**1.09**

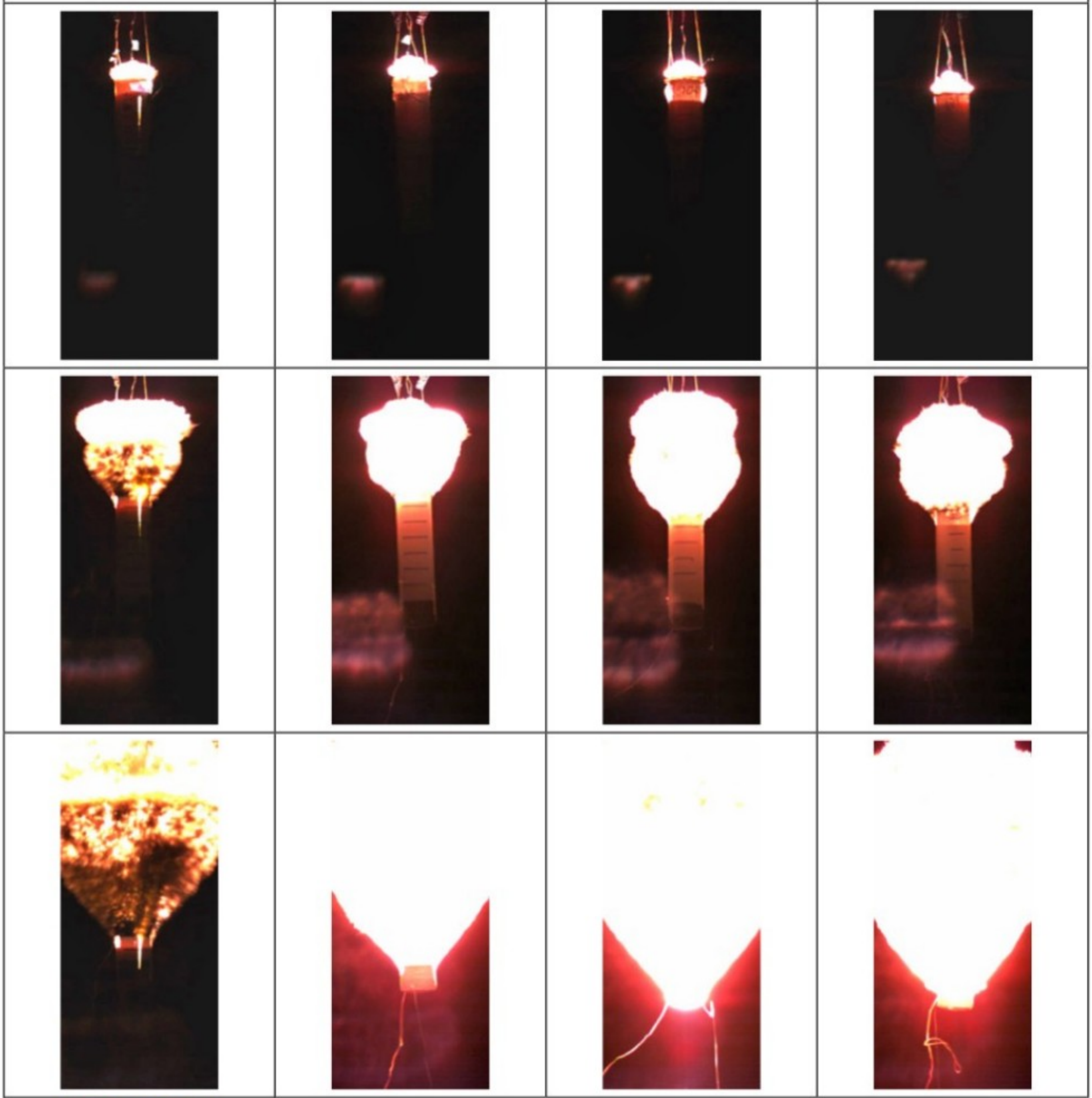


Figure 5. *High speed video of the detonation of gas bubble-sensitised HP/fuel- based mixtures*

3.5 Water content influence on the VOD

Figure 6 displays the VOD results of the HP/fuel-based mixtures when the water content of the formula was increased by using HP 40 wt.% instead of HP 50 wt.%. As expected, the increase of the water content decreases the VOD of the product in the density range of 0.80-1.10 g/mL.

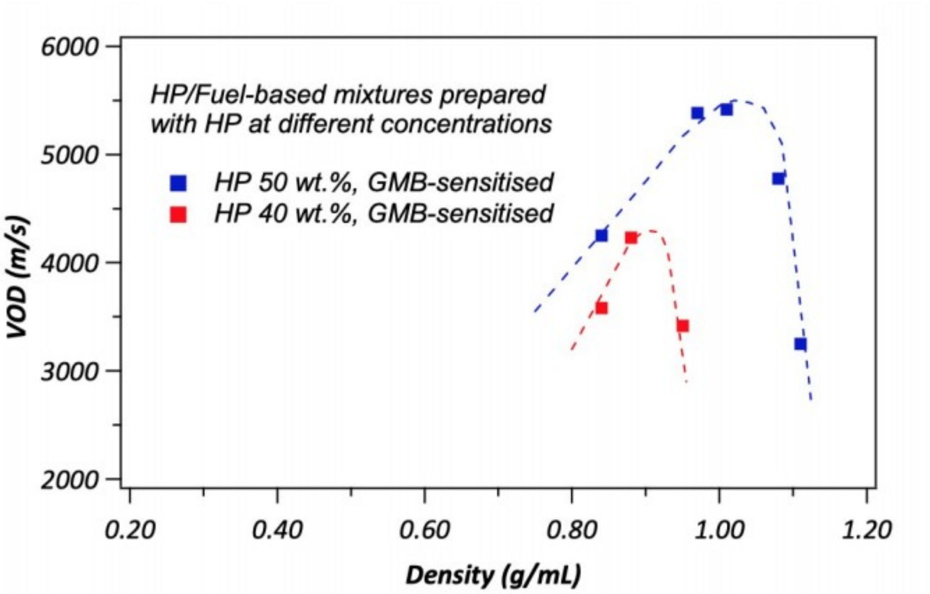


Figure 6. *Relationship density vs VOD at different water contents*

Yancik found that ANFO start failing to detonate when the water content reached 9 wt. % [3]. In the case of emulsions, there is evidence at laboratory scale that they start failing at about 35 wt.% [26] and 33 wt.% [27] water content. The reasons the increase of water renders the HP/fuel-based mixture (or any explosive) insensitive are:

- the heat of reaction released by volume of explosives decreases; and this low amount is unable to sustain the decomposition process, therefore the VOD drops or the mixture becomes more insensitive [28];
- water absorbs heat to become steam during the detonation process but steam does not participate in any reaction and therefore does not release any heat.

It was also found that the HP/fuel-based mixture made with HP 35 wt.% did not detonate in 102 mm, neither at densities of 0.55 g/mL nor at 0.90 g/mL (using gas bubbles and GMB sensitisation respectively). It was surprising to find that the HP/fuel-based mixtures (prepared with HP 40 wt.%) with a total water content of 51.6 wt.% were able to detonate. However, the detonation's density range for product is narrower – between 0.80 g/mL and 1.00 g/ mL.

It is assumed that if the water content keeps increasing, the VOD will tend to decrease and the detonation range will become narrower, until the product detonates at only one density (for a determined diameter) and that density will be characteristic for that composition.

