

The Didcot Demolition

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Abstract

In the modern world of demolition safety is paramount and unnecessary or unquantifiable risks are not accepted (FasterCapital, 2024) and all risks must be kept As Low As Reasonably Practicable (ALARP) (BSI, 2017). This principle has led to a huge reduction in deaths in the last 50 years and the statistics continue to improve although this is starting to plateau (Beal, 2007). Under normal circumstances, this is now simply part of the normal way work is done and systems are in place to ensure both safety and economic profits are assured. What happens when the environment is less controlled and risks are unknown, such as after a natural disaster, war, an accident or a stand-up from a failed demolition attempt? A dangerous structure cannot responsibly be left alone with a fence around it so some action must be taken, but how can this be done safely and responsibly? An incident in Didcot, England in which half of a power station's boiler house being prepared for an explosive demolition collapsed suddenly, killing four men in 2016 provides a useful case study of how technology, creativity and planning can be used to conduct complex demolition fully remotely to avoid any further risk to life.

Introduction

The principal difference between conventional demolition and explosive demolition is not actually the use of explosives, or the collapse mechanisms, but rather the fact that unlike burning, crushing or lifting out elements of a structure in a gradual and progressive manner that can be paused at any moment, with explosives the entire structure remains standing and (assuming the correct calculations have been done) able to stand almost indefinitely, when the initial train starts, there is no way to press pause on the demolition. It will either collapse as designed, or fail, but as one renowned “blaster” has said, that in demolition you can only “trust in God and Gravity” (Gilbert, 2024). This distinction makes explosive demolition both riskier (there is no opportunity to stop and do some more engineering calculations) and more unforgiving (if something is going to go wrong, it can be disastrous).

In the past it has been normal to accept a degree of risk to achieve a speedy resolution to situations in which structures are left in a precarious state after some form of incident, for example the Chaplain Towers South in Miami were successfully demolished a week after part of the block suddenly collapsed in 2021 (Wikipedia, 2024). The vast majority of these have resulted in a successful conclusion in which the structure ends up on the ground. Apocryphal tale of blasters re-entering structures soon after failed demolitions to place additional charges are common in the industry, but how they are justified from a safety standpoint is something that is much less talked about. As long as there have been no casualties resulting from these actions, and if huge costs can be avoided, this practice will continue, but for larger, multinational organisations, the risk of reputational damage generally far exceeds any financial gains.

The Didcot A Power Station in Oxfordshire, England began construction in 1964 and started operation in 1970 and had 4 500 MWe turbines. The construction was typical of British power stations of the day with top-hung boilers supported on large, box-section columns (‘Didcot power stations’, 2024). The original demolition contractor was following the standard method of fully pre-weakening the structure at multiple levels on each of the main columns with the bottom cuts on the columns being at roughly 45 degrees with the flanges sitting on horizontal shims. Dynamite kicking charges covered by sandbags were to be placed on the corners of the webs which were reinforced with steel plates. This method avoids the requirement for any linear cutting charges but does mean that prior to the demolition, the entire structure would be relying on gravity to hold together. It was a method that had worked for many years, until 23rd February 2016, when, for reasons that are yet to have been made public, boilers 3 and 4 collapsed during the final preparation cuts (fig. 1). Four men were beneath the structure at the time (the death toll would have been significantly higher had the rest of the crew not been on a tea break).

