UNEXPLODED ORDNANCE

ON MAY 8 1945 Winston Churchill broadcast to the UK that World War II had come to an end, marking an Allied victory in Europe following six years of war. It has been 70 years since the end of WWII yet Unexploded Ordnance (UXO) can still be a serious problem to construction projects throughout the UK. It is estimated that 10 per cent of bombs dropped on London alone failed to detonate and could therefore pose a threat if unearthed.

There has been an increased emphasis on brownfield development, which includes many inner city areas that were targeted during WWII, and therefore it is unlikely that the risk of encountering UXO during the construction phase of projects will diminish in the near future.

Furthermore, there is currently little publicly available guidance to specifically assist construction professionals. Indeed, up until 2007 construction professionals depended solely on UXO disposal contractors and there was no technical guidance. There was also no direct legislation regarding the potential UXO risks encountered by the construction industry.

Construction Industry Research and Information Association (CIRIA), through its research project, "A clients' guide for assessing risk on UXO sites", has produced the first UK good practice guidance to help developers and clients deal with UXO. The guide enables these professionals to understand the different approaches and how to appoint specialist contractors, and the second half of this feature will look at the risk and how to mitigate it in more detail.

"There is definitely limited knowledge of UXO by many developers, even ground workers might never encounter unexploded ordinance unless they are working in areas that are heavily contaminated such as London or Coventry," says Simon Cooke, managing director, 6-Alpha Associates. "They might only come across it once or twice in their lifetime. In the past, there has been inappropriate advice for dealing with UXO. Typically, there was a lot of scaremongering going on."

UXO (unexploded ordnance) can arise from both hostile and defensive military activity and is often related to World War I and II. **Simon Cooke**, *6-Alpha Associates*, explains to the March 2015 meeting of the *British Tunnelling Society* how UXO can pose a risk to tunnelling activities and how risk can be managed and mitigated to ALARP (as low as reasonably practical), in accordance with the law and using best practice

***Below:** Modern military engineers preparing unexploded ordnance (and IEDs) for disposal*

THE THREAT

Let's look at what unexploded ordnance is. According to the United Nations, "unexploded ordinance (UXO) are explosive munitions, which have not yet been set off. UXO may already have been fired, dropped, or launched, but it has failed to detonate as intended."

High explosives effectively have the capacity to transfer energy very quickly. They pose a risk of detonation. If a bomb was discovered, unearthed, and did explode it would work very much as intended during WWII; a significant blast wave will be generated together with concurrent fragmentation of the bomb case, with shrapnel flying omnidirectionally at supersonic speeds (more than 768mph).

During WWII many defensive establishments, cities and towns throughout the UK were subjected to comprehensive bombing campaigns, which resulted in extensive damage to city centres, railway infrastructure,

docks, associated industrial areas and military installations. Across London an average of 84 bombs fell on civilian targets and failed to explode every day from 21 September 1940 to 5 July 1941. Most of the unexploded bombs found were either 50kg or 250kg. However, UXO can range in size from Small Arms Ammunition to large UXBs weighing more than 2,000kg.

"A WWII 250kg bomb only contains about 25kg of high explosives," says Cooke. "Builders would find them and dig them out on a Tuesday afternoon, put them to one side and leave it until Friday afternoon because they didn't want any down time. We would then be called out, which could be highly dangerous especially if it's left baking out in the sun. Interestingly the smallest bomb dropped in London in WWII was 50kg – and over 50 per cent of bombs dropped were one of these. There were 17,000t of bombs dropped on London alone in WWII. 50 percent of these contained about some 25kg of high explosives. If a JCB at its maximum digging capacity had a 6m reach and initiated that bomb, it would kill. That's the smallest of the bomb – then it's the 250kg, around about of which 50 per cent is high explosives. Then it's the 500kg, the 1,000kg and larger varieties – so highly dangerous and not to be trifled with."

Cooke also adds that the German bombs in WWII often incorporated booby trap mechanisms in fuzes, for example the German ZUS40 anti-removal bomb fuze. "Bombs were often booby-trapped with an integral anti-withdrawal mechanism designed to kill anyone who tried to render the bomb safe," says Cooke. "However, the Germans would drop bombs and 10 percent would not go off, which was by accident and not by design. Either the electric impact fuse has hit the ground and broke or sometimes they had insufficient charge in them (they were charged in the aircraft). If the bomb was booby trapped the delayed mechanism would last from zero to 72 hours on a countdown timer. So, if a bomb hit the ground it would bury itself into the ground at a certain depth depending on a number of factors. For example, the kinetic energy associated with the bomb, the angle of the incident and the speed at which it hit the ground - which could be 500-600mph. The maximum depth is some 20m but the average is about 6m. If depends on the soil too; in London it's typically about 6m.