If the results of this study are compared with those obtained for ANFO or for emulsion, it is observed tha HP/Fuel based mixtures are able to detonate with a larger load of water.

3.6 Critical diameter

Conical charges were detonated to determine the critical diameters [29] of the HP mixtures made with HP 50 wt.%. Figure 7 shows the residues of the tests. Note that a full cone is shown at the right hand side of the picture.

No remnants of the conical charge were found for the HP/fuel-based mixture at density 0.68 g/mL. At this stage it is assumed that the product fully detonates and the critical diameter for that density would be below 8 mm. Table 2 displays the critical diameter at which the detonation stopped with the VOD at that diameter (note that more tests are needed to determine the exact VOD).

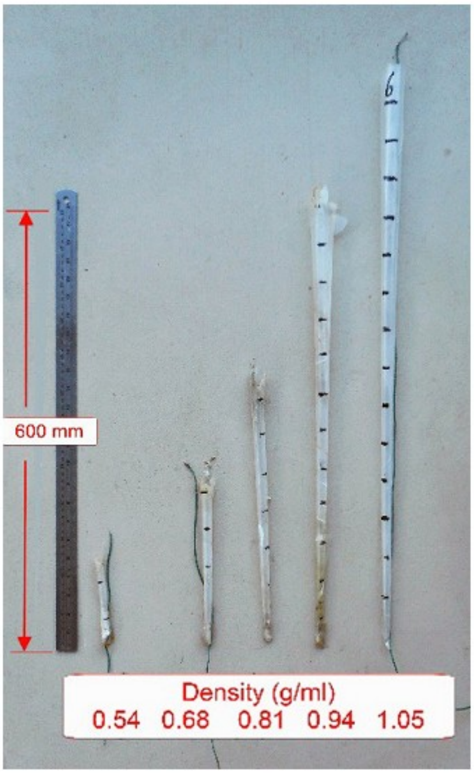


Figure 7. *Remnants of the conical charges*

Density [g/mL]	Critical diameter [mm]	VOD at critical diameter [m/s]
0.54	13±2	1916
0.68	<8	2477
0.81	1±2	2161
0.94	20±2	1777
1.05	>34	1725

Table 2. *Critical diameter of samples and VOD at that diameter*

Results showed that the lower the density, the smaller the diameter at which the product detonates. However, below certain densities, the critical diameter starts increasing. Figure 8 displays the critical diameter and VOD plot for the conical charges.

From these results it is inferred that there is a change in the behaviour of the HP/fuel-based mixtures at low density. According to Price [15] the difference between Group I and Group II explosives is that high explosives (Group I) increase their critical diameter when voids are incorporated (which also brings the density down). Group II explosives on the contrary, the critical diameter decreases when voids are incorporated. However, Price also acknowledges that in some explosives there is a transition zone. In thiscase, at density below 0.60-065 g/mL, the HP/fuel-based mixtures seem to behave like explosive Group I – the critical diameter starts increasing with an increase in the volume of voids. The results from this cone experiment show that sensitivity and high VOD of detonation are not correlated. It seems that the more voids are present in the HP/fuel- based mixtures, the higher the sensitivity of the HP/fuel-based mixtures, but this does not translate into a higher VOD.

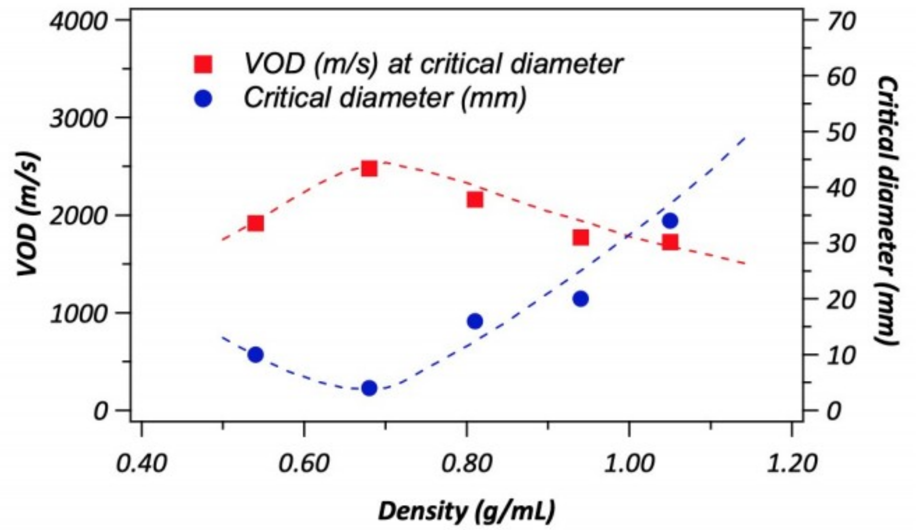


Figure 8. *Plot density vs.VOD at critical diameter and critical diameter of the samples*

4 Conclusions

The detonation properties of new explosive products based on HP/ fuel-based mixtures have been determined. In the past, studies on the detonation of HP/ fuel- based mixtures have been conducted, but in this study, the mixtures were sensitised with voids. But more importantly, the concentrations of the HP solutions to prepare the HP/fuel-based mixtures were lower than in those previous studies.

The detonation properties of new explosive products based on HP/ fuel-based mixtures have been determined. In the past, studies on the detonation of HP/ fuel- based mixtures have been conducted, but in this study, the mixtures were sensitised with voids. But more importantly, the concentrations of the HP solutions to prepare the HP/fuel-based mixtures were lower than in those previous studies.

On the other hand, it is hypothesized that for mixtures with a high percentage of voids (lower densities), the mechanism of initiation is different to the mechanism when the void presence is lower (higher densities). The large amount of voids that is present at lower densities provides most of the heat needed to decompose the energetic material. The energetic material being decomposed also assists in decomposing undetonated material, but to a lesser degree.

The HP/fuel-based mixtures are able to detonate at high water content. Most probably the energy of activation for the pair HP-fuel is lower, meaning that not much thermal energy is spent breaking the bonds. The excess of heat goes to support the detonation process.

It was confirmed that the size of the voids alters the VOD of the mixtures, that is, the larger the size, the lower the VOD.

For this study, it is suggested that the initiation of detonation by hot spots is a combination of a few mechanisms that would depend on the size, construction material and amount of the voids. The mechanisms should coexist in the whole density range of the energetic material and some mechanisms would prevail over others. In addition, the initiation would also depend on the characteristics of the pair oxidiser-fuel and the physical, thermal, and reactive properties of the reacting material at high temperatures.

High speed video footage infers that the temperature reached by the detonation process is different for different densities, and that the observed reaction zone length is much longer than that measured from high explosives.

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A guide to the use of Relevant Good Practice (RGP) for explosive demolition of structures.

Part 2 of 2

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Introduction

Explosive demolition has safety benefits in reducing risks from conventional health and safety hazards by undertaking a single demolition event under controlled conditions. The technique provides a predicted collapse mechanism to induce a progressive collapse where the structure cannot support the applied loadings and fails under gravity.

This is the second part of a two-part paper presenting the author's opinion on what Relevant Good Practice (RGP) for undertaking explosive demolition of structures (including those on nuclear sites) looks like. It identifies those aspects of client and project team activities, preparation and planning, contractual arrangements, technical design and justification, safety management systems (SMS) and supervision that experience has identified as being required to undertake a project safely. **The safety of a project does not just rely on a competent contractor but also requires an engaged and adequately resourced intelligent client with a competent project team.**

Part 1 introduced the concept of Relevant Good Practice (RGP), the UK regulatory environment and the expectations on the client's and project team's safety management systems SMS.

