EFEE

NEWSLETTER

February 2021

EFEE

11th WORLD CONFERENCE Maastricht 2021

MECC, Maastricht, Netherlands

DATE CHANGE TO : 26th - 28th September 2021

February 2021 edition

We in EFEE hope you will enjoy the present EFEE-Newsletter. The next edition will be published in May 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,
the President's voice

A difficult and stressful year has just passed. We may have all hoped that the situation will change soon. The good news is that a few vaccines have already been approved and that the vaccination process has started. However, the medical community is still under high pressure due to the new strains of COVID-19. We have recently witnessed many countries introduce tighter travel restrictions because of these new variants. National economies and businesses continue to struggle with the consequences of the lockdown measures. For those more optimistic, we may be wondering what recovery might look like in a post-COVID-19 world.

It would be a difficult task to assess the impact on the explosives industry in a few lines. The situation may be different from country to country. I'm certain that there is an impact. As far as I know, all the companies, starting with production and services, and continuing with transport, implemented new operating procedures to try to minimize the COVID-19 impact. Here at EFEE, I would like to encourage our members to share their thoughts about the challenges they may be facing and how they think recovery might look like in the future.

The Newsletter Committee and its Chairman, Ms. Viive Tuuna, are doing their best to share with you the most interesting papers. They outdo themselves to improve it from one edition to the other. Please make sure to send us your proposals so you can be featured in the next editions of the EFEE Newsletter.

Nowadays, we have also been discussing internally the September 2021 - Maastricht EFEE World Conference. Most probably, the next few months will offer more information regarding the feasibility of the schedule approved by the EFEE Council. We may have to plan the Conference for Spring 2022. We will keep you updated about our decision as the situation unfolds.

A question has been on my mind these last few days. How are you living your life now? Are you creating or surviving? Considering our shared context, perhaps most of the time we are just trying to keep afloat - and this is ok. Some of us may have managed to overcome issues regarding to productivity during lockdown, while others continue struggling with the blurring of the lines between professional and personal time. We live in complicated times, but we can rely on the strength of communities and the values that unite them.

It seems that now more than ever, professional associations and federations have a key role in facilitating discussions, projects and solutions so that the effects of this period of uncertainty can be managed as well as possible.

I am hopeful that the vacuum brought about by the pandemic will soon provide some inspiration to restart living our life creating instead of just surviving. In the meantime, may we all be more understanding of our limits as humans.

Doru Anghelache,
President of EFEE

EFEE

11th WORLD CONFERENCE
Maastricht 2021

maastricht: CONVENTION BUREAU

MECC, Maastricht, The Netherlands

IMPORTANT DATE CHANGE: 26th - 28th September 2021

Important announcement: The 11th World Conference on Explosives and Blasting will now take place from 26th – 28th September 2021. The date change has been necessary to accommodate the city of Maastricht's famous International art exhibition, which due to COVID, has moved from June to September 2021. We have received an extremely positive response to the conference and hope many of you will be able to attend.

The conference programme includes

- Large industry exhibition including the biggest names in the sector
- Technical programme featuring:
  - Blast Design Management
  - Construction, Mining & Quarrying (Blasting)
  - Explosive Detection for Security
  - New Applications and Training
  - Blast Vibration and Seismology
  - Demolition Blasting
  - Health, Safety & Environment
  - Technical Development
  - Blasting Work Experiences
  - EU Directives & Harmonisation Work
- Industry specific workshops and tours
- Spectacular Gala Dinner

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Authors are invited to submit abstracts for papers to be presented at the conference. Extended submission deadline: **2 April 2021.**

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Preliminary Detonation Study of Dry, Wet and Aluminised ANFO Using High-Speed Video

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Abstract: ANFO is a well-known, reliable and safe commercial explosive. It has been around since the late 1950s and its detonation properties are well characterized. In this study, we recorded the detonation process of dry, wet and aluminised ANFO, using two high- speed cameras recording at rates of 1,200 and 50,000 frames per second (fps).

The video footage at 50,000 fps allowed us to see the reaction zone, different areas behind the detonation front and, of course, measure velocity of detonation (VOD). The reaction zone for ANFO, regardless of the water content or aluminium present, was of the order of 40 - 50 mm, which is thicker than initially expected.

In the case of the video footage at 1,200 fps, we were able to observe post blast fumes (i.e. NOx) produced by ANFO with different water content. However, no NOx fumes were observed in the case of aluminised ANFO.

The absence of NOx fumes could have been due to the expected higher temperatures produced by the burning of the aluminium additive as observed in the frames of the high-speed video.

1 Introduction

Ammonium Nitrate Fuel Oil (ANFO) is the most well-known explosive in the mining, quarrying and civil construction industries due to its simplicity and cost. The detonation properties of ANFO were studied in the 1960s. Further studies on aluminised ANFO have also been reported by various authors [1,2,3,4].

With the advent of lower cost and high fidelity digital video technology, and particularly high-speed video cameras, it is now much easier and accessible to study fast physical-chemical processes such as the detonation of an explosive charge [5,6]. With this technology, there was an opportunity to revisit past studies on ANFO and conduct an analysis of the reaction zone at higher recording rates (i.e. 1,200 and 90,000 frames per second (fps)). This paper describes the results of unique observations when water and aluminium is added to ANFO mixtures.

2 Experimental section

2.1 Formula

ANFO made from porous prilled AN with an untapped density of 0.75 g/mL, commercialized by Extech (Australia), was sourced for the test.

For the straight ANFO test, the product was placed into a pipe without further treatment. For the ANFO-water tests, 3%, 6% and 9% w/w of water was sprayed on the ANFO product whilst being rotated in a 20-L plastic container. The aim of this procedure was to make sure a homogenous mixture of water and ANFO could be achieved. For the ANFO-Al tests, Aluminium shavings (rather than granules or powder) were blended with the product in a similar fashion.

Densities of each ANFO-water sample were measured. It is worth noting that two types of densities were measured, both tapped and untapped. Untapped density is not accurate in these tests, as water renders ANFO stickier, preventing ANFO from flowing properly. This causes the formation of voids in the cup density, causing error in the measurement. Therefore, tapped density was adopted as it provided a more realistic value to the density of the charges. Table 1 displays the values measured for each parameter.

Note that the type of ANFO used8 in 0these tests did not allow water incorporation beyond 10%. This was confirmed by a simple test, where an ANFO charge was prepared with 12% of water content, but the 20-L plastic container where the product was prepared had a pool of water at the bottom, indicated that the ANFO was unable to take more water. It was not deemed necessary to conduct specific tests to make an exact determination of the maximum water absorption of this particular product. All ANFO samples were fired within 60 minutes of preparation. Dry and wet ANFO samples were loaded into 105mm inner diameter, 1000 mm length clear acrylic pipes. The total amount of explosives was 7 kg. ANFO samples were initiated with a detonator and 150-g boosters. Figure 1 shows two typical samples, in this case ANFO with 9% water and 4% Aluminium respectively.

Table 1. ANFO- water formulas

ANFO	**Water**	**Aluminium**	**Density (g/ml)**		**Water content**		**Al content**
(g)	**(g)**	**(g)**	**untapped**	**Tapped**	**dry basis**	**wet basis**	**Dry basis (%)**
4500	0	0	0.78	0.85	0	0	
4500	135	0	0.77	0.85	3	2.9	
4500	270	0	0.83	0.87	6	5.7	
4500	405	0	0.80	0.86	9	8.3	
4500	0	180				3.8	4%

Figure 1. ANFO charge with 9% of water and ANFO with 4% of Al

2.2 Instruments

The high-speed video of the detonation front was recorded with a Photron Fastcam SA-X2. The camera was located 20 meters from the explosive charges, protected by a plywood screen having a square cut where a 20mm thick clear polycarbonate sheet was placed to protect the camera lens. The camera was enclosed to protect it against the near field air blast overpressure. The frame rate to capture the detonation was 50,000 fps (a frame was capture every 20 s) and with a resolution of 768x328. Frames of this video footage were used to observe the reaction zone, measure the angle of expanding gases and to calculate VOD.

To record the overall plume of gases evolving from the detonation, a Nikon 1 J1 camera was used and set at 1,200 fps (with a resolution of 320 x 120). This camera was placed approximately 200 meters from the blasting area.

In the test program, charges were suspended and therefore completely unconfined. Figure 2 displays a typical set up for the detonation test.

3 Experimental results

3.1 High speed video showing the detonation front and reaction zone

Selected frames of the detonation reaction recorded with the Photron Fastcam SA-X2 camera are shown in Figure 3. The numbers shown on the pipes (i.e. 2, 3, 4, 9 and 10) refer to the order of firing during the test day (different tests were also being conducted at the time).