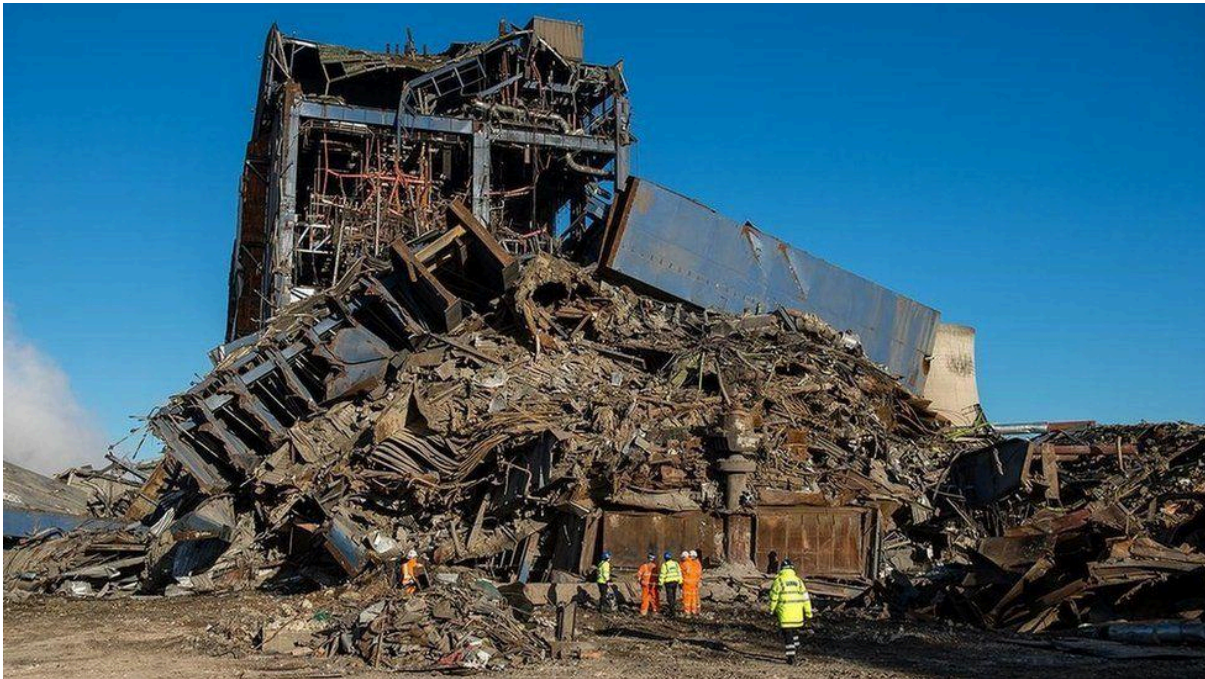


Fig. 1 Didcot Power Station's boiler house was set for demolition when it collapsed in February 2016 (Thames Valley Police)

The UK's Health and Safety Executive (HSE), the government's health and safety's governing body, were automatically involved because of the loss of life and the police took overall control of the site as they opened a criminal investigation looking into whether there had been any criminal wrongdoing that led to the accident. From a demolition perspective, the biggest consequence of this is that a 50m exclusion zone was put in place around the entire remaining structure. From that moment on, no-one crossed that line until after the demolition of the remaining structure was completed.

Discussion

The task of collapsing the structure using explosives without being able to send anyone within the safety cordon was undertaken by Alford Technologies, a UK-based explosive engineering and technology company best known for its EOD tools which also produces a range of user-filled linear cutting charges (Alford Technologies, 2021). (Hereafter referred to as "the Company".)

The company had not undertaken any commercial demolition work for many years but were uniquely qualified because of their explosive charges and most importantly, their ability to design and test new methods and techniques with their own in-house test facilities and production capabilities. Coming from outside the demolition "industry" was also seen as a major advantage as it meant the ability to understand problems without reliance on dogma and being able to inject fresh ideas and experience from other fields to solve new problems. This was essential to the ultimate success of the project as there were no tools and techniques that existed or had been attempted in demolition that could achieve the desired result remotely.

To fully appreciate the complexity of the project, it is important to understand the factors beyond the 50m exclusion zone that influenced all decision making and what could and could not be attempted.

Grieving Families and Politics

At the heart of the situation were the bodies of three of the four men killed in the accident, the fourth having been just next to the structure and recovered immediately after the accident. Their bodies remained under the debris and could not be recovered as they lay within the exclusion zone. The speedy and respectful recovery of their bodies was the top priority for all. In the immediate aftermath of the accident, plant was used to start removal of the debris, starting at the furthest position from the standing section, but that work stopped at the 50m line. In the very early stages, it was a possibility that at least one of the men might have been alive, but as time went on hope was lost of that. Specialist dogs trained to find bodies were brought in and a bomb disposal robot was brought from the nearby EOD regiment to look at the structure close-up, but no sign of the bodies was seen.

The grieving families soon became increasingly vocal and hostile to what was going on as they were not well informed of the efforts to recover their loved ones (fig. 2). As soon as the initial attempts to remove steel ended, there was little visible activity on site which they mistook for a lack of effort and action. Little could have been further from the truth, but perhaps worried about future legal actions if they said the wrong thing and lacking an alternative way to avoid the bear-pit environment of face-to-face meetings, the site's owners kept engagement with the families to a minimum. The same was not the case in the other direction and the company was required to give weekly briefings to the Prime Minister's office on progress. They were clearly felt squeezed somewhere between a rock and a hard place.