Part 2 identifies how effective implementation of that RGP in the management of the contracting process, the development of proportionate method statements and the operation of those SMS bring together the technical and people-based aspect of a project to ensure that it can be delivered safely.

These papers have been condensed to meet publication requirements.

Disclaimer

The content in this paper represents the opinion of the author, and is a product of professional research. It does not represent the position or opinions of the Office of Nuclear Regulation (ONR).

Tendering and Award of Contract

Having developed their competence as an intelligent customer the client will need to appoint their demolition contractor. Employing a robust pre- qualification, tendering and contracting process will enable an effective exchange of information that should identify an appropriate contractor who can work effectively with the client's project team. It should also minimise so far as is reasonably practical (SFARIP) risks to the project, those working on the project and those elsewhere who could be affected should any of the hazards associated with the project be realised.

Failing to establish an open and robust process can result in uncertainties in management arrangements, commercial certainty and technical requirements, as well as program pressures that may reflect in the tender price or influence human behaviour when undertaking the works. For example a failure to follow adequate tendering procedures might result in a contractor exhibiting "perverse behaviours" such as inappropriate acceleration of the works or taking unnecessary risks in order to deliver contractual expectations that could have been revisited and revised as part of an effective tendering process.

Prequalification processes should be established to identify suitably qualified experienced contractors (SQEP) who have previously safely undertaken explosive demolition work of the same scale, hazard, complexity and technical content.

The prequalification and tendering processes should be organised so that the client's project team, acting as the intelligent customer, is provided with sufficient information to assess:

- The adequacy of the tenderers' SMS including arrangements for:
    - ensuring compliance with the Construction Design and Management Regulations (CDM2015);
    - staff competence including how the tenderer would expect to deliver the competence requirements of BS5607:2017[1] and BS6187:2011[2];
    - their arrangements for Temporary Works in accordance with BS5975:2019[3].
    - ensuring that engineered design solutions are robust and are subject to design review and assurance;
    - supervising the works;
    - subcontracting and assessing the competence of any subcontractors.
- The tenders' financial stability and ability to sufficiently resource the project to safely undertake the works. The tenders' accounts should be subject to a proportionate due diligence process covering a range of areas including cash flow, liquidity, asset and debt levels. This benefits all parties in assuring commercial stability particularly for large projects with long contractual periods that may require guarantees, performance bonds and complex financing. Similarly, this improves the clients' confidence in the eventual total project cost.

Masonry Chimney on power station site

The tendering process should follow recognised industry practices. Appropriate forms of contract for demolition projects should be selected. For example the Institution of Civil Engineers' (ICE) 'New Engineering Contract' (NEC) forms or the National Federation of Demolition Contractors' (NFDC) 'Form of Direct Contract' or the client may choose to use their own standard form. Whichever form of contract is selected, it should reflect the "balance of risk" between the client and contractor. This is particularly relevant for NEC forms of contract where there are six different payment options available and contractual clauses can be modified by the use of "Z" Clauses.

The prequalification and tender documentation should be clear in what constitutes the formal tender suite and what documents are for information only. There should be opportunities for tenderers to assess the structure by site visits and meetings. Any technical queries could potentially be of critical safety importance to both the tender process and the ultimate success of the project. Where they can, technical queries should be clarified and the outcome should be recorded by the project team with provision for managing and controlling any uncertainty or unforeseen element.

Assessment of the tender returns should include detailed consideration of:

- Compliance with the requirements of the tender document, including any specified limits, restrictions and conditions.
- Adequacy and quality of the demolition blowdown design including the substantiation of the tenderers collapse philosophy with the justification of the claims and evidence in their outline engineered design.
- Residual risks arising from the proposal and the adequacy of the tenderer's risk register in identifying, collating and managing that information,
- The safety record of the tenderer including evidence of trends and improvements resulting from incidents, investigations and near misses.
- Training records for relevant personnel and CVs, including any membership of relevant professional bodies (e.g. Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE), Institute of Explosives Engineers (IExpE) and Institute of Demolition Engineers (IDE),) possession of relevant vocational qualifications as well as evidence of Continued Professional Development (CPD) through, for example, attendance at relevant training courses.
- Clarification should be sought from the tenderer of the basis of any assumptions made or any omissions of facts, hazards or risks that have been identified by the project team as part of the project planning and tendering process.

- Any alternative methodology or technology to that envisaged by the project team. Alternative techniques should not be precluded and may offer benefits and opportunities from advances in technology, methodology and safety. However, they should be subject to rigorous engineering assessment based on the evidence of the technical aspects, safety claims, arguments and evidence when compared against current Relevant Good Practice (RGP). This assessment should confirm that the alternative technique can be carried out safely without increased risk and that the potential for unintended consequences or different hazards has been considered. The project team may choose to retain a competent third-party consultant to provide an independent assessment of any alternative methodologies.
- Whether a robust engineering justification of safety has been provided for all proposed techniques before proceeding to other issues such as quality, programme and cost.

The client should seek clarification on any gaps in the information supplied by the tenderers before coming to a final judgement on which tenderer to appoint as the contractor. The client should also independently obtain references from tenderers previous clients to substantiate their claims and evidence.

The outcomes of the tendering process should include

- clarity on who owns and is responsible for the risks identified in and from the tender submission; and
- demonstrable assurance that the works can be undertaken safely.

In making their appointment decision, the client should have confidence that the preferred tenderer can produce an engineered design that is robust, technically underpinned, conservative, fault tolerant and safe to undertake. The project team should have sufficient competence to be confident that the chosen design is robust to engineering scrutiny and challenge by both the project team and external third parties. Commercial considerations should not disproportionately influence the final decision.

The client should document the evidence they have used to inform their decision-making process to provide an audit trail for record purposes and future review.

CDM2015 : Construction Phase Plan (CPP) and Method Statements

Depending on the contractual arrangements, the Principal Contractor may be the explosive demolition contractor. Whatever the arrangements, the expectations of the "contractor" would be as below.

The principal contractor should comply with the requirements of CDM2015 by producing the Construction Phase Plan (CPP) and this should be supported by detailed method statements. On nuclear licensed sites the CPP would be included in the licensee's safety case.

The aim of the CPP is to demonstrate that the activity will be the safely managed, that good engineering practice will be followed, that appropriate safety principles have been applied, that the project, so far as is reasonably practicable, is safe to undertake and that residual risks are as low as is reasonably practicable. The CPP and associated method statements should be understandable to those who will undertake the demolition blowdown works and those with direct responsibility for safety. The CPP should be developed in parallel with the Building Information Modeling (BIM) [4]model or an equivalent Virtual Reality (VR) process appropriate for the project scale.

The Principal Contractor's CPP and method statement should cover a range of topics appropriate to the project and should be based on or take account of relevant guidance relevant such as BS5607:2017, BS6187:2011 and BS5975:2019 as well as UK or other national regulator produced guidance and industry and professional bodies' publications.

The CPP and method statements would generally be expected to include:

- A **general description** of the site and scope of works to be undertaken, including any limits or conditions on the site as well as a description of offsite features that may be affected by the demolition blowdown works. These should input into a detailed risk assessment for all activities on the site including any effects that may affect areas outside the exclusion zone boundary and that could affect public safety or the environment.
- verified **clearance certificates** or the equivalent from the client or licensee, that demonstrates that hazardous materials such as asbestos, ionising radiation, polychlorinated biphenyls (PCBs) and other chemical or biological contamination has been removed so far as is reasonably practical. This clearance process should reflect an awareness of the potential for concealed contamination or trapped liquids, solids or gases in valves, pipework and features that are difficult to decontaminate or investigate.