BACK TO TOP

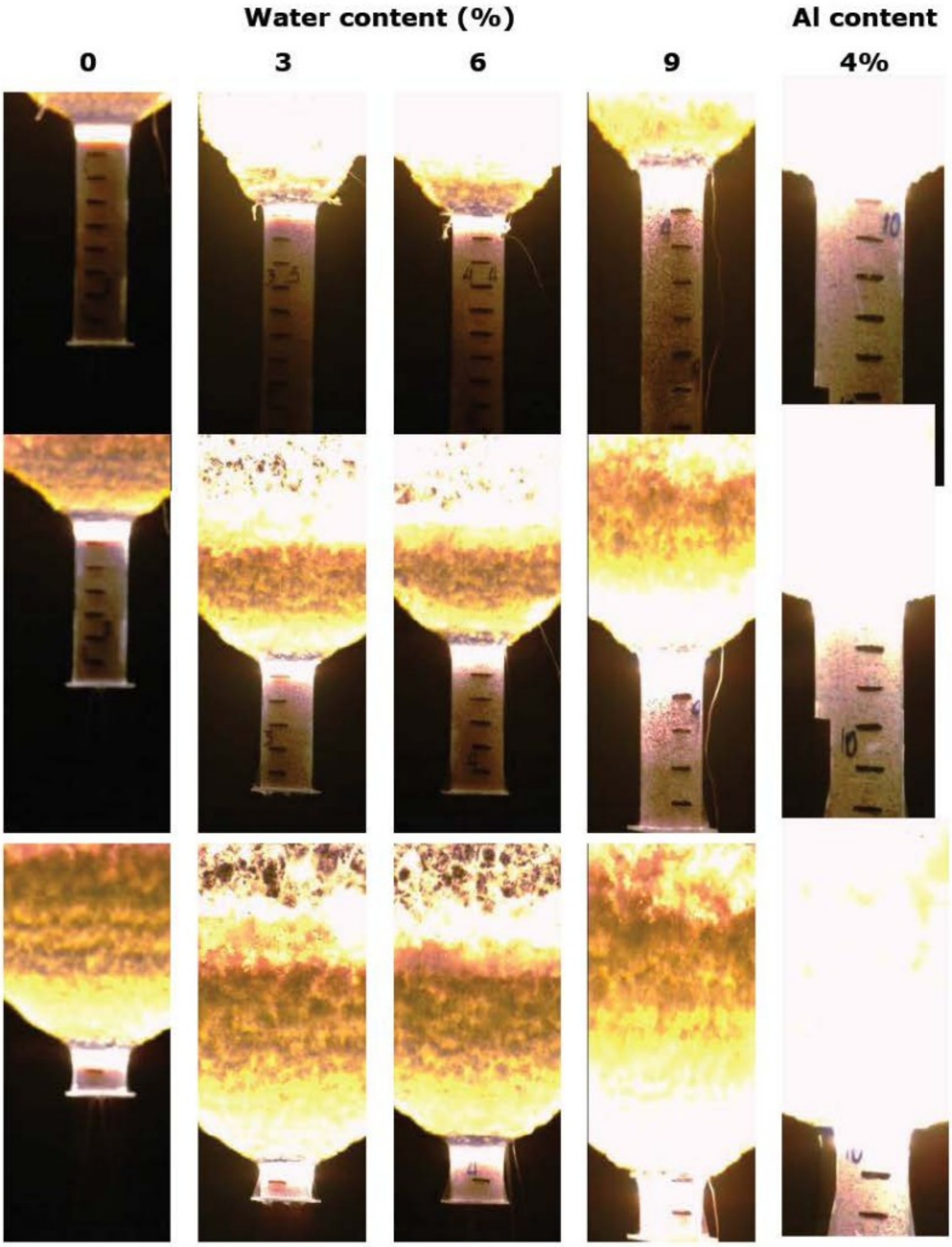

Figure 3. Detonation frames

Some interesting features can be observed when looking closely at different frames corresponding to different samples. Firstly, it was observed that the intensity of the light for both ANFO with 9% water w/w and ANFO with 4% aluminium appeared much brighter that for the charges made with ANFO having less water. It can be hypothesised that the brighter light intensity from the Al-ANFO is due to the high temperature generated by the burning of the Al, but in the case of the ANFO with 9% water is difficult to explain as instinctively one would assume that temperatures would reduce.

It was also noted that the reaction zone appears to be more consistent in shape in the unaltered ANFO sample, it can be observed that as water and aluminium is added, a more irregular detonation front is observed, almost suggesting some type of ignition ahead of this front.

3.2 VOD and expanding gases

The video images allowed us to measure velocity of detonation (VOD) and the angle formed between the pipe and the expanding gases. The angle was measured according to Figure 4.

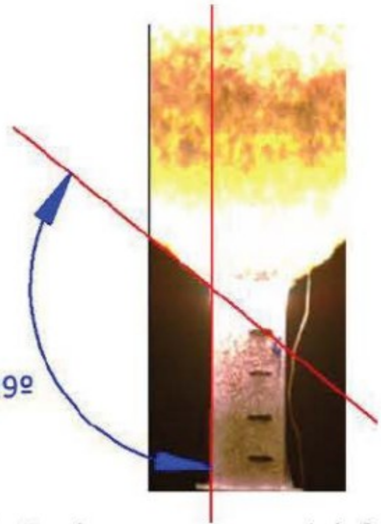

Figure 4. Angle measurement definition

Table 2 displays a summary of the results using the data from the high-speed video footage (VOD, angle of expanding gases and length of reaction zone).

The plot with the measured VOD and the reaction zone length obtained both from the high-speed camera footage are shown in Figure 5.

Table 2. Data for the samples tested

Water Content (%)	VOD (m/s)	Angle of expanding gases	Reaction zone (mm)
0	3126	136	41
3	3162	128	45
6	3201	128	57
9	3211	129	80
Al 4%	3062	118	66

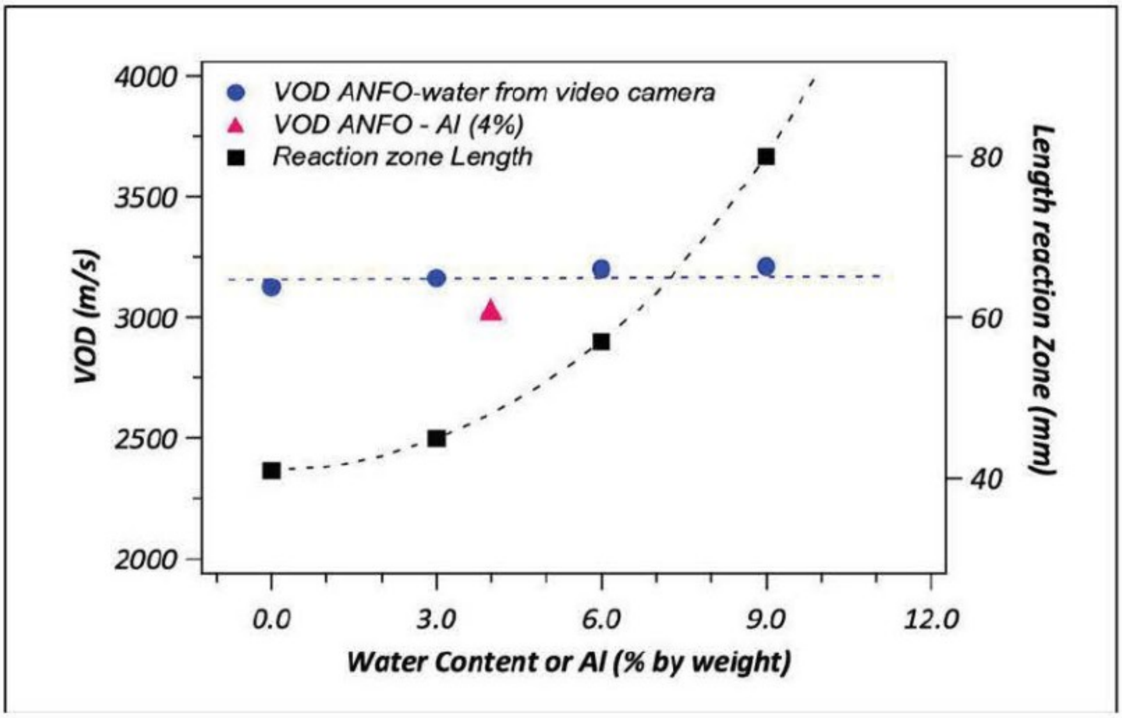

Figure 5. VOD for samples using high speed camera

Based on these preliminary experiments, the VOD of ANFO appears to remain constant and it is not influenced by the presence of water in the range of 0% to 9 % w/w. The aluminium additive does however exert some influence in the detonation of ANFO. It is also noticed that the reaction zone grows with the water content.

Figure 6 shows the gases generated during each test recorded at 1,200 fps. We can observe the generation of NOx fumes for ANFO and wet-ANFO products. In the case of aluminised-ANFO, the detonation appears to be brighter and there was NOx fume observed. It is worth noting that for the ANFO sample with 9% water, the level of NOx appears to be higher, but the video showed the conveyor mat just below the charge flying up. The conveyor belt mat was heavier than 60 kg. The other ANFO-water charges (0, 3 and 6%) did not move the conveyor belt mat. Overall, the ANFO with 9% of water seems to have detonated with a higher intensity. The ANFO-water with 9% also showed a higher VOD (see table 2 in previous section), but the difference seems marginal.