Jade Ali, from Swansea, criticises the search for her missing partner Christopher Huxtable

Fig. 2 The families took to protesting outside the main gate of the site demanding more action to recover the bodies of their lost ones (BBC)

At some stage during the project members from The Company demolition team were asked to meet the families. It could have been like being thrown under a bus had it not been for the fact that, as

former army EOD operators, they had been trained specifically on how to deal with bereaved families properly. They invited the families into the area where The Company's team was developing techniques for placing charges using robots and talked through the complexities of the task at hand, assuring them that every effort was being made to bring the situation to a speedy conclusion. Comments along the lines of "we had no idea" and "now we understand what you are doing" were expressed and from then on regular meetings were held, although that did not mean an end to the often emotional and confrontational nature of the "conversations".

Police Engagement (and HSE)

The first consequence of the original accident having led to the death of four men was that both the police and HSE descended upon the site. They didn't leave until well after the demolition was complete. The entire area became a crime scene and anyone entering had to sign in through a police checkpoint despite having already passed through two separate checkpoints. No photos or videos were allowed to be taken without permission and any that were taken had to be submitted as evidence, complete with written police reports before they could be taken off site.

Anything recovered from the site also had to be taken to a secure evidence yard set up in a separate area. This included all sections of steel which had to be checked by a structural engineer for any evidence of having been part of the cause of the collapse or which might show evidence of the pre-weakening work that had been done. Anything that was considered of interest was retained in a long-term evidence yard and are apparently still being held at an HSE site in another part of the country.

The practical implication of having the most senior HSE inspectors permanently on site was that everything done was always under the spotlight. Fortunately, such was the determination of everyone involved to succeed, a very positive set of working relationships were formed between all parties that ensured that things that might normally have become divisive were rapidly resolved and progressed.

It is perhaps because the accident occurred in the UK but at the time of writing, more than eight years after the accident, the report into what caused the accident has not been released. The author speculates that this is due to the police not wishing to compromise any future prosecutions by putting information into the public domain.

Treat like an EOD Task

It was in this complex environment that a demolition plan had to be developed. Working under the spotlight, The Company's had to start pulling a team together. Within their ranks there were ex-army and navy personnel who had many years of experience using explosives but no commercial demolition experience. The decision was made to maintain this situation and to build a team almost exclusively consisting of people from a military background. This was because it was decided to run the project very much as a military exercise on the basis that the most relevant expertise for conducting complex remote operations came from the field of Improvised Explosive Device Defeat (IEDD) which is a sub-category of Explosive Ordnance Disposal (EOD).

While movie depictions of IED operators historically show someone trying to figure out whether to cut the red or the green wire but the reality is that the first option is always to act remotely, normally using an EOD Robot or Remotely Operated Vehicle (ROV) that is typically a wheeled or tracked

vehicle brisling with cameras and a robotic arm. If that fails or is not possible, normally due to a limitation of the available robot, a semi-remote method would be tried in which a robot will do some of the work and the human intervention is reduced as much as possible to reduce the exposure time. Only if both these methods have failed would a fully manual technique be attempted. The same philosophy was going to be applied to the demolition. Sending men into the exclusion zone would not be done unless all remote methods had been exhausted and failed. In the event, the entire demolition was done fully remotely.

Plans

The basic plan was drawn up during the first phone call that came in and although detail was added, this outline remained. It was fundamentally simple:

1. Use EOD robots to fix charges using strong magnets normally used for fixing explosive charges underwater for destroying limpet mines
2. Use the company's existing linear cutting charges to make the final cuts on as few columns as possible to guarantee a full collapse (Alford Technologies, 2021)
3. Use the company's expertise in explosive breaching charges to kick cut sections of columns out of alignment to trigger a collapse (Alford Technologies, no date)
4. Design a method of connecting charges together to allow charge groups to be initiated simultaneously enough to not cause cut-offs

A Fleet of Robots

While it might sound simple to get some EOD robots and drive them under the structure, it was soon proven to not be the case. They are generally built to order, and the manufacturers generally only have one or two that they use as demonstrator vehicles. Trying to get hold on them was not a simple task and required a good contact list. Eventually a company in the Republic of Ireland were able to provide two vehicles one of which was the only existing final prototype of their latest and most sophisticated model ('Reacher', 2024) which the manufacturers said they could not afford to lose (fig. 3a). A second British manufacturer were able to supply two smaller vehicles that were several years old, but which had just been upgraded to the latest specification (AB Precision, 2017).