BACK TO TOP

- The **collapse philosophy** for the explosive demolition which should be clearly defined and articulated. This may be illustrated within the BIM model or VR equivalent or on a series of drawings, illustrating the collapse mechanism at different time delay intervals. This will also inform the design of the protection works including the use of shielding bunds and the size of the exclusion zone.

- The contractor's structural engineer should provide the project team with the **temporary works design** required for any **pre- weakening**. This should include structural calculations and detailed drawings showing the type, details, location and setting out of all the pre-weakening works and the direction of fall of the structure. This design should justify the collapse philosophy and should reflect an understanding and working knowledge of the different types of structure, their layout, provision of load paths, joints and connections, tying and bracing, material characteristics, degradation mechanisms and historical properties in both the permanent and temporary load cases. There should be a statement of how the design is to be implemented that follows the guidance in BS5975:2019.

- The design may require structural alterations to existing structural members, for example, where part of a flange has to be removed, where kicking plates are required or where members need local reinforcing. The structural engineer's design should justify the adequacy of these structural alterations and assess any subsequent consequences on the collapse philosophy. The structural engineer should also confirm that the pre-weakening design has been through a demonstrable robust process of **challenge and peer review** and that the structure will remain stable pending blowdown. This process should be appropriate to the project size and complexity and should follow relevant guidance such as BS 5975:2019 and Part 3.4 Vol 1 of the Design Manual for Roads and Bridges.[5] It is recognised that these are usually undertaken as "CAT 3" independent checks. Some structures, particularly those on nuclear licensed sites, are robust and highly resistant to progressive collapse due to the provision of substantial foundations, heavily reinforced robust RC concrete sections, moment resisting steel frames and other construction forms.

- The requirements for **3rd party review in Europe** will be specific to individual countries and the project team should identify those details and implications at the earliest practical stage in the planning process. For example, in Germany, the 3rd party peer review process follows the principles undertaken for a new or refurbished structure. A chartered design review engineer, usually working on behalf of the local building control authority will check the structural analysis, the working drawings and the chosen method. The client and project team will have to allow for this process as they develop their overall programme and project costings.

- Nevertheless, the structural engineer should be able to demonstrate an **understanding of risks arising out of**:
  - Missing, inadequate, uncertain, unrecorded or out of date structural information, together with the risks from unauthorised changes or modifications carried out during the structure’s construction and life cycle.
  - degradation from recognised corrosionmechanisms that may affect the properties and behaviour of structural members. the ways that certain

- the ways that certain structures were constructed e.g. thin- shelled cooling towers, water towers, bridges and arches. Some forms of construction will have required temporary works and elements of those works could remain as part of the built structure. Those details may not have been recorded as part of the permanent work record.
- uncontrolled transfers of loads into parts of the structure that do not comply with the original design philosophy and calculations. This can cause redistribution of loads giving overstressing, rotations or collapse of structural members leading to structures falling or rotating in the wrong direction, partially failing or collapsing onto their foundations in “a sit down”. Similarly, structural framing containing splices, joints, connections, stiffeners, tying members or compound sections that may unexpectedly either attract loading, become overstressed or fail when they become part of the temporary load paths should be identified and considered because they can adversely affect the collapse mechanism.

- Having incomplete cutting in separating service pipes, cables or ducts that are fixed or supported on connecting structural elements. A single uncut armoured electric cable between two elements can provide enough restraint over a few milliseconds, to adversely influence the predicted collapse mechanism.
- failure of retained or pre-weakened sections of the structure that contribute to the development of the collapse mechanism. For example, assumptions made on the presence and extent of continuity of lapped reinforcement in reinforced concrete sections should be supported by robust evidence.
- the contractor's need to alter the existing structure to enable installation of explosive charges. The removal of member sections and cutting holes in webs or flanges to allow access needs to be recognised by the structural engineer and any requirement for strengthening should be included in the design.
- a failure to implement rigorous monitoring and supervision of any pre-weakening activities.

the differences in the Codes of Practice and Standards used in the original design and construction, together with the recognised shortfalls or conservatism in the methods of structural analysis be that empirical or software based. There can be significant risks if modern design codes are used to model or analyse older structures where it would be more applicable to use the original design code and undertake a gap analysis against modern codes. A list of commonly used codes of practice, standards and guidance applicable to the demolition industry is available in the parent technical paper.

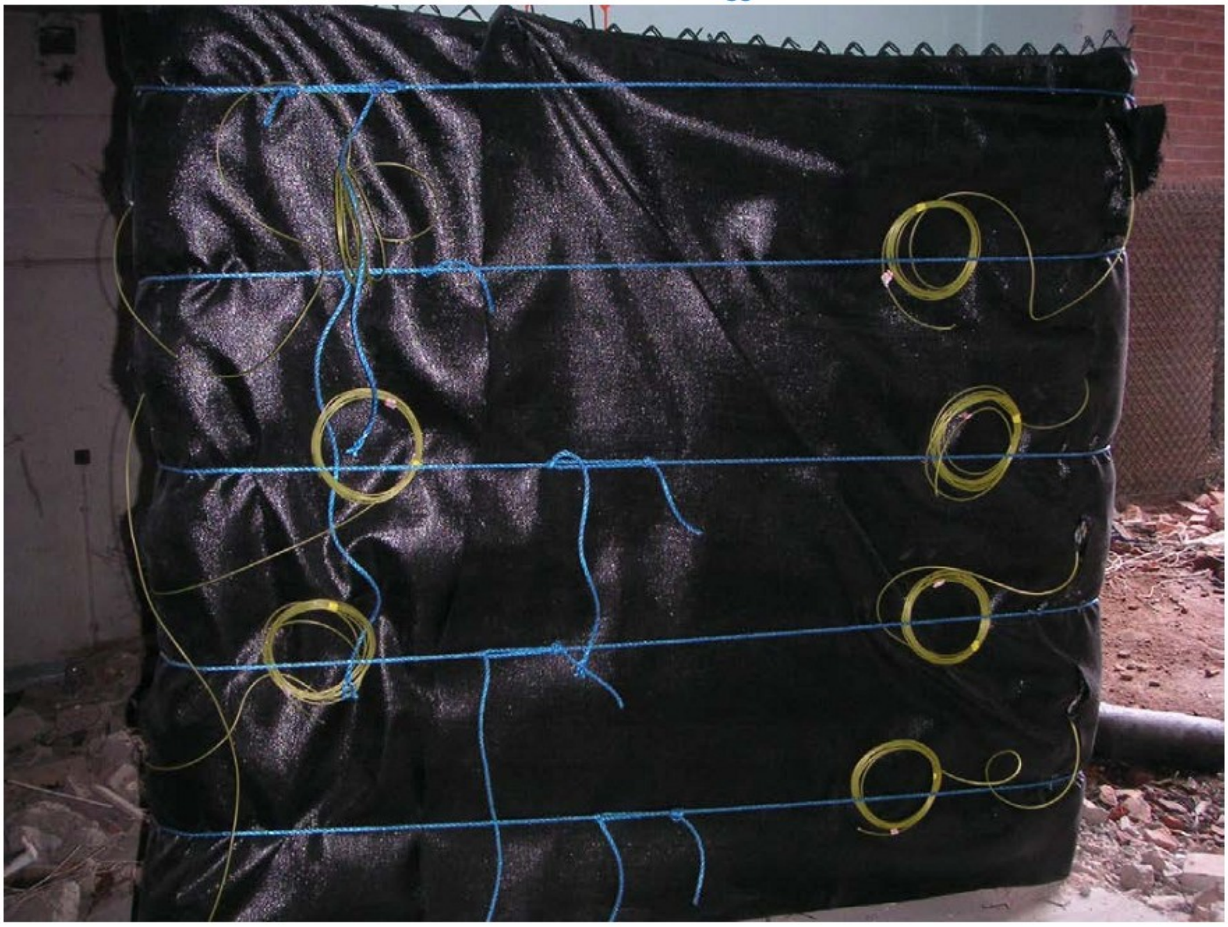
- The structural engineer should also be able to demonstrate that structures have been **investigated** to identify the means of construction and any consequential risks those means might present. The investigation process should consider what features and materials could be present in the structure that are not immediately obvious. Risks can arise from the presence of non-structural elements or features that would not be immediately recognised as having an influence on the structural behaviour during a blow down. For example mechanical plant and services or ventilation ducts and shutes, cable trays and cables etc.
- The structural engineer should also identify and record the arrangements for **cooperating** with the project's personnel. Depending on the contractual arrangements, these could cover a range of BS5975:2019 roles including a Temporary Works Designer (TWD), Coordinator (TWC), Principal Designer (PD) and the Designated Individual (DI).