BACK TO TOP

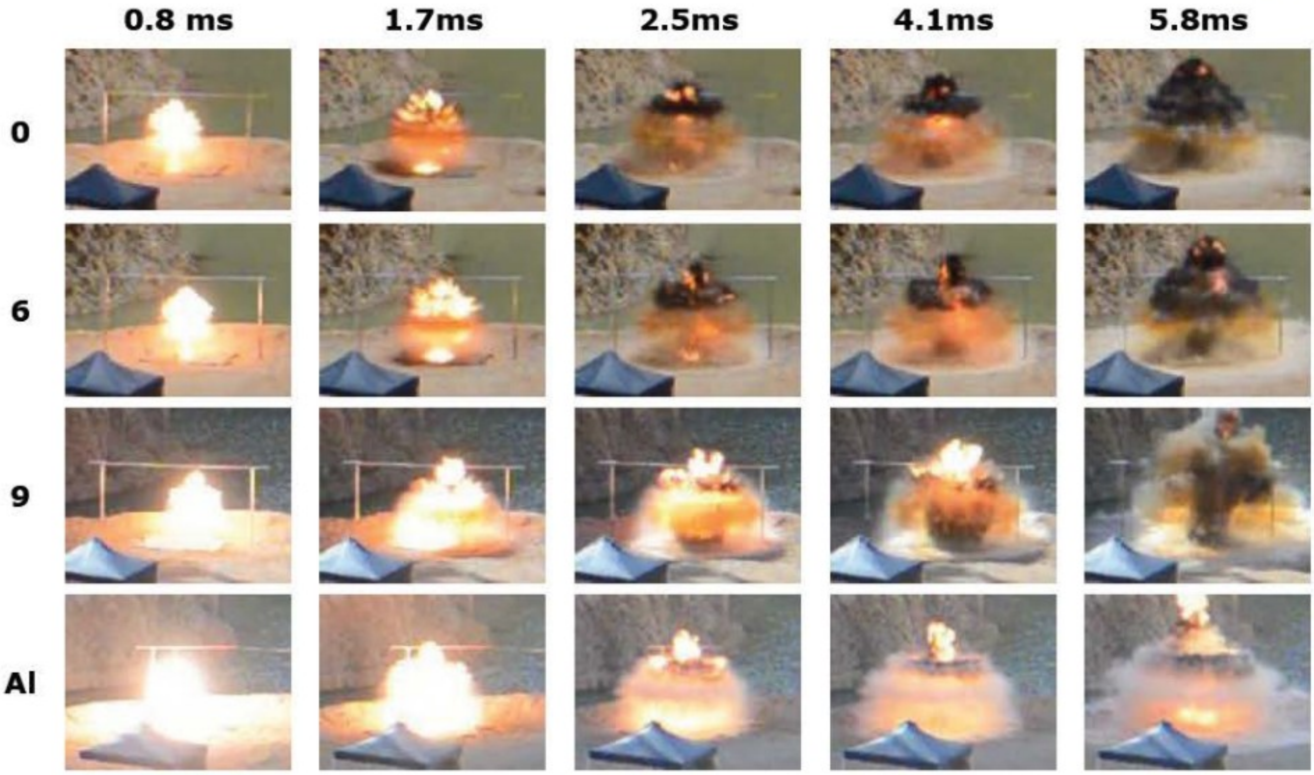

Figure 6. Analysis of the gases of detonation using 1,200 fps video camera. The left column indicates the % of water content or Al.

4 Discussion

4.1VOD of samples

Results from this preliminary study showed that the VOD of ANFO does not vary with an increase in water content of up to 9% w/w (see table 2). As displayed in Table 1, the density in the entire range is 0.87±0.02 g/ml. This low or no decay in the VOD contrasts with the work conducted by Yancik in the 1960s [7]. In that study, a water content of 7-8% w/w caused the ANFO VOD to drop by approximately 12-14%, and in the case of 9% w/w of water, the VOD drop was significant (~ 38-40%). Differences in the results shown may be associated with differences in prill characteristics.

The AN prill used in this study could have had a higher porosity and thus more sensitive to initiation than the AN prill manufactured in the 1960's which could have had coatings, as they were primarily used as fertilizer AN. This is the main possible reason as to why the water increase in the ANFO did not affect the VOD. In our study, we could not test a ANFO with a higher water content as during the preparation, we noticed that a load of 12% w/w of water was too high for the ANFO to absorb. However, we acknowledged that the presence of water, to ANFO, in percentages above 9% (10% or higher) may cause an inefficient/partial reaction or potential failure in the detonation process. Having said that, when ANFO is used in the field, the conditions vary day to day, so care should be taken when extrapolating results obtained in this study.

Surprisingly, in addition to the absence of a VOD decay with an increase in water content, we observed that the detonation of ANFO with 9% water appeared to be more energetic than the other samples with less water.

In the case of ANFO with 4% of Aluminium, the VOD observed is slightly lower. Previous studies conducted by Katsabanis, found that Al with a small particle size increased the VOD of ANFO [2]. The different size of Al used in Katsabanis work and in this one indicated that depending on the particle size of the Al, it could react at different stages in the process of detonation [2]. Aluminium could react at the detonation front (when using small aluminium particles that can burn quickly) or it can react only at the reaction zone (larger particles, where the burning takes more time to travel the diameter of length of the Aluminium particle) or it can burn poorly after the CJ plane or does not burn at all – in this case Aluminium would act as an inert, and that would be the case of very large Aluminium particles – like granules. In summary, very large size aluminium particle would lower the VOD of the ANFO.

4.2 Angle of gas expansion

This goal of this study was to observe the reaction zone of ANFO with different levels of water, however after analysing the video footage, we found that the gases displayed a different extent of expansion depicted by a change in the angle of expansion relative to the detonation front. In the case of ANFO with no water, this angle is 136$_{o}$, and for ANFO plus water, the angle drops to 127º degrees, which is marginal. However, we observe a larger variation, when aluminium is used in the formulation. In that case the angle was 118º. Aquarium tests of ANFO explosives with aluminium and without aluminium have shown the energy output is larger for ANFO explosives [8]. Whether there is a relationship between the gas expansion angle and the different gas bubble detected in the tests, it is a question we cannot answer with the limited tests conducted in this study, and it needs further study. The data obtained in this study could however be used to implement and test a hydrodynamic code and incorporate different degrees of confinement to gain a better understanding of the expected effect of gas expansion on detonation performance.

4.3 Reaction zone

One of the most interesting observations in this study was our ability to see and measure the length of the reaction zone (i.e. 41mm in the case of ANFO with no water – see Table 2). Usually military explosives have a reaction zone that is anywhere between 0.1 – 4mm [see for example reference 9], which is below one tenth the length of the reaction zone observed in this study. Although the expectation was to obtain shorter reaction zones for ANFO, around 4 - 6 mm as found by Helm *et. al* [10], the reaction zone lengths found in this study are surprisingly large.

It was also observed that the reaction zone grows longer with the increase of the water content. By extrapolating at higher water contents in Figure 5, we can see that the reaction zone would be larger than the diameter of the pipes used for the detonation (105mm). Jones established that the high pressure within the reaction zone causes the gases to expand before the reaction becomes complete, causing a drop in pressure and temperature and ultimately this will lead to a decrease in detonation velocity or even failure [11]. This effect is more pronounced at longer reaction zones.

This reaction zone length is an important feature of non-ideal explosives that requires further study which can also provide a reference point for hydrodynamic numerical codes mentioned above. In the case of ANFO and aluminised ANFO, work has been conducted to determine the change of the properties of ANFO when Aluminium is added. Thornley [1] noticed that in underwater tests, the increase of aluminium content increased the strength of the ANFO. Crosby presented is his review on field studies that Aluminium presence in ANFO produces better fragmentation outcomes [12]. Based on these studies and the increase in the reaction zone length when aluminium is added, we would be able to correlate an Aluminised ANFO's longer reaction zone with a more energetic product that could induce more fracturing and improve overall fragmentation, despite of the low VOD observed (below 3000 m/s, Versus VOD of 4,500 – 5,500 m/s for emulsion explosives-based products). However, this cannot be studied in isolation as the lower VOD could have been the best match for the ground conditions encountered.

We also observe that the reaction zone length increases with the water content. At this stage, due to the lack of studies of wet ANFO in bench blasting, we are unable to relate their increased reaction zone's length to an outcome in blasting, whether this is a better or poorer fragmentation or heave.

Figure 7 displays a description of the different areas seen during the detonation process. The frame selected is from ANFO with 6% of water after 180 S of initiation. The image is sharp enough to see the unreacted prill in front of the detonation front.

The list below describes the different zones observed in the detonation of ANFO:

- Zone A – This is the ANFO reaction zone.
- Zone B – Expanding zone – pipe starts expanding and some purple gases are seen – most probably gases whose temperature drops due to the volume expansion
- Zone C – Gas expansion zone, with gases increasing their temperature as the heat from the reaction start transferring to the outward gases.
- Zone D – Gases expanded and cooling down.
- Zone E – This zone may be influenced by the booster detonation and the temperature is higher than zone D – oxidiser and fuel have fully reacted.
- Zone F – Gases fully expanded and most likely influenced by the detonation of the booster and hence its high temperature.

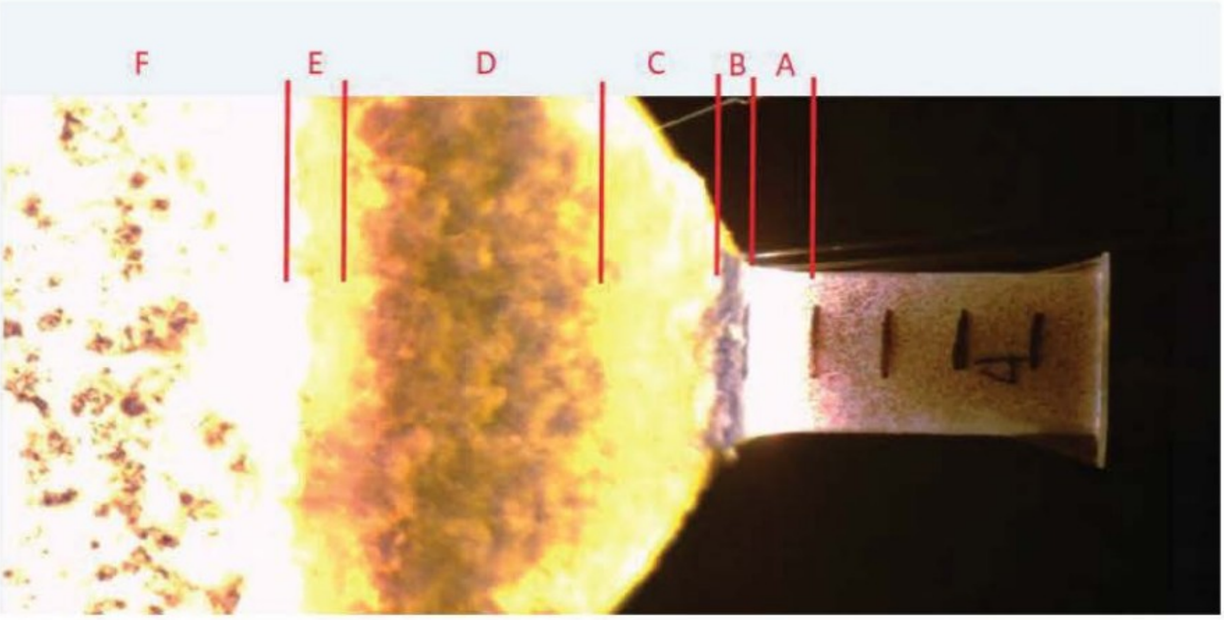

Figure 7. Different areas observed in the ANFO reaction zone

4.3 NOx production

We can see the generation of NOx fumes during the detonation in ANFO samples with water and without water (see figure 6) using a 1200 fps camera. However, the footage does not allow to determine any difference in NOx fumes evolution among samples. In the case of the aluminium as an additive in ANFO, NOx fumes production was not observed, or at least, the fume amount produced was lower than fumes production by the dry / wet ANFO tests. Maranda *et. al* [4] and Sapko *et. al* [13] and also found that the aluminium reduced the NOx production, in their studies, using a chamber to measure the NOx. Most likely the higher temperature reached by the aluminium during the detonation helps with the conversion of $NO_{3-}$to N_2.