These ROVs are like the Formula One cars of the military. Costing more than a sports car, they are highly sophisticated vehicles that are looked after and maintained by a crew of mechanics and technicians. They are designed to work for a few hours and then to go back into the workshop to be serviced. They were not designed to be used constantly for weeks as would be required in Didcot so both suppliers also provided technicians to keep them working. Former military robot operators were recruited to drive them.

It was also decided to bring in a pair of commercial Brokk 160 machines which could be used with an extended umbilical, but which had the latest remote controls fitted. Unlike the military robots, the Brokks are designed to be used on commercial demolition sites and are expected to work, day in, day out with little maintenance. What they lack are any cameras or the dexterity and ability to do delicate work.

Finally, it was discovered that the British Army still had two JCB backhoes, painted green, fitted with remote controls and called the Light Wheeled Tractor but that they had been scheduled to be taken out of service in the next two weeks. A few calls to the right people in authority and their scrapping was halted and they were delivered to site along with a team of servicemen. For that to happen, the police had to request support (in the form of the robots) which was given as a Military Aid to the Civil Power (MACP) task (fig. 3b).

The entire fleet of ROVs ended up consisting of a total of eight vehicles, each with its special capabilities but with overlap wherever possible to give depth and redundancy. The manufacturers of the robots estimated that in three months the robots had done the equivalent of three years of normal operations. This had shown them which components were breaking most frequently, giving them the opportunity to redesign and improve them.

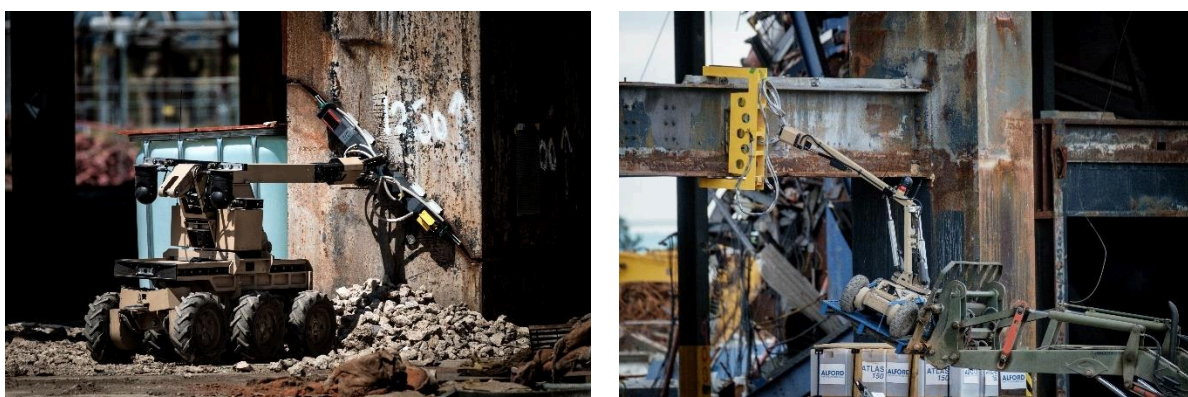


Fig. 3 a. The prototype Reacher was used to place linear cutting charges on the structure. B. The army's Light Wheeled Tractor lifted the Hobo robot on forks to place charges above the maximum reach of the robot's arm (Alford Technologies)

Explosives

Cutting the three-inch flanges on the steel box-columns required the largest linear cutting charges made by the Company, the 80mm DIOPLEX Charge. Given the critical nature of the project, several large section of column, recovered from the debris of the collapsed structure, were delivered to the Company's test site. This allowed charges to be tested on actual pieces of the structure but also gave columns to test new kicking charges against.

Testing demonstrated the ability to cleanly cut through the columns with a single charge. The charges were then tested on a single column at another demolition site to demonstrate to some sceptics who maintained that linear cutting charges were unreliable. High-speed film clearly showed the column being cut and successfully being kicked out, putting that argument to bed.

The Dioplex charges contain a built-in stand-off to ensure connect positioning so attaching the charges simply required the addition of strong, rare-earth magnets originally designed for fixing shaped charges to ship's hulls for removing limpet mines. Spigots were then attached to the ends to allow the charges to be aligned with the channels that had already been burned into the ends of the

flanges and the robot operators got to work practicing the delicate operation of placing these charges, each weighing roughly 8kg, in the correct location and orientation (fig. 4).