- There should be clear and **demonstrable links** to the work undertaken by the contractor's structural engineer in the demolition design and the contractor should provide and confirm details of how the structural engineers' design has been checked. In some cases, depending on project scale or complexity, this may be by retaining a competent independent third-party organisation. Alternatively, the client may choose to appoint that **independent third party consultant** for their own assurance. On a nuclear licensed site this would be in the form of an Independent Structural Assessment (ISA) together with an Independent Nuclear Safety Assessment (INSA) of the overall project. The check and any resultant changes should be recorded along with a discussion of how those changes have been assessed, approved and taken account of in the final design.
- The design should describe how the contractor intends to **undertake the pre- weakening works** on the structure. The details should be clearly stated on approved drawings showing the latest revisions. These drawings should be subject to robust **change management** procedures and should be regularly updated to record the date and scope of the completed work.
- All structural cut points or openings should be clearly marked prior to cutting or breaking out. When cuts or openings are made, they should be inspected to confirm that they are in accordance with the method statement and clearly identified as agreed along with the details of who was responsible for making it. It is good practice to **record pre weakening works** such as the cut positions or openings before and after they have been made.
- This can be done using physical markings and records, digitally dated photographs or other suitable techniques. This visual evidence supports details recorded on drawings, sketches and schedules and allows ongoing assessments to be made of the stability of a pre- weakened structure. The client and contractor should agree the proposed technique to be used for recording this detail. Depending on the project scale and complexity, consideration should be given to recording and visualising the information within a BIM model or equivalent depending on the project scale.
- The contractor's explosive demolition design should describe the:
    - chosen demolition technique; approach to any pre-weakening not detailed above
    - the specification and quantity of all the explosives to be used;
    - drilling patterns to be used for charge placement in concrete or masonry or
    - the location, orientation, and fixing methods of different types of charges for example cutting and kicking charges on steelwork,
    - approach to securing explosives in place e.g. stemming of holes
    - type of initiation system for example nonelectric, electric or electronic time delay sequence and backup systems;
    - protection of the initiation system from damage due to shrapnel fly
    - provision and design of primary and secondary protection
    - provision of any visual indicators to confirm that specific sections of the works have been successfully initiated,

- arrangements for the delivery and return of explosives to an offsite store or storage of explosives on site,
- arrangements for security on site and accountability of explosives "in use" or being prepared on site,

- If the design requires cutting charges to be used then full details of the requirements for their specification, placement and initiation should be included. The explosive contractor's design should demonstrate a clear understanding of issues around their use, such as the potential for liner or secondary fragment fly, and describe how the initiation system and timing requirements between cutting and kicking charges will be managed.
- The design should explicitly consider the **protection** requirements against the effects of debris fly, fragments, vermin attack or any other circumstances that may result in a misfire or a hangfire and where such a risk exists it should detail the preventative and mitigatory measures that will be employed. The design should also describe how:
    - any flying debris will be retained to ensure safety; and what protection methods will be used to provide effective containment around the structural members to minimise both the transmission of fly and protect the initiation system.
- Recognised methods used for primary and secondary protection include chain link fencing and geotextile, geotextile screens, rubber matting or belting, sandbags, steel plates and water drums or similar.
- The design should include estimates of the levels of **vibration and air overpressure** that may affect neighbouring structures. These can be verified by the retention of competent independent consultants. Estimates can be calibrated from results obtained during test blasts to produce regression lines and be considered iteratively as the design progresses during the works.
- The method statement should provide details of reducing and controlling air overpressure, ground vibration and **dust** that cannot be eliminated in the engineered design. They should address the potential adverse effects on people, infrastructure, plant and equipment sensitive to damage or degradation due to dust ingestion or vibration. Examples are dust filters to hospital ventilation systems, vulnerable or sensitive buildings or infrastructure, dust settling on roads, drainage systems and surface water courses. Similarly, details should be provided for proposed control measures such as protection, water suppression from hoses, Intermediate Bulk Containment (IBC's) or other appropriate methods, and the clean-up of surrounding areas after the demolition. The design of the exclusion zone should allow for these environmental effects.
- **Environmental monitoring** usually involves subcontracting to a competent specialist environmental testing contractor and the use of remote or automated monitoring stations. Any hazards and risks arising from how the environmental monitoring equipment operates should be considered and incorporated into the relevant risk assessments and method statements. Remote monitoring for asbestos or other dusts provides public confidence that any previous decontamination works have been adequately undertaken.

- **Test blast** results should confirm deterministically if the proposed explosive design will generate a structural collapse. The contractor should detail any proposals for undertaking test blasts in their demolition design. These proposals should include including drawings and photographs, confirm the suitability of the proposed explosives and the reasons for this as well as the predicted failure mechanism of the structural element and the adequacy of the protection design. Reports should be produced following test blasts and provided to the project team. These reports should consider whether the test blast achieved its intentions and how the demolition design will be modified to take account of the results of the test blast. The report should also include results from environmental monitoring of vibration, air overpressure and witness materials, to give an indication of the expectations for the main blowdown. Any changes to the demolition design should be subjected to a formal change control process before demolition designs and associated method statements are modified. Where test blasts are precluded on the structure to be demolished or similar structures, alternative options such as using a mock-up or similarly constructed and loaded structural element should be considered. However, such test blast results generally require a cautious approach to decision making to be followed when assessing how the results of tests might influence the demolition design for the main structure.
- The extent, establishment and control of the **exclusion zone** are key elements of the demolition design and the associated method statements. The contractor should provide details of how the exclusion zone has been determined as well as how it would be expected to be established and controlled as part of the demolition design. The determination should consider the type of structure and the collapse mechanism, charge weights and placement, primary and secondary blast protection, and environmental considerations. This is important if public attendance is anticipated because dust and fly can travel over distances and present significant risks. Effective design of the exclusion zone should take account of the available space and any natural features such as roads, rivers or residential areas which act as boundaries. Guidance can be found in the HSE guidance document Construction Information Sheet No. 45[6], BS6187:2011, BS5607:2017 and NFDC publication exclusion zones DRG 110:2014 7.
- The design of the exclusion zone should also consider the residual risks to sensitive infrastructure, buildings, other structures or facilities and populations (including spectators) outside the exclusion zone. Similarly, arrangements for adapting to changing **weather conditions** such as thunderstorms, high winds or changes in cloud level and density.
- Arrangements and identification of who is responsible for the **post blowdown clean up**



Column protection wrapping

Cooling tower test blast location

The project team should assess the contractor's demolition design and associated method statement to ensure it provides a clear, coherent, conservative, fault tolerant design and safe method of work. The project team should take into consideration the results of the independent 3rd party organisation (or ISA / INSA review on a nuclear licensed site). The client should then make the decision as to whether to permit the start of the works.