The important point here is that the colour of the gases, which can be observed at 1200 fps, can tell us more about the detonation process when changing parameters (like diameter, density, etc.). A high-speed camera, with a better frame resolution and higher speed could help to understand better the NOx production. Conversely, the use of a 50,000 fps camera, focused mainly in the detonation process, did not reveal any difference in the NOx fumes production.

5 Conclusions

ANFO with water is still able to detonate with up to 9% of water and the VOD does not appear to vary in the range 0 – 9% water, in 105 mm diameter pipes, unconfined. However, the reaction zone length gets longer with water increase. It is suggested to conduct further studies on this matter.

Aluminised ANFO has been the subject of extensive research and this work is a further contribution with the added benefit of providing a closer and unique look at the reaction taking place during detonation. High-speed digital video has become a great tool to understand the detonation process and this group will continue to conduct research in that area. High speed camera proved to be up to 2000 fps cameras are also useful to observe the types of gases (based on colour) produced during the detonation.

The high-speed camera with significantly higher resolution and recording rates also assisted us in observing the detonation process of the products. The footage allowed to determine the angle formed by the expanding gases and it was found that this angle was different for ANFO with aluminium.

Detailed images taken at 50,000 fps allowed us to observe the ANFO reaction zone, which was longer than measurements results from previous studies. Work should be conducted with ANFO detonation at different diameters to further understand the potential impact of the reaction zone in the efficiency of detonation. Finally, it should be noted that these conclusions are based on a limited number of tests and further work should be conducted.

6 Acknowledgements

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BACK TO TOP

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

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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).

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 first part of a two-part paper presenting the authors 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.

Editorial note: The second part of this paper will be presented in the May 2021 edition.

Coal fired power station

BACK TO TOP

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 covers the client's and project team's SMS and aims to capture RGP seen in industry that can help contractors and guide client's (including Nuclear Licensees) when considering resources, risk balance, management arrangements and control that need to be in place as part of an effective contractor-intelligent customer relationship.

Part 2 starts at the contractual process and follows through to the day of the blow down and will appear in a later edition of this magazine.

Differences in the regulatory framework

Although the regulatory regime on UK nuclear sites is different to that encountered on non-nuclear sites, the relevant good practice necessary to safely undertake the high hazard (and potentially high risk activity) of explosive demolition is common.

The Office of the Nuclear Regulator (ONR) regulates the UK nuclear industry (including demolition activity on nuclear sites) through a permissioning regime made against the Safety Assessment Principles (SAPS). Its principal focus is ensuring that the demolition activity is undertaken in a way that is compatible with the principles of nuclear safety. In comparison, demolition activities elsewhere within Great Britain are regulated by the Health and Safety Executive (HSE), principally acting in an enforcement rather than permissioning role and solely focussed on ensuring that risks to employees and others arising out of the demolition activity are subject to proportionate control.

Challenges

As experienced shotfirers retire and commercial long term demand for explosive demolition on nuclear and non-nuclear sites increases, the industry will be challenged in its ability to satisfy that demand.

Most previous incidents during explosive demolition have led to property or commercial loss and not loss of life.

However, there have been fatal and serious incidents such as Gorbals Tower Block Glasgow (1993)[1], Royal Canberra Hospital (1997)[2], Bakersfield USA[3] and Didcot Power Station (2016)[4]. These have resulted in long-term consequences to individuals, businesses and society. These highlight the importance of the available learning from past incidents during explosive demolition and developing safe and robust systems of work.

General safety considerations

Safe and effective explosive demolition requires a detailed engineering analysis integrated with a robust SMS to produce a clear, coherent, conservative, justifiable fault tolerant design and safe system of work. In the UK, this is achieved through a series of robust engineering and process reviews that compare the design to RGP and seek to reduce the risk "So far as is Reasonably Practical"[5] (SFAIRP).

The SMS together with the selection of a competent contractor and appropriate contractual arrangements influence the engineering design and how the works are undertaken and supervised. The client's involvement is fundamental to providing the resources and setting the culture and expectations of this process.

Definitions

SFAIRP

The concept of reasonably practicability is fundamental to UK health and safety legislation as key part of the general duties of the Health and Safety at Work etc. Act 1974 (HSWA).

"So Far As Is Reasonably Practicable" (SFAIRP) involves weighing a risk against the trouble, time and money needed to control it. SFAIRP describes the level to which we generally expect to see risks arising out of work activities to be controlled and is core to the consideration of RGP in the nuclear industry and elsewhere. Whether activities are taking place on a nuclear site or not, a proportionate identification and analysis of the hazards associated with a specific activity, as part of an overarching system of risk assessment, should be undertaken to demonstrate that the overall level of risk is acceptable.

Relevant Good Practice (RGP)

RGP is "an aid to making a judgement". The word "Relevant" is an important qualifier, because what may be good practice in one scenario may be less applicable to others. It allows a test of applicability in situations where there might be an alternate applicable standard.

RGP is defined[6] as "those standards for controlling risk which have been judged and recognised by HSE/ONR as satisfying the law when applied to a particular case in an appropriate manner."

Meeting RGP is therefore the starting point in demonstrating that risks are being appropriately controlled and an activity is SFAIRP safe.

Intelligent Customer

The concept of an Intelligent Customer (IC) has gained international acceptance in both the civil and nuclear industries. An IC is defined[7] as "an organisation" (rather than individual post holders) "that has the competence to specify the scope and standard of a required product or service and assess whether the supplied product or service meets the specified requirements".

It is the summation of the capability of an organisation to understand what work is needed, the hazards involved, to specify what needs to be done; to set suitable standards; to supervise and control the work, to review, assess and evaluate whether relevant standards and legal requirements have been met. Most importantly, the client or Nuclear Licensee are responsible for the overall control of site activities. This includes any work commissioned from consultants and subcontractors.

BACK TO TOP

Explosives demolition contractor

Depending upon the scale, complexity and contractual arrangements of the project, the Principal Contractor (PC) as defined in the Construction Design and Management Regulations 2015 (CDM 2015), may be the explosives demolition contractor, or the explosives specialism may be subcontracted out. Whatever the arrangements, in this paper both are referred to as the "contractor".

Project team

The project team comprises the client and their internal engineering and project management resource advised in some cases by competent external consultants. Those consultants should be selected by the client based on a judgement of their demonstrated competence in specialist areas of expertise for the specific project under consideration. The basis of that judgement should be documented to allow audit.

Independent Structural Assessment (ISA)

In the nuclear industry, ISA provides the licensee with an independent third-party review of the adequacy of the licensee's own structural engineer's or any contractors design proposal including any temporary works. This check would be independent from any Category 3 (CAT 3) check referred to in BS5975:2019 undertaken by the contractor.

In the civil industry, an ISA may be disproportionate to the scale and scope of the project however its role and use should not be precluded. The client should record the basis for that decision and keep it under review should circumstances change. Requirements for ISAs should be included in the contract specification and documentation.

Safety Case

Safety cases for a nuclear site should include the Construction Phase Plan (CPP) required under CDM 2015. Irrespective of the format it should be:-

- Understandable and useable by those with direct responsibility for safety.
- Communicate a clear and comprehensive argument and evidence that an activity such as explosive demolition, can be undertaken safely.
- Demonstrate that the risks and hazards have been assessed, an adequate and detailed engineered design has been undertaken, appropriate limits and conditions defined and adequate safety measures identified with clear arrangements to implement and supervise them.

BACK TO TOP

UK Regulatory environment

All parties should comply with the legal requirements and regulations of the country in which they are working. These may differ from the UK and how those requirements are to be met. In GB, the primary legislation is the Health and Safety at Work etc. Act 1974 (HSWA), and in Northern Ireland the Health and Safety at Work (Northern Ireland) Order 1978 fulfils a similar function. A number of further Acts and Statutory Instruments support these key pieces of legislation.

The UK regulatory regime is a "goal-setting" regime rather than a more prescriptive standards-based regulatory regime. Such a principle is flexible and supports goals and principles underpinned by codes of practice and guidance. This is designed to deliver a proportionate, accountable, consistent, transparent and targeted approach. This encourages continuous improvement and the adoption of RGP as a mechanism for demonstrating compliance with the goal setting requirements of the law.

Construction activities in GB are largely regulated by CDM 2015. Standards for what compliance looks like under these regulations can be found in recognised standards such as BS5975:2019 on Temporary Works, BS6187:2011 Code of Practice for Full and Partial Demolition, BS5607:2017 Code of Practice for the Safe Use of Explosive in the Construction Industry. The Project Team and contractor(s) should be able demonstrate compliance with those regulations and relevant guidance throughout their undertaking.

The legal requirements for the acquisition, manufacture and storage and security including tracking tracing and recording of explosives in GB are found in the Explosives Regulations 2014. HSE's website www.hse.gov.uk and the overarching guidance supporting those regulations identifies relevant standards and industry guidance on how to deliver those requirements.

Clients or contractors undertaking works in the UK should be conversant with and are expected to comply with the requirements of UK legislation and regulations.

Clients or contractors undertaking works in the UK should be conversant with and are expected to comply with the requirements of UK legislation and regulations.

Key elements to demonstrate compliance with RGP

The key elements that will demonstrate that RGP is being followed are:

- An Intelligent Customer complying with legal requirements and providing the finance and information to deliver a safe project. The client should set a high expectations with respect to behaviours and recognition of human factors.
- A competent project team assembled by the client to;
    - collect together all obtainable, relevant information on the structure[8] and its environment.