Kicking the cut sections of columns would not be as straight forward. The Company had experience designing and making breaching charges which could be applied to the exterior of walls to make man-sided holes. These use water-tamping to significantly increase the efficiency of the charges by extending the impulse applied to the target. The scale of the columns at Didcot, which weighed approximately 24 tonnes, would require charges an order of magnitude larger than any of the existing breaching charges.

The typical kicking charges for this sort of column would be approximately 3kg of dynamite applied to the edges, aligned with the flanges and covered by approximately 20 tonnes of sandbags. Placing these charges and sandbags remotely was not considered practicable so a system capable of being carried and placed by ROV was required.

Many variants of existing charges were tested against the sample columns at the test range to come up with a new system powerful enough to move the columns far enough to ensure that they could not be pinned in place. Eventually, the ATLAS 150 charge was developed. This was a modular charge system, taking its name from the Titan condemned to hold up the heavens in Greek mythology and the 150-litre volume of each module. Taking approximately 7kg of high explosive surrounded by water. When two or more charges are placed side by side, the collision effect of the shock waves from adjacent charges produced an additional forward projection of the water in front of the charge giving greater impulse than the sum of each charge separately (Alford *et al.*, 2016). This was used to project a pusher plate consisting of a steel covering the entire front of the combined charges and extending far enough beyond the sides to ensure that the plate would push the web and both flanges of the box-section to avoid all the energy being applied to the web which would simply fail.



Fig 4. The modular ATLAS 150 was designed and developed specifically to kick columns out of alignment. The Magnetic Bunch Connector board can be seen with two protected detonating cord links.

All these charges required plastic explosive which is not readily available in large quantities to civilian companies. Using their industry contacts, a manufacturer in Finland agreed to supply their PENO military explosive (Forcit Defence Oy, 2015). Obtaining an export licence is normally a process taking at least a month, but the urgent nature of the project meant that the Finnish Minister of Defence personally signed the licence in only four days.

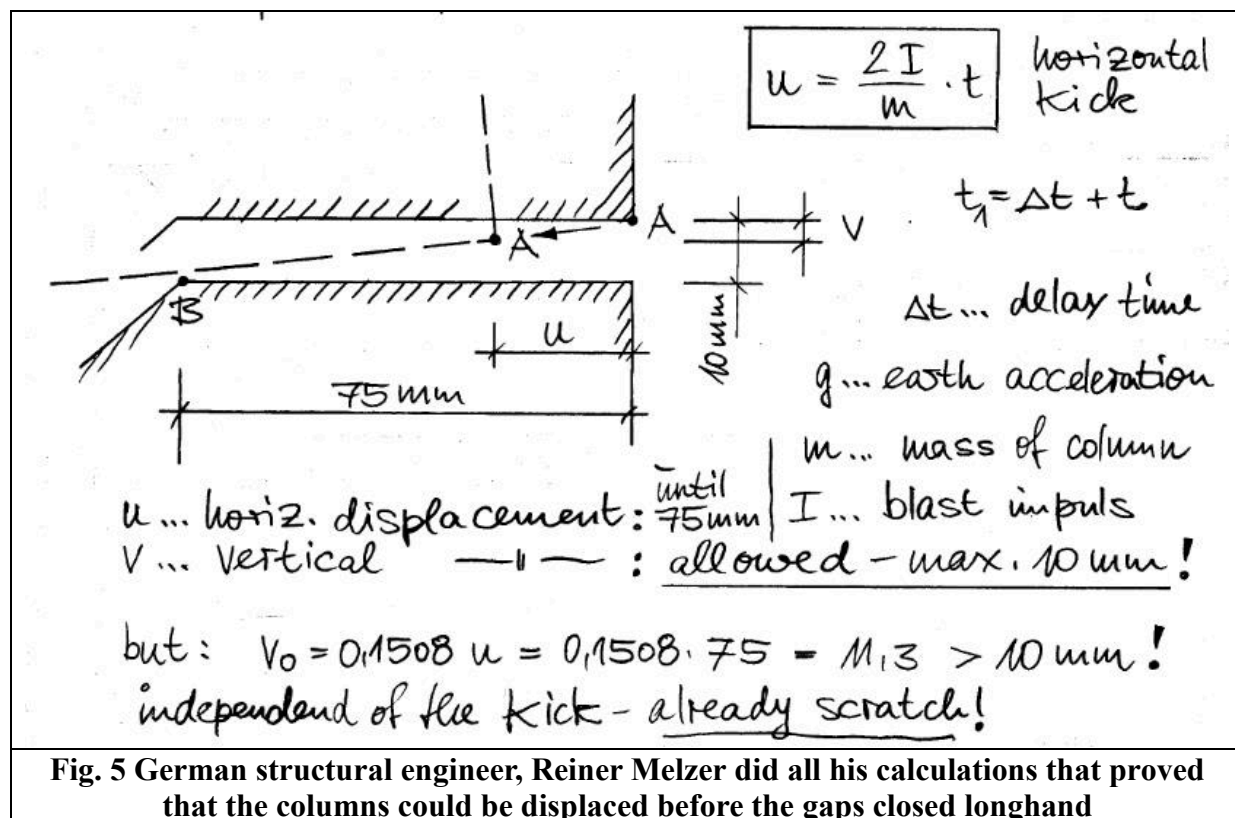
The final problem to be solved was how to ensure that all the charges would initiate at the correct times. Charges fitted to a single column would need to go off simultaneously to avoid the shock, blast and fragmentation from charges displacing or destroying adjacent charges. This is normally achieved by using equal lengths of detonating cord from the initiator as even electronic detonators connected to each charge has been shown not to provide the degree of simultaneity needed to guarantee success. It was also realised that having too many connections, whether they were wires, shock tube or detonating cord would increase the risk of an ROV snagging and pulling charges off. A simple means of connecting charges was required.