Safety management system (SMS)

The contractor should provide the project team with details of the arrangements and procedures that will be in place for undertaking the management, supervision, auditing and record keeping for the works. This would be expected to include holding daily toolbox talks to specify the works to be undertaken that day, arrangements for monitoring, supervising and inspecting those works as they proceed and identifying and recording responsibilities for signing the works off as complete and in accordance with the method statement.

The arrangements should include a written and photographic record of the finished works, suitably identified, labelled and referenced. These records can provide an audit trail to provide assurance that the works have been carried out as per the method statement with no unauthorised deviation or changes. This process of record-keeping should be undertaken for the structural pre- weakening, initiation and backup system and protections works.

This process of recording should be audited at an appropriate frequency to suit the scale, complexity, risks and consequences of failure for the works. These audits should be undertaken not only by the contractor but also the project team, the client, and if appropriate, independently by a separate body within the client's or Licensee's organisation or an independent 3rd party acting on behalf of the client or Licensee. HSE's guidance document HSG159 Managing contractors:

A guide for employers [8] provides a useful framework for managing the work of contractors in a high hazard environment and can be used to supplement the arrangements expected by CDM2015. Similarly ONR guidance document TAG 76 Construction Assurance NS TAST GD 076 (Rev 4)[9] provides additional guidance for nuclear licensed sites.

Collecting, maintaining and reviewing a record of the finished works also allows the contractor and the project team to identify any changes to the structure that might have occurred as a consequence of the temporary works, any pre-weakening activity or unauthorised changes. The contractor's safety management system should identify how the risks associated with any changes to the structure will be assessed and what techniques they would expect to employ to inspect any suspected changes in detail.

Key elements of the project's safety management system will also include the approaches to be taken to:

- emergency planning
- change control processes
- supervision
- liaison with stakeholders and the public

The contractor should detail proposals for dealing with foreseeable emergencies that may arise on site during the works. Proposals should include a communications plan for liaison with the client and the project team as well as all the emergency services. The client and project team should have arrangements for communicating with external stakeholders where that would not be part of the contractor's role and responsibility. The plan should be clear in the roles and responsibilities of all parties and include the actions required under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) [10].

There should be a process to assess and control any proposed changes to the demolition design and agreed method statements that may arise. The changes should be categorised according to their safety significance and given the appropriate level of engineering assessment and scrutiny, which may include additional independent third-party checks. The decision as to whether to accept the proposed changes should be made at the appropriate level of competence, responsibility and authority within the project team. The evidence and justification of the change should be fully detailed and provide an auditable trail of the review and decision- making process.

The project team should have arrangements for the adequate supervision of the contractor's work. Supervision should include physical site inspections, review and planning meetings, safety audits and program meetings. Site inspections and meetings should be attended by the contractor, the project team and the client and have agreed minutes to record results and any matters arising that need to be actioned. There should be a clear procedure for showing how any issues have been resolved, including what decision- making process is to be followed. This approach provides an audit trail of how and when information and decisions have been shared with other appropriate contract parties.

The client may choose to have a permanent presence on site and this is accepted practice on UK nuclear licensed sites.

Arrangements for supervision should identify roles and responsibilities in the client, project team and contractors and describe the chain of command, the methods of communication, and mechanisms for liaison with third parties. The extent of the arrangements should reflect the complexity of the project and the extent of the hazards and risks it involves.

Security of explosives

The contractor may choose to store explosives on site or more usually have them delivered on a daily basis as charging requires. The requirements for the secure and safe storage of explosives, including the permissions required and the prevention of access by "Prohibited Persons" are provided in the Explosives Regulations 2014 (ER 2014) with additional guidance available in the HSE publications L151[11], and L150 [12]and relevant subsector guidance[13]. On a nuclear licenced site such arrangements will require the involvement of the Civil Nuclear Constabulary (CNC) and the Office of Nuclear Regulation (ONR). Away from nuclear licensed sites regular contact with the relevant police force's explosives liaison officers will be key to ensuring the arrangements for security are proportionate and effective.

The explosives must be subject to appropriate security arrangements after being charged into the structure and security provisions should continue if the demolition is either delayed or only partly successful and unexploded charges are left in the structure or debris. Arrangements for appropriate stock control and for checking the quantity and locations of explosives charged into the structure should be robust and monitored on a daily basis.

Blowdown Day

The contractor and the project team should have well established and rehearsed arrangements in place for managing the day of the blowdown well before the event. These should include the arrangements in place for establishing and maintaining the exclusion zone, timings and cooperation with the project team on site as well as external stakeholders such as local and highway authorities, the emergency services, the public and any other stakeholders appropriate to the project circumstances. There is an expectation that these arrangements will have included adequate levels of public information and consultation. A checklist of required actions and go/no-go criteria can be beneficial in ensuring that no issue or procedure has been overlooked prior to blowdown. Relevant parts of this checklist should be shared with the appropriate project members and third parties on the day. For example, the sentries providing the exclusion zone will require details of the blowdown timings, contact numbers and a guide on what actions to take in the event of any contingency being invoked.

Contingencies and associated actions should be considered and developed as soon as the blast design has been finalised. The contractor should detail proposals for dealing with any contingencies. For example, what needs to be done in cases of full or partial stand-up, misfires, hangfires, unauthorised intrusions into the exclusion zone, 3rd party stoppages of the work and any other external occurrences that could impact on the blowdown. Provision should be made for example for maintaining the exclusion zone for extended periods and the availability of onsite and offsite plant required to address the identified contingencies should be prearranged. Confirmation that these arrangements are in place should be included in the relevant checklists.

The contractor's shotfirer has to be confident that all the safety management arrangements, particularly establishing and securing the exclusion zone, are adequate and have been confirmed as such on the day of the blowdown. Only at that stage should the shotfirer decide whether it is safe to proceed and whether or not to fire the shot.

The safety management arrangements should identify full details and timings of the sequence of events before and after the blowdown and when the exclusion zone can be removed. The explosive demolition contractor's shotfirer should be the person making the decision to call "all clear". This should follow a physical inspection of the collapsed structure to ensure that full detonation has occurred, that there are no stand-ups or structural sections left in an unstable condition and that no explosives and detonators are knowingly unfired.

The contractor and any employees clearing and processing the demolition waste should be provided with explosive awareness training and should have procedures in place to follow if unfired explosives or detonators are identified during the clearance operation.