  - produce the CDM2015 Pre-Construction Information (PCI) and any required Safety Case;
  - advise the client on the choice off the most appropriate risk balanced form of contract.
  - support the client in procuring a competent contractors(s);
  - manage, control and supervise the works through a SMS;

- Detailed planning to identify and control the demolition risks. A detailed plan provides focus to assure the production of a safe design and site works whilst providing commercial certainty with a reduced risk of increased costs and time.
- An adequate Safety Case and CPP that demonstrates that risks are controlled and the demolition activities are SFAIRP safe.
- A documented SMS capable of ensuring that controls are proportionate to each hazard and that include robust peer review, challenge, monitoring and supervision.
- A contractual process clearly identifying and balancing the risks owned by both the client and the contractor.
- An engineered demolition design that is technically underpinned, conservative, fault tolerant and safe to undertake. The design should be demonstrably robust, and be supported by a transparent audit trail[9].
- A competent explosives contractor retained to:
  - identify appropriate blow down methodologies;
  - develop, produce, justify and implement a detailed engineered design.
  - produce a detailed method statement to demonstrate how the works are to be implemented and undertaken safely.

- A robust system of site supervision to ensure works are undertaken as specified in the agreed Safety Case and CPP.
- A change management system that identifies and addresses all aspects of change decision and records all changes or modifications to the original design and method statement.
- Thorough, well planned and practiced command and control arrangements for the day of the blow down which address contingencies, emergencies and mitigation if issues arise.
- Evidence that key elements of the engineered design and the supporting information have been subject to both appropriate internal challenge and 3rd party peer review.

Demolition works are often outside of the clients core business activities but they should recognise they need to be an "Intelligent Customer" (IC) before the start of the planning and procurement phase. On a Licensed Nuclear site the Licensee is solely responsible for the site activities and this responsibility cannot to be transferred to another commercial entity or organisation.

Experience indicates that effective clients:

- Recognise their legal duties and have a core capability of competent staff able to manage and control the safety of their undertaking and works carried out by contractors.
- Have IC capability and show that they are a learning organisation, sourcing information and knowledge from appropriate engineering institutions, organisations and professional bodies in the UK or overseas as well as from other private, public organisations and industry which have undertaken similar projects. This approach helps them to learn from previous shortfalls and past incidents together with examples of good practice on safety culture.
- Ensure that members of the Project Team attend an explosives awareness course. Details of providers can be obtained from the Institute of Explosives Engineers (IExpE) or Mineral Products Qualifications Council (MPQC).
- Provide appropriate levels of resource and information to safely deliver a particular project.

Effective project teams generally include a Temporary Works Designer (TWD) and Coordinator (TWC) with experience of similar explosive demolition projects. Their early involvement can provide valuable assistance in preparing adequate tender documents, assisting design development, peer review of contractors design and constructability.

Similarly, project teams should be aware of sources of RGP for structural engineering from Structural Safety (SCOSS)[10] and the Temporary Works Forum[11].

On a nuclear licensed site, the Licensee should also ensure that an Independent Nuclear Safety Assessment (INSA) is undertaken to provide the Licensee with assurance that the overall project is being undertaken safely. The role of INSA is to challenge the assumptions, philosophy and details of the developing project. All parties should be clear in their roles and responsibilities as defined in CDM 2015. For large scale or complex demolitions or demolitions taking place on a major civil hazard site or environment, a client may choose to appoint a similar form of 3rd party organisation to fulfil a similar function mirroring the INSA methodology.

BACK TO TOP

Planning

Detailed planning is important for any demolition work, particularly where the overall characteristics of the structure and its hazards are not fully quantified. This is particularly significant in explosive demolition where the blowdown is a single operation. The degree and rigour of planning should reflect the complexity, hazards, unknowns and risks from the structure to be demolished. Greater information provides better understanding and certainty whilst information gaps lead to higher uncertainty so requiring extra caution, conservatism and contingency planning.

The planning process should aim to deliver:

- A comprehensive CDM2015 PCI document, together with a procurement and tender strategy and arrangements for how the design and works are to be developed and reviewed. Similarly there should be clear expectations on how the method statement and any Safety Case are to be produced, peer reviewed and approved, then supervised and implemented on site.
- A project risk register which is regularly reviewed to identify changes in existing conditions and address any new arising risks.
- Optioneering and feasibility studies to seek and assess all available information relating to the structure and different blowdown techniques and methodologies. Planning requires identifying the conditions, hazards, methods and opportunities that provide certainty and reduce risks SFAIRP. Competent planning includes consideration of options and their feasibility which generally reduces design risks and improves the safety of the works and certainty of programme delivery and costs.
- Early Contractor Involvement (ECI) from the explosives demolition contractor. Their experience of hazard identification and working methods can inform decision making during concept design stage. The timing of engagement depends on the selected contractual process, together with the scale and complexity of the project.
- Appropriate contingency plans and command and control procedures. This should cover not only site issues but also interfaces and communications with external stakeholders and the public.

Capturing Existing Information

The project team should collect all reasonably available, relevant information held by the client. An assessment should be undertaken to identify the degree of confidence that can be put in its accuracy. Any gaps or identified shortfalls should be resolved by undertaking further investigations. If there has been a change in site ownership, then information should still be available as part of the legal "due diligence" procedure. Post 1994, the clients should have a Health and Safety File under the extant CDM 1994 / 2007 regulations. However it is recognised that the content of this file is often incomplete, unreliable or entirely missing. On a nuclear Licensed Site it would be expected that this information would be available through existing safety cases.

A valuable source of information is that held by current or previous employees who can provide "unrecorded" details of the design, construction, contamination sources and other hazards, modifications or changes, maintenance or operation of the plant or structure. This information should be captured for inclusion in the PCI.

The client and the project team should follow the guidance in BS6187:2011, BS5607:2017, BS5975:2019 and CDM 2015 which, for example, covers such areas as:-

- The identity and location of services on the site, including gas, electricity and steam, telephone and other cabling, chemical gases, demineralised water and all wastewater drains.
- The original structural design and construction details with any refurbishments or changes of the structure to be demolished.
- Similarly any structural or geotechnical information required for the temporary work design and construction.
- The identity and location of any adjacent structure sensitive to vibration, blast loading, dust, or impact. Any limits, conditions, protection requirements or other safety requirements should be included in the Pre-Construction Information.
- The type, extent and implications of the hazard from any contamination arising from the demolition, together with the implications for the safe containment and treatment of that waste, which may introduce its own hazards and risks.

The aim should be to accumulate as much information as reasonably practical to be included in the PCI. This information is essential for adequate tender submissions, demolition design and safe systems of work.

Information on expected standards of construction forms can be sourced from withdrawn BSI Codes of Practice and technical guidance for structures in different materials. Other sources are technical papers submitted to professional institutions, conferences, industries and other organisations such as the UK Building Research Establishment (BRE).

However confirmatory studies should be undertaken to provide assurance that historical standards were followed. Publicly available HSE accident and research reports, together with information on the internet are another useful source.

SMS – summary of key requirements

The client and design team should have arrangements that demonstrate the appropriate levels of controls including robust, auditable and transparent reviews and internal challenge within the SMS. Milestones or gateways should define where and how rigorous the reviews and challenges should be. Examples of gateways include contractor pre-selection and tender award together with design reviews and 3rd party checks of the contractor's method statement.

The system should identify who is responsible, what they are responsible for, and how they exercise the appropriate level of control. It should also identify the process for undertaking monitoring, reviews, and audit as well as recording decisions and retaining documents.

On a nuclear licensed site these requirements would be included in the Licensee's safety case as the Licensee remains responsible for safety. On other sites, the responsibility for safety may change as the project progresses in accordance with CDM 2015. Such changes should be clearly identified, suitably authorised and effectively managed to ensure that the SMS continues to operate effectively and as designed.

Note - First published in Explosives Engineering September and December 2020 editions. Published here with the kind permission of the author and publisher.

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[1] https://www.heraldscotland.com/news/12719259.woman-dies-in-demolition-blast/

[2] h#ps://www.canberratimes.com.au/story/6030620/katie-benders-family-commemorate-20-years-since-royal-canberra-hospital-implosion/

[3] Enr.com news article August 19 2013 Pacific Gas and Electric Co incident 3 August 2013

[4] h"ps://www.independent.co.uk/news/uk/home-news/didcot-power-station-reports-of-explosion-at-building-in-oxfordshire-a6891596.html

[5] ONR and HSE do not discriminate between the levels of safety expected by the terms 'So Far as is Reasonably Practicable', 'As Low as is Reasonably Practicable' and 'All measures necessary'.

[6] https://www.hse.gov.uk/risk/theory/alarp2.htm

[7] ONR Technical Assessment Guide NS-TAST-GD-049 Revision 6

h"p://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-049.pdf

[8] This will generally involve the project team undertaking a comprehensive and effective survey of the existing structure (including where appropriate use of intrusive techniques) to identify and confirm the structural information from the clients existing records. This survey should also identify any missing structural or contamination information not previously identified. This will enable the tenderer to develop and produce the preliminary engineered design. The tenderer should be provided with sufficient resource by the client to undertake any additional structural or contamination investigations. The tenderer can then clarify or confirm any doubts in the adequacy of the Pre Construction Information required in Appendix 2 of CDM 2015.