Above: ***Disposal of a bomb dropped during World War II in Germany***

Below: ***Pile of recovered unexploded ordnance***

"The rule of thumb is the bomb will travel laterally no more than three times its depth. So if you have a bomb that's 6m deep it would not travel more than 18m. It will not travel 50 or 60m but you might be told that to get some survey work out of you. Commonly a bomb will be be missing its tail and it's rare to find one attached , I've only come across that once."

Furthermore, unexpected ordanance may be subject to the 'J-Curve', which is used to describe the characteristic curve followed by an aerial delivered bomb dropped from height after it penetrates into the ground. As the bomb is slowed by its passage through the ground its trajectory curves around to a final heading that points back towards the ground surface. Some UXO are found with their nose section pointing upwards. "With some very high energy bombs, they come out, they fly in the air and go in the ground again. So you have an entry hole, an exit hole and another entry hole. It's not that common but it has happened and it has been recorded," says Cooke.

Finally, sources of contamination include WWI and WWII, in the UK this is especially prevalent in London, Coventry, Manchester and Birmingham; military training sites; and weapons/explosives manufacturing plants. Whereas the generic threat comes from German air-delivered bombs; British Anti Aircraft Artillery; Allied Land Service Ammunition; Allied Small Arms Ammunition (the British have contaminated their own areas with training, especially in the South East of England); and training/practice munitions.

DESIGNED TO KILL

It is vital to understand the risk if unexploded ordinance initiates. "Military weapons are designed to destroy equipment or kill people," says Cooke. "If you have

unexploded ordnance personnel is the key thing you need to think about. If a bomb goes off on the surface shrapnel can be thrown out 1,000m and kill you. So it has significant destructive capacity."

In addition to the risk to personnel, UXO can cause destruction to underground utilities, property, tunnelling equipment as well as damaging corporate reputation.

"Some years ago there was a housing developer that built on a former RAF site. The company took no risk mitigation measures whatsoever; so people were laying gardens at the back of their "executive homes: when unexpected ordinance was discovered in the ground. Phase two didn't sell quite as well as phase 1, especially when 250 people were evacuated from their homes" notes Cooke.

Discovering UXO can have the following consequences for a tunnelling project: programme delay; standing time; project redesign; it can affect the reputation; and cause increased costs.

Cooke explains that the risk of unexplained ordnance needs to be considered early: "Think about UXO early and it's cheaper and cost-effective to mitigate. If you think about it when you encounter it, it's a nightmare, especially in the offshore environment. Which poses the question when it comes to risk management, what should you do?"

Indeed, Cooke adds that "the possibility of UXO being encountered on a site falls within the category of a potentially significant risk and is therefore a matter that should be addressed as early as possible in the life-cycle of a project".

All employers have a responsibility under the Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1999 to ensure, so far as is reasonably practicable, the health and safety of their employees and that of other persons who are affected by their work activities. Construction professionals have further specific duties under the Construction (Design and Management) Regulations 2007 (CDM). Under CDM, the client has the legal responsibility for the way that a construction project is managed and run and they are accountable for the health and safety of those working on or affected by the project.

"Clients have a legal duty under CDM 2007 to provide designers and contractors with project specific H&S information needed to identify hazards and risks associated with design and construction work," says Cooke. "The possibility of UXO being encountered on a site falls within the category of a potentially significant risk and is therefore, a matter that should be addressed as early as possible in the life-cycle of a project. :

CIRIA's research project has been approved by the Health & Safety Executive (HSE). The forward, by Dr Donald Lamont, HM principal specialist inspector (construction engineering), HSE, states the following:

"One unintended outcome from construction activity is that UXO is occasionally discovered. When it is, it usually generates considerable media interest and causes major disruption to the public. Fortunately experience shows that the risk of casualties has been very low.

"However, as it is a high consequence but low probability event, appropriate allowance should be made at the design stage for assessing the risk of encountering UXO on-site and for assessing the risk of encountering UXO on site and for mitigating that risk if significant."

In the past the lack of guidance and understanding about UXO has resulted in project delays and occasionally forced developers to pay for unnecessary and expensive mitigation measures. However, in CIRIA C681, Unexploded Ordnance (UXO): a guide for the construction industry, there is explanation and guidance given including good practice guide for the management of UXO risks; good practice methodology using tiered assessments; how to prepare transparent UXO risk assessments; UXO mitigation options; and the role and appointment of UXO consultants and contractors.

CIRIA has designed a robust four-stage risk management process to help construction professionals to deal with UXO hazards.