The answer was what became known as the Magnetic Bunch Connector. This was an explosive connection board consisting of a sandwich of plywood, sheet explosive and perforated sheet steel. This was fixed to the structure using magnets and acted as a central “exchange” for the initiation train. Each charge being connected was fitted with a detonating cord tail terminating in a magnetic connector that could be attached to the MBC using powerful magnets. Each board would be initiated with a detonator fitted with a small booster-charge that was also fixed using magnets. When the

detonator fired, the entire MBC board initiated and each of the detonating cord tails, of equal length, were initiated simultaneously. Looking about like an explosive spider when installed, the system was found to be highly effective.

Structural Engineering

Although the Company had been awarded the contract to develop a demolition design, a Plan B was being developed elsewhere for a traditional and fully manual method to complete the job and there was a degree of scepticism, sometimes even hostility to what was perhaps seen as a disruptive new organisation. This created a problem when it came to finding a structural engineer who would not be blinded by dogma and pre-conceived ideas of what would and would not work. It was therefore decided to look further afield for a structural engineer. Eventually Dr R Melzer from Germany was found who was vastly experienced and who still did all his calculations long-hand on very elegant hand-written pages (fig. 5). His calculations estimated that there was approximately a 25ms window between charges cutting the steel and the gap created closing as the structure dropped vertically. At that moment the coefficient of friction would increase dramatically making it much harder to kick the columns out of alignment (Melzer, 2016).



The robots were used to take a laser scanner (*FARO Focus Laser Scanner*, 2024) under the structure to conduct laser scans of all the key elements to conduct a virtual recce that would allow accurate measurements to be taken and to confirm which cuts had been completed before the accident and which would need to be done explosively. This allowed Melzer to complete his calculations. The positive outcome was that it was concluded that only the eight major columns supporting the boilers needed to be removed to trigger a full collapse of the boiler house.

Modelling Charges

The ATLAS 150 had been designed as a modular system that could have various adjustments made, such as changing the type and quantity of explosive, and the tamping medium used. Testing of the system had been conducted on short sections of column weighing only a few tonnes, far less than the 24 tonnes of the actual columns. The only thing that was known was that 3kg of sand-tamped dynamite would be expected to work, although whether that was the optimal amount, just enough or massive overkill was not known.

It was decided that in the absence of any other data, the 3kg charge would be used as the benchmark for success and the ATLAS 150 would need to be capable of delivering the same impulse. Measuring the impulse from these charges is not practicable as the normal tools for measuring, such as the *Hopkinson bar* (Hopkinson, 1915) and the *ballistic pendulum* (Alford, Hazael and Critchley, 2023), would not survive the shock from these large charges. The only way to obtain data was to use finite element analysis to model the charges.

The veracity of modelling is subjective as the person creating the model must make decisions and assumptions that might not be correct that can influence the results (Madier, 2024). Sceptics sometimes point out that a model can be tweaked to show whatever result you wish it to but in truth, models may become inaccurate if the wrong boundary conditions or inappropriate constraints are used (Ansys, 2024). In this case, the modelling was the only tool available to guide the selection of the final load of the ATLAS 150 charges and was an essential part of the design.