[9] The design should be developed within a 3D Building Information Modelling (BIM) model where appropriate. This facilitates the demonstration and accurate simulation of the demolition philosophy in

BACK TO TOP

[9] The design should be developed within a 3D Building Information Modelling (BIM) model where appropriate. This facilitates the demonstration and accurate simulation of the demolition philosophy in order to design out risks. It has advantages for the decision-making processes whilst providing improved visibility and communication both within the project and to external stakeholders. For small-scale works, the use of BIM may not be appropriate but as uptake and familiarity of digital technology increases its use or other forms of Virtual Reality (VR) should not be precluded

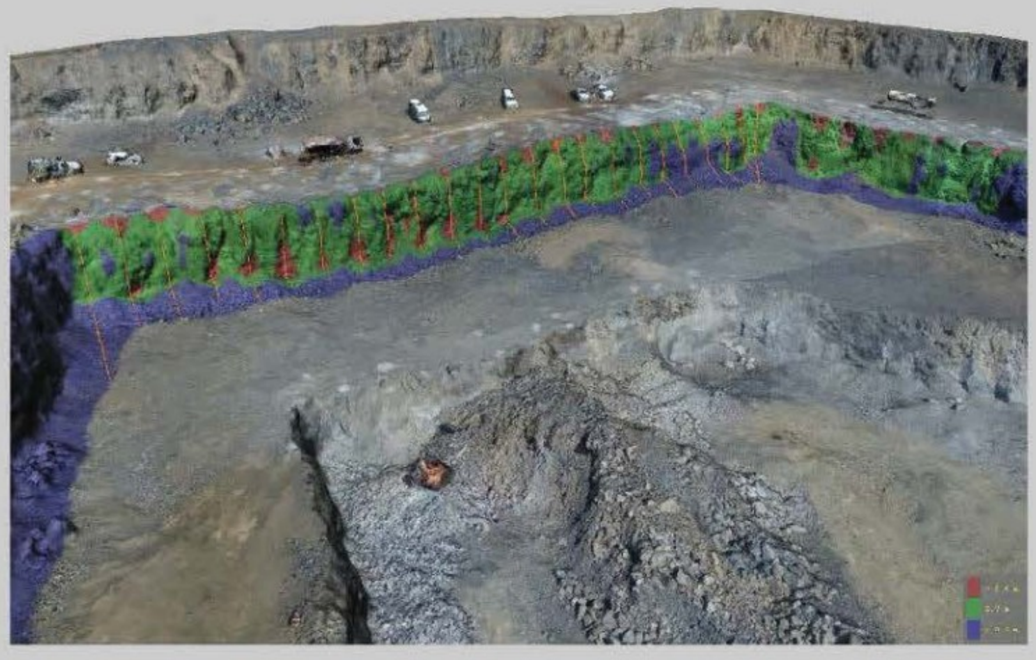
[10] https://www.structural-safety.org/about-us/

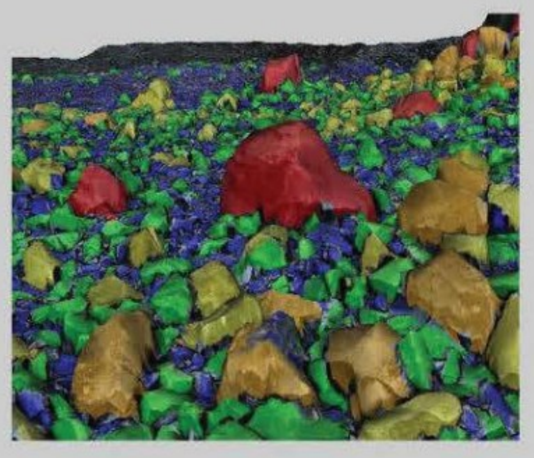
[11] https://www.twforum.org.uk/home

Steel framed Paraquat tower + 100ms

Author in front of demolished Paraquat tower

BACK TO TOP





The Development of Pressure to Young Modulus Models for Precision Presplit Blasting

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ABSTRACT: Precision Presplitting has been defined as a new method of presplitting which utilizes light explosive loads of less than 0.15 kg/m (0.1 lbs/ft) of borehole and a close spacing of 0.61 m (2 ft) or less. This new method of presplitting has been used on hundreds of construction projects to control overbreak in weak and heavily jointed rock, specifically in construction projects. This paper will look at the mechanisms of how this presplit forms under these light loads and present new models which relate borehole pressure to the rock characteristics, specifically the Young's Modulus with multiple variations in spacing. This gives explosive engineers a new tool to help design this presplit through various borehole diameters, spacing distances, rock types, and structural environments while assuring a smooth neat line is developed with a minimal slow zone.

1. RESEARCH OBJECTIVE

The ability for a mining or construction project to generate smooth walls through the use of explosives is paramount to the operation being economically effective and safe for employees. The use of proper presplitting can reduce the amount of scaling required to 1/10 of that required when traditional blasting is utilized (Paine, Holmes, & Clark, 1961). This has large economic savings in reduction of manpower ad equipment required and increased excavation capacity. This also leads to a safer project as less rockfalls occur during the scaling process when men and equipment are near the highwall. The minimization of backbreak is not only seen on the face of the excavation, but the reduction in blast damage is meters thick where proper presplits show no degradation of the rock beyond the presplit line (Matheson & Swindells, 1981).

While traditional presplit methods can be utilized in hard rock types, they encounter problems when they are applied to weaker rocks. This has led to a false concept that weaker sandstones, shales, mudstones, and siltstones cannot be presplit. However, the method of Precision Presplitting has been applied to all of these conditions effectively and shown presplits with near perfect walls in full-scale construction projects (Spagna, Konya, & Smith, 2005). Traditional presplit methods often caused problems with this type of rock as the explosive load was too great and crushing or cratering around the borehole would cause overbreak.

Oftentimes, the structural properties of the geology being blasted also cause backbreak beyond the presplit lines (Worsey, Farmer, & Matheson, 1981; Worsey & Qu, 1987). The solution to minimize the effects of these geologic conditions is to bring the borehole spacing closer together. Traditional presplit design would use 'split-factor' to adjust the explosive load based on a linear relationship with spacing.

The mechanisms behind a presplit formation are not well researched and understood. The shock breakage theory is still widely taught and studied (International Society of Explosive Engineers, 2016; Salmi & Hosseinzadch, 2014) even though this theory has numerous studies showing how it is not applicable and is a false concept (Konya C., 1973; Worsey P., 1981). In fact, under this theory methods such as Precision Presplitting could not work to produce a presplit. A new theory that the explosive generated gasses in a borehole causes a hoop stress field which causes the presplit fracture to occur (Konya & Konya, 2017) would indicate that very small explosive loads could be used, depending on the rock type and structural environment, to generate a fracture without causing any overbreak to the surrounding structure. It has been proposed that this hoop stress field will be a function of the gas pressure and the research on this project will focus on defining this gas pressure in a borehole from detonating explosives to determine if borehole pressures are possible to generate these hoop stress fields.

2. MECHANICS OF PRESPLITTING

In today's blasting industry both shock breakage (Zhang, 2016) and gas pressure (Konya & Konya, 2017) breakage is presented in modern technical papers focusing on the mechanism behind presplit blasting. Many have also argued that the mechanism behind the presplit is unimportant or academic, which may be true for the traditional case of presplitting which remains the same under almost all circumstances. However, with the advent of Precision Presplitting the mechanism behind a presplit is of importance as changes to dimensions such as the spacing of boreholes and explosive load in a hole are designed to meet the structural geology and rock properties. Without an understanding of the mechanisms behind a presplit formation a strategic design to eliminate overbreak while allowing for smooth breakage is impossible.

The first large scale explosive presplit was produced on the Niagara Power Project which was completed in 1962. This project was based in dolomite and limestone with a single layer of shale near the bottom of the excavation and had to have smooth walls in order to pour concrete against. During the project, numerous methods of controlled blasting were attempted including Line Drilling, Line Drilling with explosive loads in every third hole, Modified Cushion Blasting, Decks of Dynamites throughout the borehole, and finally presplitting. Presplitting was reported that the only method that produced satisfactory results to minimize overbreak was the presplitting which was accomplished by taping 32mm (1¼ inch) by 100mm (4 inch) sticks of dynamite on Primacord every 0.30 meters (1 foot). The boreholes were 63mm (2½ inch) to 75mm (3 inch) in diameter and spaced 0.61 meter (2 feet) apart and stemmed with crushed gravel. This resulted in increased rock excavation and a reduction in scaling by a factor of 10. Additionally, the project had significant savings on concrete costs and increased safety as the walls were cleaned smooth (Paine, Holmes, & Clark, 1961).

At the time, the project was designed based on the gas pressure generated by the explosive. The engineers assumed that if the gas pressure was kept below the compressive strength of the rock, they would avoid crushing the rock around the borehole. In order to create a break between boreholes the belief was that the borehole pressure had to be above the tensile strength. While this was a bit of a rudimentary theory at its time, however the project was completed and the presplit functioned extremely well. Following the project presplitting was widely accepted as the best and most cost-effective method of overbreak control.

Based on this theory, researchers of presplitting both in a laboratory and practical setting began looking into the decoupling of charges, or the reduction of the diameter of the explosive compared to the diameter of the borehole. This was done to decrease the dynamic gas flow on the borehole wall and to reduce the gas pressure in the borehole (Konya, Britton, & Lukovic, 1987) preventing large compressive strengths which would lead to overbreak (Day, 1982). However, this increase in decoupling ratio also led to minimal shock pressure transmission into the rock mass due to large impedance mismatches between explosives and air, then air and rock.

With the large increase in research of shock breakage in rock blasting, many authors began to investigate possible effects of shockwave collision between boreholes to develop tensile zones and causing presplit formation (DuPont, 1975; Crosby & Bauer, 1982).

This theory was widespread due to the popularity of the DuPont Blasters Handbook and it is still circulated amongst many leading organizations today (International Society of Explosive Engineers, 2016) and researchers (Salmi & Hosseinzadch, 2014). This theory was heavily disputed and shown in numerous studies of the day and it was shown that the shockwave has almost no correlation between the dynamic shockwave and the presplit formation, with numerous studies showing that the quasi-static gas pressure in the borehole was responsible for presplit formation (Konya C., 1973; Worsey P., 1981; Worsey, Farmer, & Matheson, 1981; Daehnke, Rossmanith, & Kouzniak, 1996). Additional studies were conducted utilizing a propellant charge, Pyrodex, to fire a presplit blast. These propellant charges produced no shockwave as they deflagrate, not detonate, (Akhavan, 2011) which completed isolated the gas pressure as the only working energy. Using the same principles as in traditional presplit design (Konya C., 1980), the propellant charges produced the exact same results as a presplit blast that was fired with detonating explosives (Konya, Barret, & Smith, 1986). This proved that presplit mechanisms on a full-scale blast had no reliance on the shockwave generated by detonating explosives.