CONCLUSIONS

Explosive blowdown of structures is an appropriate technique if it is carried out safely. The demolition design should provide a justifiable and engineered solution that meets expectations of Relevant Good Practice (RGP). Those expectations are reflected in the assessment of a safe, robust and fault tolerant design and the implementation of a safety management system that ensures the method statement is implemented correctly. They should draw on the application of the UK codes, standards, industry guidance and where appropriate nuclear ONR Safety Assessment Principles (SAPS) and Technical Assessment guides (TAGS).

Explosive blowdown requires competent people within the client or licensee's management team, the project team and contractors if an adequate engineered design and a safe system of work that reduces the risks so far as is reasonably practicable are to be developed and implemented.

The client or licensee should demonstrate an intelligent customer capability, ensuring that they have employed competent people, processes and procedures with a robust challenge function and change control process to deliver a safe blow down. The client or licensee should also be a learning organisation that seeks to obtain information and experience from others who have undertaken similar works.

There should be detailed planning and the provision of all reasonably obtainable information to both the project team and tenderers if they are to adequately develop the engineered demolition design and identify risk reduction opportunities. There should be in compliance with the requirements of CDM 2015.

The client should select a suitably qualified and experienced contractor that is financially stable and has sufficient resources to undertake the works safely. There should be a contractual process that appropriately apportions the risk balance between client and contractor together with a suitable payment process.

A competent explosives contractor should develop a justifiable engineered design including any temporary works, which is robust against scrutiny, challenge and review. Similarly, a robust system of site supervision should be implemented to make sure the works are undertaken in accordance the contractor's agreed method statement.

An adequate safety management system is required to introduce proportionate controls to the safe undertaking and supervision of the works.

A change management system should be implemented to assess any change from or modification of the agree method statement and records of the decision-making process in approving any such change should be made and kept.

Thorough, well planned and practiced command and control arrangements should be exercised in preparation for the blow down. These arrangements should include provision for contingencies, emergencies and incident mitigation.

Acknowledgement

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The Use of Explosives for Reflection Seismic Survey Applications in the Netherlands and Europe by Rossingh Drilling /Geophysics and Rossingh Explosives

Rossingh Drilling / Geophysics and Rossingh Explosives are a Dutch family business based in Gasselte in the Netherlands, founded in 1999 by Owner Jan Rossingh.

The company covers a large span of drilling expertise from drilling water wells and installation of ground source heat arrays to speciality drilling for seismic survey operations for the oil and gas and geothermal energy sectors.

Seismic drilling incorporates the distribution and use of specifically designed seismic explosives and zero delay detonators as the energy source for the recording of seismic data to enable deep underground regional geological studies to be undertaken throughout the world. The company has operated in many European Countries including France, United Kingdom, Germany and the Netherlands and are currently around halfway through a major 2D Seismic Survey covering much of Central and South Netherlands on behalf of EBN B.V. a state-owned company that contributes to the Dutch climate and energy policy on behalf of the Ministry of Economic Affairs and Climate Policy.

Over 1,000 kilometres of seismic data recording had been completed on the project by the end of 2020. (see www.scanaardwarmte.nl)

Reflection Seismology is a method of exploration geophysics that uses recorded reflected seismic waves to produce an underground mapping of the earth's subsurface structures. This mapping is then used to highlight potential subsurface features that could hold oil and gas deposits or have potential properties for Geothermal Energy production. A land seismic survey is conducted by deploying an array of energy sources and an array of sensors/receivers on the surface.

Figure 1 Sonic Drilling Rig mounted on standard agricultural tractor unit for Seismic Operations. Location Schiphol Airport, between airstrips.

The source of seismic waves is either an explosive or a mechanical source such as a seismic vibrator. In the Netherlands the use of hi-velocity (6000m/s approx.) specialized seismic explosives has been proven to provide excellent data quality and is often used in conjunction with the vibrator source when seismic traverses pass through urban areas where the use of explosives can be too challenging. Through careful planning and line positioning it is usually possible to avoid the use of vibroseis methods entirely even in dense urban areas.

The seismic waves are generated by explosive charges that are set beneath the surface in a consolidated layer of the ground. The point of generation is the bottom of a drilled hole – typically around 10 to 25 metres deep where the charge is placed and tamped to ensure downward energy transmission and fired at a known location at a known time.

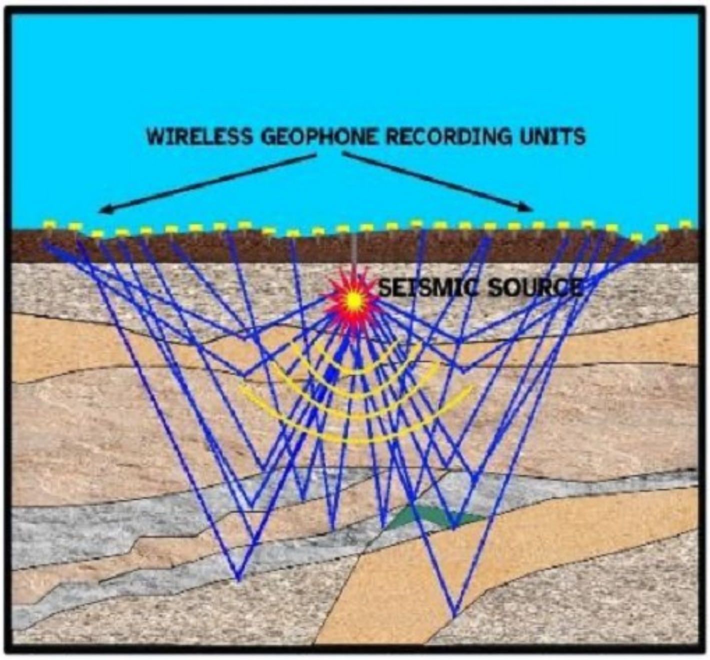

Figure 2 Seismic Wave Reflection Diagram

The seismic waves that travel from this source point are reflected from the various subsurface strata levels and are received by geophone sensors planted on the surface at regular incremental distances on either side of the source point. The distance of the receiver array to each side of the source point is approximately the same as the distance to the subsurface target depth. The reflected seismic traces are recorded as a function of time delay from the source initiation. Positions of both source and receiver points are provided through DGPS surveying and the timing of source initiation relative to the receiver spread is provided through GPS link in the source initiation blaster. The line of receivers and source points is moved along the planned seismic profile route and in 2D seismic there are generally a number of crossing/ intersecting lines which serve as confirmation of accuracy of recording at the points of intersection. High quality seismic is provided on the current operations in the Netherlands through the use of a very dense receiver spacing interval using state of the art wireless data recording receiver units and a high receiver channel count which provides the optimum amount of data while still enabling a cost- effective daily progress along the seismic routes.

For the drilling part of the seismic operations, the team deploys between five and ten tractor mounted "Sonic" hammer type drill rigs with the capability of drilling source energy holes to depths in excess of twenty-five metres but generally drilling to depths of around ten to twelve metres in daily production operations.

The company also provides, when required, very low impact smaller drilling units for areas of difficult ground conditions or restricted access. These reduced impact top- drive drilling units are mounted on a small crawler track based chassis and are able to provide source holes to a depth of around ten to twelve meters where the tractor drills are unable to travel.

Both Sonic and TD Drills have the capability of drilling using an auger system where ground conditions are suitable as well as sonic hammer and roto-flush options.

Figure 3 TD Track Mounted Drill for entry into confined areas

The storage, transport and deployment of explosives are all controlled by the company group under the licensing authority of the SodM (State Mining Authority) in the Netherlands. In other EU countries the company is under the control of the various explosives control authorities that accept the Dutch and German explosives handling licenses of the key explosives technicians. Drillers, Explosives Transport (ADR) Drivers, Shot Firers and Supervisors are all licensed through a German and Dutch licensing body.