The complexity of the model and the performance of the software meant that the run time was over 24 hours, however after the initial runs had been completed, it was found that some factors could be simplified in the model without significantly changing the outcome and the run time was eventually brought down to about 3-4 hours allowing more iterations to be run as the target impulse of 24-28 kNs was approached (fig. 6).

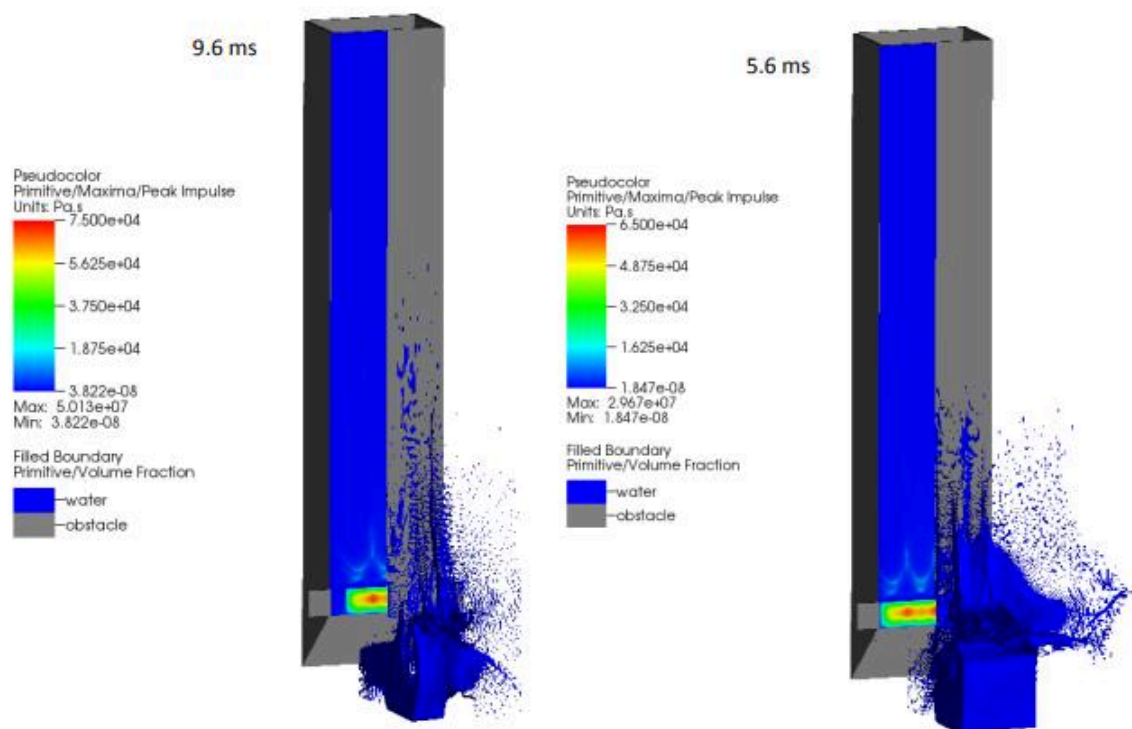


Fig. 6 Finite Element Analysis was carried out to calculate the impulse being applied by charges, allowing the correct number of modules and explosive load to be used in the kicking charges (Fluid Gravity Engineering)

Training

A key element of all military actions is frequent and realistic training. While the charges and demolition plans were being developed, training began for the ROV operators. This became an essential part of the ultimate success of the project. Each of the ROV operators practiced each of the manoeuvres they might be required to perform on a training area set up adjacent to the structure. Techniques were developed to carry and place charges, connect charges to the Magnetic Bunch Connectors and to find out what could go wrong and to find solutions to overcome those long before the first charge was going to be fixed. Each operator then had to undergo “certification” in which they had to demonstrate that they were able to operate effectively under the structure.

The training became more and more realistic, ultimately with dummy charges being fixed to the actual structure. This allowed operators to become familiar with the area under the structure. They were operating inside an ISO container, relying entirely on their cameras and unable to see the robots. Missions were then run to prepare the area, removing stray bits of re-bar that could snag or cause punctures and removing piles of crushed concrete that had been piled against the base of columns that were now in the way of the ATLAS 150s.

Special techniques had to be used to allow the EOD robots to place charges on beams 4.5m above ground. In operations in Northern Ireland during The Troubles, the Light Wheeled Tractor had been used to lift a smaller “wheelbarrow” ROV, strapped down to a pallet, so that it could operate through the window of a double decker bus. The same technique was now used to fix a charge group that would cut both flanges and the web.