This led to the development of a Precision Presplit style of blasting, where extremely light loads of detonating cord are utilized to prevent all breakage except for the breakage between boreholes (Konya C., 1982).

BACK TO TOP

This design utilized closely spaced borehole of 0.61 meter (2 feet) or less, to minimize the impacts of rock structure on the presplit (Worsey P., 1984; Worsey & Qu, 1987; Tariq & Worsey, 1996). As this design methodology has begun widespread use, new empirical research into the explosive loading based on the rock properties has been developed (Konya & Konya, 2015; Konya & Konya, 2016; Konya & Konya, 2017).

This method of Precision Presplitting has effectively zero shock energy to form a fracture after accounting for impedance mismatches (Cooper, 1996), non-ideal detonation (Cook, 1974), and attenuation of the shockwave in the rock mass (Spathis & Wheatley, 2016). It has then been theorized that the mechanism behind the presplit formation is due to large hoop stresses which are generated between the boreholes causing a fracture, with no advancement of the fracture from gas penetration (Konya & Konya, 2017).

3. PRECISION PRESPLITTING

Precision Presplitting is a presplit design technique which was first applied in the 1982 (Konya C. , 1982) and utilized extremely light loads in closely spaced boreholes to form a presplit with no overbreak in weaker rocks. As it developed, the rock type was considered which dictated variations in the explosive load, with granites requiring a much higher load than a sandstone or siltstone. Those with experience in this method began to have a feel for general ranges that each rock type required based on a 0.61 meter (2 foot) spacing between boreholes, and in a test blast could identify the required load in most rock types. These empirical methods were the basis behind precision presplit design originally, just as they are on traditional presplit design, and relied on the engineer's experience.

The borehole loads were typically so light that no commercially sold presplit powder was available for the application of precision presplitting. The use of dynamite charges on detonating cord was also not applicable as the areas of dynamite would cause significant overbreak. The only available choice to keep the borehole loading light and consistent was detonating cord which in weak rocks, such as mudstones and siltstones, which may be kept under 64 g/m (300 grains/ft). In 2015 the authors began analyzing this empirical data from numerous construction projects around the United States to develop equations to estimate the explosive load for a precision presplit based on a rock's Young Modulus (Konya & Konya, 2016). The authors found this to have a good correlation and Figure 1 shows the linear relationship between the explosive load (g/m) and the Young Modulus (GPa).

The Young Modulus was chosen as the major parameter for this work as it is normally readily available on major construction projects in the United States. Other parameters such as tensile strength would also be of importance, however these are typically not included in most geological reports for contractors on construction projects or in mines.

Figure 1. Explosive Load to Young Modulus Comparison with a 0.61 meter (2 foot) spacing between boreholes

If the Young Modulus of the rock is not known, it can easily be found for a majority of rock types through a literature review as well and the Young Modulus does not vary as much as tensile strength. The equation to estimate the explosive load for a 0.61 meter spacing is shown below in

Equation 1:

$$EL = 4E - 11.8$$

Where: EL = Explosive Load (g/m)
E = Young Modulus (GPa)

The next step of the research was to develop a method to design the explosive load at any distance borehole spacing (Konya & Konya, 2017). The first step of this was the development of a presplit factor which could be scaled using the Young Modulus of a rock. The Konya Presplit Factor was developed and is shown by

Equation 2:

$$K = \left(\frac{40579}{E}\right)^{0.625}$$

Where: K = Konya Presplit Factor

This could then be used in Equation 3 to determine the explosive load for a rock considering any variations in spacing:

$$EL = 2{,}306{,}400 * \left(\frac{S}{K}\right)^2$$

Where: S = Spacing (meters)

The chart of various rock types explosive load (g/m) versus spacing (meters) is shown in Figure 2.

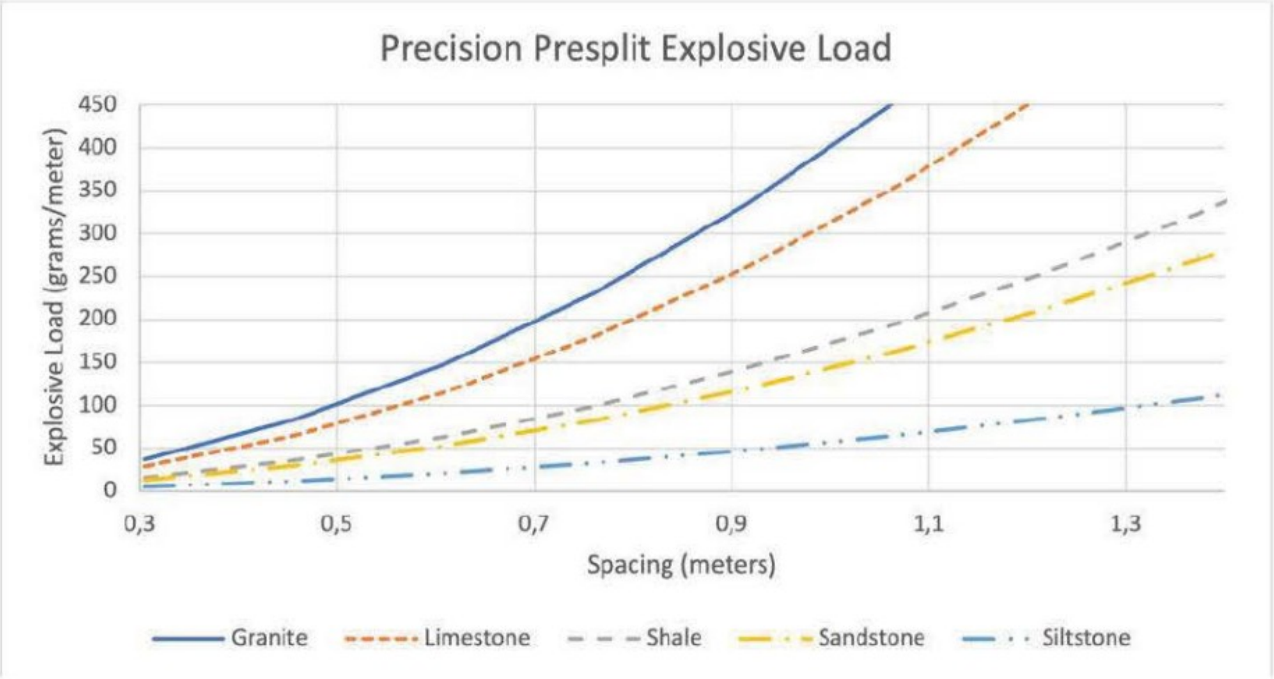

Figure 2. Explosive Load Variations based on Spacing for Multiple Rock Types

4. BOREHOLE PRESSURE

The mechanism of breakage being analyzed for the Precision Presplitting is the effect of gas pressurization of the borehole generating hoop stress fields between boreholes leading to fracture formation. This relies on the proper pressurization on the borehole and an accurate determination of the inter-borehole pressure. The authors have relied upon stemming studies utilizing borehole simulation equipment which could accurately measure the inter-borehole pressure from decoupled charges (Otuonye, 1981). The table of pressures has been recreated below in Table 1. This pressure data was developed using decoupled PETN charges which were highly decoupled. In addition, this data includes holes that where stemmed and all stemming was retained and holes which had the stemming ejected at some point during the detonation.

Weight of Charge (Grams)	Pressure (PSI)	Weight of Charge (Grams)	Pressure (PSI)
10	9,000	30	27,000
10	11,000	30	28,000
10	10,000	30	27,000
10	10,000	30	26,000
20	19,500	30	27,000
20	17,000	30	25,000
20	18,000	30	30,000
20	15,000	40	37,000

Table 1. Recreation of Borehole Pressure Based on Charge Weight (Otuonye, 1981)

The authors have utilized this data to create Equation 4, which can be used to estimate the pressure in a borehole (GPa) based on the explosive load (g/m). This equation has a R_2 value for the data of 0.9696 showing excellent fit even with various stemming ejection conditions. This equation is specifically applicable as a basic equation for precision presplitting and has not been evaluated in various other applications.

BACK TO TOP

This equation has a R_2 value for the data of 0.9696 showing excellent fit even with various stemming ejection conditions. This equation is specifically applicable as a basic equation for precision presplitting and has not been evaluated in various other applications. The authors do not recommend using this as an all- encompassing borehole pressure equation for other charge configurations and methods of blasting as this equation is based on extreme decoupling with PETN charges and would be unrepresentative of other situations.

$$P = 0.0009\mathrm{EL} - 0.0095$$

Where: P = Borehole Pressure (GPa)

This equation 4 will then be utilized in accordance with equation 3 to develop an equation determining the total pressure required for fracturing of various rock types.

This will result in Equation 5, which can be utilized to determine the borehole pressure required for a presplit to form based on the spacing of the presplit boreholes.

$$P = 2075\left(\frac{S}{K}\right)^2$$

Where: P = Pressure (GPa)
S = Spacing (m)
K = Konya Presplit Factor

This equation has then been used to develop Figure 3 which shows the inter-borehole pressure required to cause a presplit to form in various rock types.