Under current governing legislation there is a strict software-based track and trace system in use for each item of explosives material. This covers every aspect from the delivery from supplier to storage to the distribution from storage to individual explosives technicians in the field. There is an additional database logging of loading and firing details to ensure that all loaded explosives are detonated within a stipulated time allowance. Daily usage and storage balances are maintained and logged for inspection by the governing authorities and for internal auditing compliance.

Charge size and number of detonators per charge can vary depending on the ground conditions but in typical operations on agricultural land a charge size would be around 250-1500 grammes of plastic cased seismic explosive which incorporates a recessed pocket for the installation of the zero- delay seismic detonator. An anti-pullout device, specifically designed for the charge, is used to retain the detonator in the pocket and to ensure that the charge cannot be tampered with or extracted from the hole by a third party.

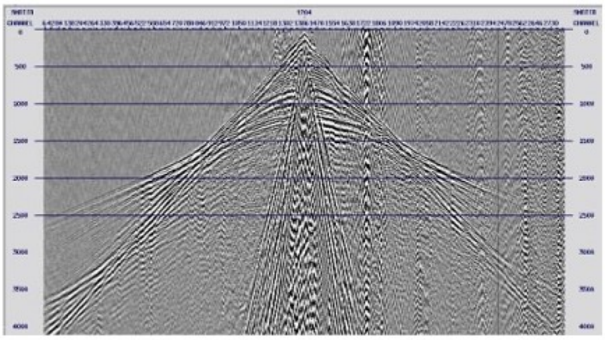

Figure 5 data recording single shot

Each charge is tamped to the surface with cardboard cased tubes of pelleted bentonite (swell clay) this has a two- fold purpose, to tamp the charge and to seal off the hole to ensure minimal transfer of ground water between different aquifer levels. Charge size is determined through the recording of peak particle velocity tests to ensure that regulatory limits in the vicinity of buildings, structures and properties are not exceeded. This ensures the ideal balance between reduced disturbance to the general public while maximizing the energy source required to produce clean and usable data for the client.

In 2016 the company expanded to include Rossingh Geophysics a Seismic Data Acquisition Company capable of deploying around 5000 channels of state-of-the-art wireless data recording units. This provides a fully encompassing seismic service to the client including permitting, surveying, drilling, recording and data qc and product delivery to the client processing department or processing contractor. This integration of an all- inclusive service has proven to be extremely adaptable and capable, through the fully flexible trained workforce, of recording accurate, efficient and cost-effective data for our clients in a safe and controlled manner.

Figure 4 wireless data recording units

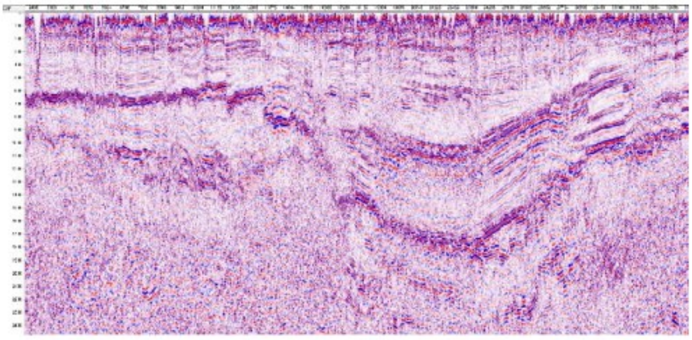

Figure 6 data recording multiple shots

EFEE

EFEE Photo Competition

We are delighted to present the first EFEE industry photography competition. This is your chance to have your work in the field recognised with the bonus of the possibility of winning a free place at our next World Conference in Maastricht from 15th – 17th May 2022.

The deadline for entries is **Tuesday, 31st August 2021** so there is plenty of time to take and select the perfect image for your entry.

A winner in each category will be selected by EFEE. The overall winner will receive the free place the World Conference in Maastricht with the runner up receiving a free place at the Maastricht Gala Dinner. Entries will be confirmed in September with winners being announced in October.

We hope as many of you as possible will submit photographs for this exciting competition following the guidance below. Entries don't necessarily need to be professionally taken; a smartphone picture is acceptable as long as they are relevant to the category.

If you have any queries regarding the process please contact marketing@efee.eu

Categories
You are invited to submit photographs that fit within the categories shown below:

Mining
Quarrying
Construction
Pyro techniques
Demolition
Manufacturing
Energy

Format
Files should be provided in .jpg or .png format, 300 dpi, where possible and no larger 5MB.

Entry
Entries should be submitted using the link below where you will be asked to provide photographers name, photograph title and a brief description of the project.

EFEE will review submissions for relevance and we will be in touch to confirm if your entry is successful in September.

Voting
Successful entries will be posted on our website and judged and scored by EFEE.

Prize
A winner will be judged for each category who will be published in the EFEE newsletter and website. One lucky overall winner will receive free entry to the EFEE 11th World Conference due to be held in Maastricht, The Netherlands valued at circa €650 and one runner up will receive free entry to the Maastricht Gala dinner, valued at circa €100.

Terms and Conditions
Photographers retain ownership and use rights but accept permission for the European Federation of Explosives Engineers full rights to publish, modify and use images in print and digital formats. Entrants are welcome to submit more than one photograph. One winner and one runner up will be selected by EFEE.

Click here to enter

New EFEE members

We would like to welcome the following member who have recently joined EFEE.

Congratulations and a warm welcome for joining EFEE as a member.

Corporate Members

Irish Industrial Explosives Ltd., Ireland

Individual Members

Henriette Rossing-van Os, Rossingh Explosives, Netherlands

Hector Parra, Forcit, Finland

Albert vanNiekerk, Contract Drilling & Blasting LLC, USA

Abhinav Sharma, First Quantum Minerals Limited, Zambia

Aivars Ivanovs, Dinamix, Latvia

Marilena Cardu, Politecnico Di Torino, Italy

Upcoming International Events

MINExpo INTERNATIONAL 2021
September 13-15, 2021
Las Vegas, Nevada, USA
https://www.minexpo.com/

ISRM's EUROCK 2021
September 20-25, 2021
Online event.
www.eurock2021.com

SEE 48 thAnnual Conference on Explosives and Blasting Technique
January 30-February 2, 2022
Las Vegas, Nevada, USA
https://www.isee.org/conferences/2022-conference

SME Annual Conference and
Expo February 27–March 2, 2022
Salt Palace Convention Center
Salt Lake City, Utah, USA
www.smeannualconference.com

SAFEX International Congress
April 3-8, 2022
Salzburg, Austria
https://www.safex-international.org/safex/news-safex-congress-xx-in-salzburg.html?sid=1580472102

WORLD TUNNEL CONGRESS 2022
UNDERGROUND SOLUTIONS FOR A WORLD IN CHANGE
April 22-28, 2022
Bella Congress Center Copenhagen, Denmark
https://www.wtc2022.dk/

EFEE 11th World Conference on Explosives and Blasting
May 15-17, 2022
Maastricht, Netherlands
www.efee2022.com

HILLHEAD 2022
June, 21-23, 2022
Hillhead Quarry
Buxton. UK
https://www.hillhead.com

FRAGBLAST 13 October
15-21, 2022 Hangzou,
China
www.fragblast13.org.cn

EFEE