The Demolition

Four months after the first site visit, all the elements were in place. A demolition collapse mechanism was in place, charges loaded and ready to be fixed in place and a fleet of robots with highly trained and ready operators. The client was satisfied that the plans were as ready as they could be and the go ahead was given to proceed on the afternoon of Wednesday 13th July. Despite the complexity of fitting the charges, by the end of Friday, all the charges were fixed, and the last detonator was connected to an MBC. Only one robot was still working, the rest having failed in some way due to the constant battering and back-to-back missions.

The final preparations went like clockwork and the final demolition went perfectly (fig. 7). It would be another six weeks before the three bodies would be recovered from the debris and returned to the families.

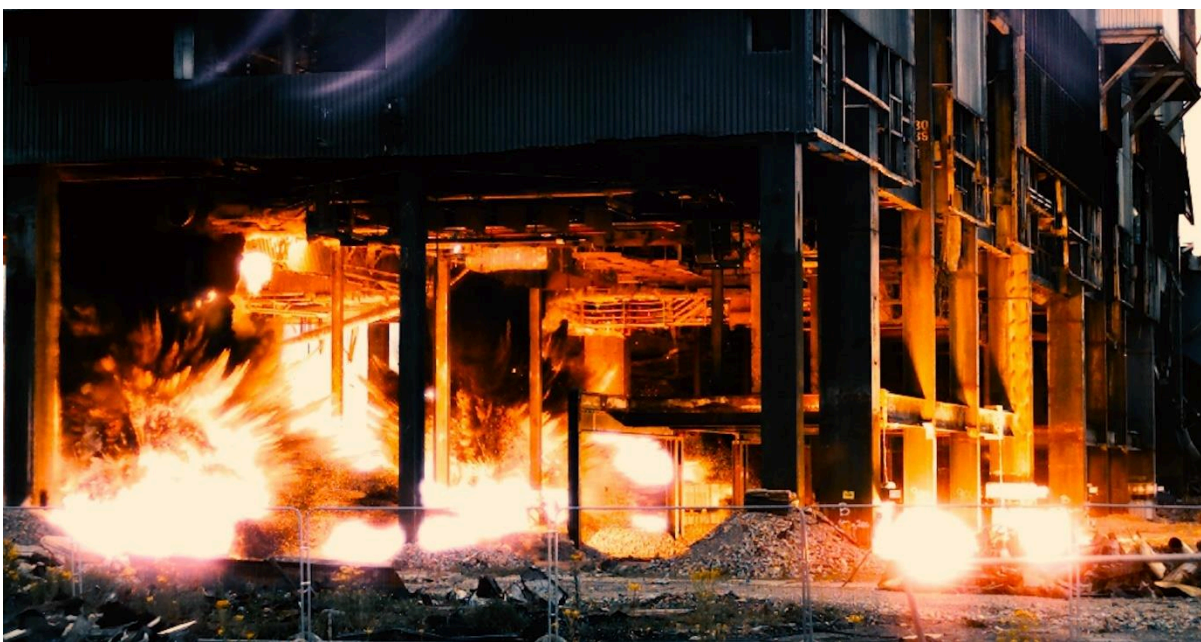


Fig. 7 Slow motion video allowed the detonation sequence to be captured in detail for post-bast analysis

Conclusions

The Didcot Demolition was a unique situation that presented several problems that had to be overcome. What it did show is that it is possible to conduct complex demolitions completely remotely if necessary. The historical acceptance of accidents and fatalities moved, and the new paradigm is one in which simply running into a potentially dangerous structure to place charges for a speedy resolution is often deemed reckless and unacceptable meaning that this situation is likely to happen again.

Technology has continued to advance since 2016 and other commercially available robots could potentially do many of the things that were once the exclusive domain of EOD robots.

The highly political environment in Didcot meant that no expense would be spared, and the job would take as long as it needed. It is unlikely that this attitude could become the norm on all sites, so

some compromises might be required, for example by monitoring structures for a few days before moving to a semi-remote method to reduce the exposure to risk to a minimum.

No report on what caused the accident has been released, possibly to secure evidence for a future prosecution. This is a highly unsatisfactory situation, not only on a human level for the families of the men who died, but also for the industry who need to be made aware of what happened to prevent it from happening again.

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International Society of Explosives Engineers

<https://isee.org/news-landing/2025/02/24/isee-hosts-51st-annual-conference-on-explosives-and-blasting-technique-in-cherokee--nc>

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