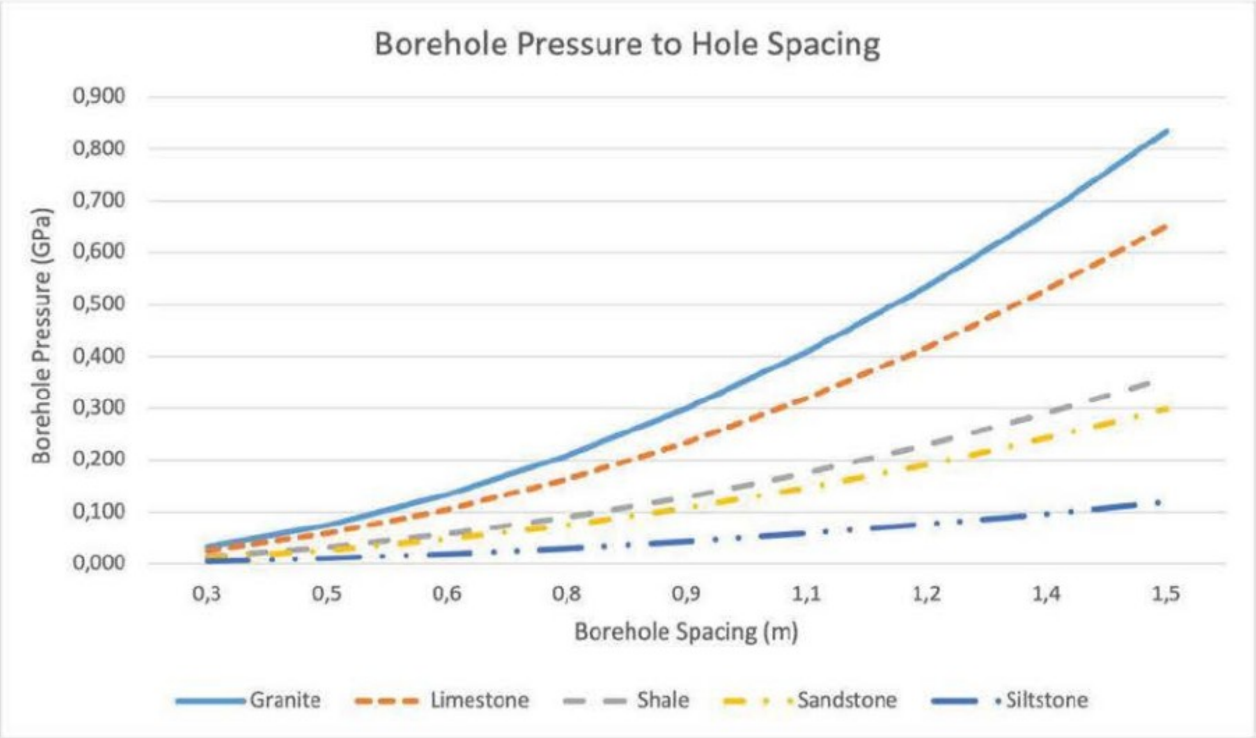

Figure 3. Borehole Spacing to Borehole Pressure based on Equation 5 for Various Rock Types

This model gives engineers the ability to change numerous parameters in a presplit blast, such as the stemming length and stemming type in accordance with the retention and ejection borehole pressure models; the explosive type; the decoupling ratio; the loading parameters; etc. in order to obtain proper borehole pressures for fractures to form. This can be considered a low level of required pressure to obtain fracture which is slightly above the minimum. The model does slightly overestimate the pressure required for a presplit at close spacings, especially for weak rock, and it is advised that this be utilized for spacings above 0.61 meter (2 feet).

The authors are currently conducting research using a borehole simulation pressure cannon to further develop the pressure to presplit relationship, particularly at close spacings for weak rock types.

5. CONCLUSION

In this paper a model has been presented to determine a low-level required borehole pressure to cause a fracture to form from a presplit blast. This was completed using previous research projects the authors had completed using empirical data to define explosive loading versus Young Modulus and spacing equations along with research completed collecting data on borehole pressure from extremely decoupled PETN charges in a borehole simulation device. This indicated that two main parameters are important to determine the pressure required in a presplit; the rock type and the spacing that is between boreholes. The rock type is characterized by the Konya Presplit Factor, which is based on the rock’s Young Modulus. Equation 5 can then be utilized to obtain a low-level inter- borehole pressure required for a presplit to form. This can then be utilized by engineers with other inter- borehole pressure models to develop presplit blasts in various rock and hole alignment conditions.

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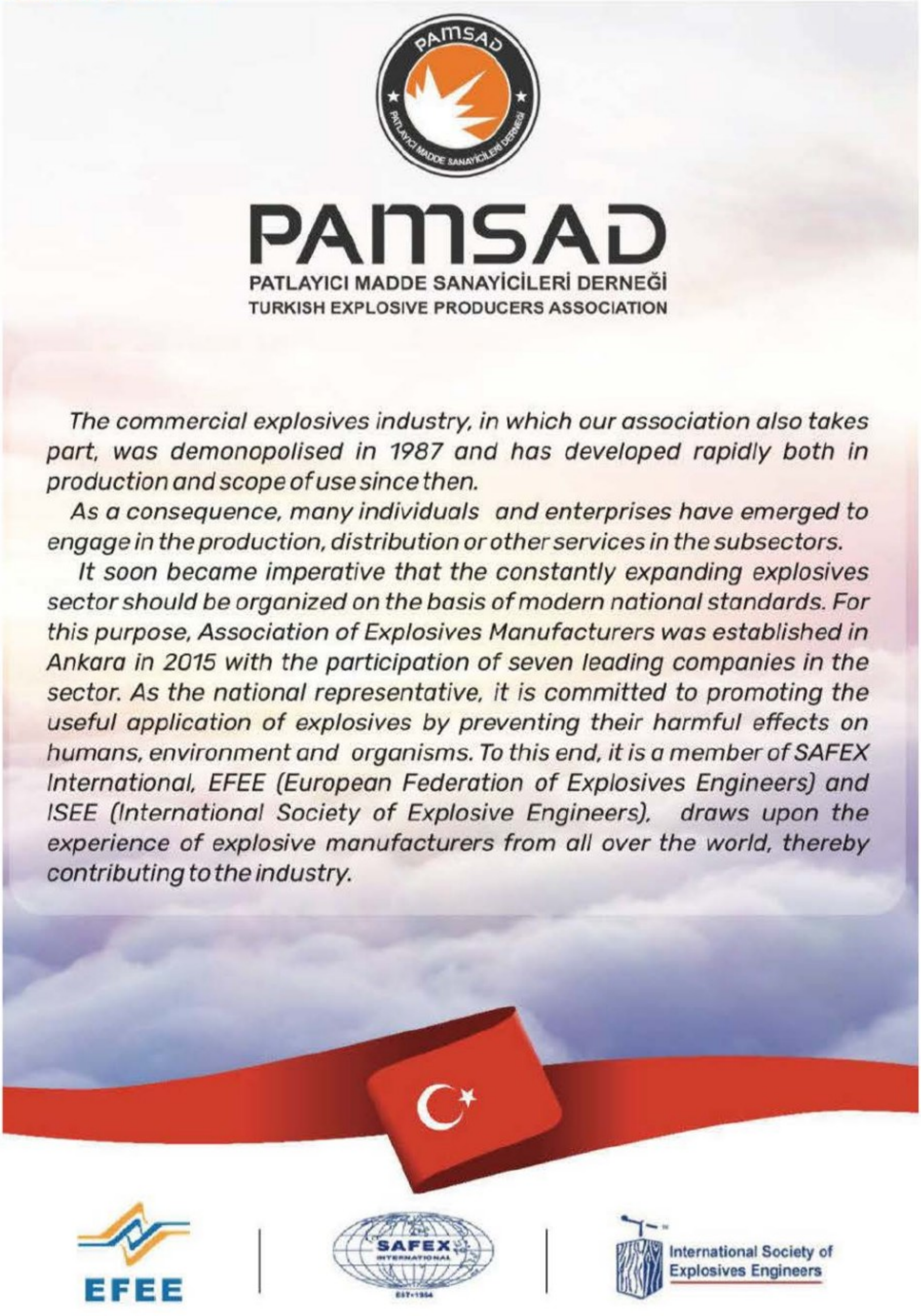
Introducing the EFEE Members - Turkish Explosive Producers Association PAMSAD



PAMSAD

PATLAYICI MADDE SANAYİCİLERİ DERNEĞİ
TURKISH EXPLOSIVE PRODUCERS ASSOCIATION

The commercial explosives industry, in which our association also takes part, was demonopolised in 1987 and has developed rapidly both in production and scope of use since then.

As a consequence, many individuals and enterprises have emerged to engage in the production, distribution or other services in the subsectors.

It soon became imperative that the constantly expanding explosives sector should be organized on the basis of modern national standards. For this purpose, Association of Explosives Manufacturers was established in Ankara in 2015 with the participation of seven leading companies in the sector. As the national representative, it is committed to promoting the useful application of explosives by preventing their harmful effects on humans, environment and organisms. To this end, it is a member of SAFEX International, EFEE (European Federation of Explosives Engineers) and ISEE (International Society of Explosive Engineers), draws upon the experience of explosive manufacturers from all over the world, thereby contributing to the industry.

BACK TO TOP

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.

Individual Members

Scott Scovira, BME Explosives, USA

Upcoming International Events

SME Annual Conference and Expo
1-5 March, 2021
In virtual format
www.smeannualconference.com

HILLHEAD 2021
June, 22-24, 2021
Hillhead Quarry
Buxton. UK
HILLHEAD Digital
9-10 March 2021
https://www.hillhead.com

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

EFEE 11th World Conference on Explosives and Blasting
September 26-28, 2021
Maastricht, Netherlands
www.efee2021.com

ISEE 48 th Annual Conference on Explosives and Blasting Technique
January 30-February 2, 2022
Las Vegas, Nevada, USA
https://www.isee.org

SAFEX International Congress
April 3-8, 2022
Salzburg, Austria

The SAFEX Congress planned for September 2021 has been postponed till 3-8 April 2022 as a result of the uncertainty around the effect the COVID-19 Virus.

https://www.safex-international.org/safex/news-safex-congress-xx-in-salzburg.html?sid=1580472102
WORLD TUNNEL CONGRESS 2021
UNDERGROUND SOLUTIONS FOR A WORLD IN CHANGE
April 22-28, 2022
Bella Congress Center Copenhagen, Denmark
https://www.wtc2021.dk/

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

26th World Mining Congress
June 25-29, 2023
Brisbane, Australia
https://wmc2022.org/

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