1. Preliminary Risk Assessment (In order to identify whether more detailed assessment might be required. The assessment is based on data obtained from a desktop review of historical information.)
2. Detailed Risk Assessment (Detailed risk assessment enables an estimate to be made of the likelihood

Questions from the floor

Q: Some years ago, I was working on a tender that involved driving a tunnel in soft ground conditions under a harbour somewhere in the North West of England. The harbour was used for storage in the Second World War. The contractor's attention was drawn to the likelihood of unexploded ordinance in the soft harbour muds and they should mitigate the effects. I didn't know how to address this so I sought advice and I was given all sorts of information but without any specific guidance. Then I recalled a story some years previous in Tunnels & Tunnelling about a TBM in Berlin that managed to chew its way in to unexploded from WW2, it went off and two tunnel workers were killed. So, what's your advice, what do we do?

A: Firstly, if it was a number of years ago I would argue that the client, the developer, the principle designer and contractor would all try and avoid the liability. That used to happen. Since the 2007 Act came out, it is not acceptable to put out to tender a project saying that it could have unexploded ordinance, for the contractor to deal with it and wash your hands of it. They will not get away with it. If a developer or a designer puts that out in a contract now and the contractor doesn't deal with it appropriately or deals with that risk negligently, the directors of the organisations be prosecuted. So, I'm not saying it doesn't happen any more, but they would be putting themselves at terrible risk if this happened today. Everyone has a stake in this and must take reasonable measures to manage and mitigate that risk.

So, if there is an unexploded ordinance risk what you need is a preliminary assessment. The preliminary assessment is important if there is suspicion that unexploded ordinance is there. If the answer is yes, you need a detailed risk assessment and the risk assessment will confirm what kind of unexploded ordinance is present. You'll then continue to follow the four-stage risk management process to reduce the risk.

Q: Working for London Underground for many years, one of the more interesting jobs I've had is looking at possible bombs going off near the tunnels. With Government department and others I'm quite surprised at how much information they have with regards to coordinates of where the bombs were. However, these maps are quite difficult to get hold of.

A: You've hit the nail on the head; these maps are difficult to get hold of. We, and others, have spent a lot of time getting hold of these maps and we've geo referenced them and loaded into a UK database every bit of information we have and we use that database to produce risk assessments. You can get hold of the information yourself - it's just time consuming and the data isn't digitised. There's a lot of information scattered all over the place, there are probably half a dozen companies that have this information. My advice to you would be don't do it yourself, it has taken us a decade to get the information we have. If you do it, it could be inaccurate and you'd be liable for it. Just buy it.

Q: Is there a difference between the ratio of unexploded bombs to exploded bombs between bombs hitting the river and those hitting the land?

A: The only ratio between exploded and unexploded bombs that we have is that 10 per cent didn't go off. If you have a bomb that falls on very soft material or rivers or lakes, then there might be a higher percentage of unexploded ordnance. Often in those areas there is a higher risk as there is no sign of entry (for example, with water there is clearly no sign of entry and with marsh (or soft) land it falls back in on itself). So if you have an area with hard and soft ground, there is likely to be more unexploded ordnance present in the softer ground.

Rapporteur: Rhian Owen, Tunnels and Tunnelling

of encountering a UXO hazard present on a site, giving due consideration to the development type and construction methods to be employed)
3. Risk Mitigation (to eliminate risk or reduce it to an acceptable level)
4. On-site UXO Survey & Clearance (to ensure that the selected plan is implemented correctly and efficiently during the construction phase of the development works and that the works are verified as having been completed to the required level)

Companies need to consider whether a project falls into the as low as reasonably practicable (ALARP) category. "Any risk mitigation should be both necessary and sufficient," says Cooke. "The risk - harm, delay, blight - needs to be considered against sacrifice - money, time, and effort. You don't need to spend millions of pounds if there is no risk. The law allows acceptable residual risk. You don't have to get all risks to zero, because otherwise we wouldn't build anything."

For sites where there is a possibility of encountering UXO, there should be an emergency procedure in place that provides clear guidance on what to do should an item of UXO be encountered, and/or initiated as part of the site works, with accompanying emergency management team roles and responsibilities.

6 ALPHA'S EMERGENCY MANAGEMENT GUIDELINES INCLUDE THE FOLLOWING STEP (PRINCIPAL CONTRACTOR'S RESPONSIBILITY)

- Cease work
- Confirm
- Clear (get personnel at risk behind hard cover)
- Cordon (the area to prevent accident access)
- Control
- Communicate

UXO has continued to cause many problems for construction projects in the UK and elsewhere. These problems have led to expensive delays, during the site investigation and especially groundwork phases of construction, and could have been avoided if an appropriate risk management procedure had been implemented.

"Knowledge dispels fear," concludes Cooke. "Give yourself knowledge: you're not going to die if you do come across unexploded ordinance, as it probably won't go off. It's not my aim to terrify people, quite to opposite. However, if you do come across unexploded ordinance or think that it might be present, then call in the professionals"