Feature

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

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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

Demolition of the five coal-fired boilers on former chemical manufacturing site at Widnes. Copyright J Wolstenholme ©

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

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

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

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

These papers have been condensed to meet publication requirements.

Tendering and award of contract

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

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

Prequalification processes should be established to identify suitably qualified experienced contractors (SQEP) who have previously safely undertaken explosive demolition work of the same scale, hazard, complexity and technical content.
The prequalification and tendering processes should be organised so that the client's project team, acting as the intelligent customer, is provided with sufficient information to assess:

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


Masonry chimney on chemical works.

- Their arrangements for Temporary Works in accordance with BS5975:2019[3].

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

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

- Compliance with the requirements of the tender document, including any specified limits, restrictions and conditions.
- Adequacy and quality of the demolition blowdown design including the substantiation of the tenderers collapse philosophy with the justification of the claims and evidence in their outline engineered design.
- Residual risks arising from the proposal and the adequacy of the tenderer's risk register in identifying, collating and managing that information,
- The safety record of the tenderer including evidence of trends and improvements resulting from incidents, investigations and near misses.
- Training records for relevant personnel and CVs, including membership of relevant professional bodies (e.g. Institution of Civil Engineers (ICE), Institution of Structural Engineers (IStructE) and Institute of Explosives Engineers (IExpE)), possession of relevant vocational qualifications as well as evidence of Continued Professional Development (CPD) through, for example, attendance at relevant training courses.
- Clarification should be sought from the tenderer of the basis of any assumptions made or any omissions of facts, hazards or risks that have been identified by the project team as part of the project planning and tendering process.
- Any alternative methodology or technology to that envisaged by the project team. Alternative techniques should not be precluded and may offer benefits and opportunities from advances in technology, methodology and safety. However, they should be subject to rigorous engineering assessment based on the evidence of the technical aspects, safety claims, arguments and evidence when compared against current Relevant Good Practice (RGP). This assessment should confirm that the alternative technique can be carried out safely without increased risk and that the potential for unintended consequences or different hazards has been considered. The project team may choose to retain a competent third-party consultant to provide an independent assessment of any alternative methodologies.
- Whether a robust engineering justification of safety has been provided for all proposed techniques before proceeding to other issues such as quality, programme and cost.

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

The outcomes of the tendering process should include
- clarity on who owns and is responsible for the risks identified in and from the tender submission; and
- demonstrable assurance that the works can be undertaken safely.

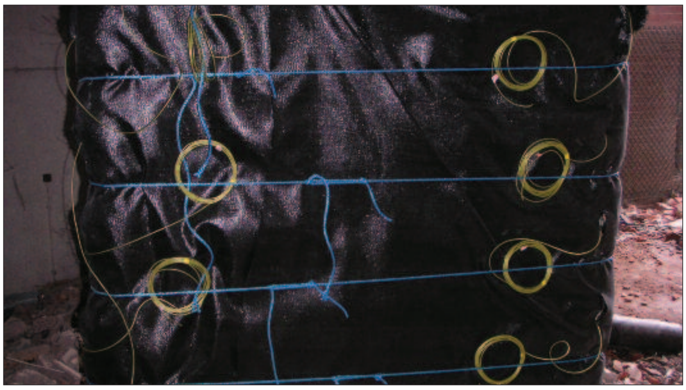
In making their appointment decision, the client should have confidence that the preferred tenderer can produce an engineered design that is robust, technically underpinned, conservative, fault tolerant and safe to undertake. The project team should have sufficient competence to be confident that the chosen design is robust to engineering scrutiny and challenge by both the project team and external third parties. Commercial considerations should not disproportionately influence the final decision.
The client should document the evidence they have used to inform their decision-making process to provide an audit trail for record purposes and future review.

Construction Phase Plan (CPP) and method statements

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

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

The aim of the CPP is to demonstrate that the activity will be the safely managed, that good engineering practice will be followed, that appropriate safety principles have been applied, that the project, so far as is reasonably practicable, is safe to undertake and



Wrapping protection to RC column.

Test blast on thin shelled wall of cooling tower.

that residual risks are as low as is reasonably practicable. The CPP and associated method statements should be understandable to those who will undertake the demolition blowdown works and those with direct responsibility for safety. The CPP should be developed in parallel with the Building Information Modeling (BIM)[4] model or equivalent process appropriate for the project scale.

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

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

- A **general description** of the site and scope of works to be undertaken, including any limits or conditions on the site as well as a description of offsite features that may be affected by the demolition blowdown works. These should input into a detailed risk assessment for all activities on the site including any effects that may affect areas outside the exclusion zone boundary and that could affect public safety or the environment.
- verified **clearance certificates** or the equivalent that demonstrates that hazardous materials such as asbestos, ionising radiation, polychlorinated biphenyls (PCBs) and other chemical or biological contamination has been removed so far as is reasonably practical. This clearance process should reflect an awareness of the potential for concealed contamination or trapped liquids, solids or gases in valves, pipework and features that are difficult to decontaminate or investigate.
- The **collapse philosophy** for the explosive demolition which should be clearly defined and articulated. This may be illustrated within the BIM model or equivalent or on a series of drawings, illustrating the collapse mechanism at different time delay intervals. This will also inform the design of the protection works including the use of shielding bunds and the size of the exclusion zone.
- The contractor's structural engineer should provide the project team with the **temporary works design** required for any **pre-weakening.** This should include structural calculations and detailed drawings showing the type, details, location and setting out of all the pre-weakening works and the direction of fall of the structure. This design should justify the collapse philosophy and should reflect an understanding and working knowledge of the different types of structure, their layout, provision of load paths, joints and connections, tying and bracing, material characteristics, degradation mechanisms and historical properties in both the permanent and temporary load cases.
- The design may require structural alterations to existing structural members, for example, where part of a flange has to be removed, where kicking plates are required or where members need local reinforcing. The structural engineer's design should justify the adequacy of these structural alterations and assess any subsequent consequences on the collapse philosophy. The structural engineer should also confirm that the pre-weakening design has been through a demonstrable robust process of **challenge and peer review** and that the structure will remain stable pending blowdown. This process should be appropriate to the project size and complexity and should follow relevant guidance such as BS 5975:2019 and Part 3.4 Vol 1 of the Design Manual for Roads and Bridges[5]. It is recognised that these are usually undertaken as CAT 3 independent checks. Some structures, particularly those on nuclear licensed sites, are robust and highly resistant to progressive collapse due to the provision of substantial foundations, heavily reinforced robust RC concrete sections, moment resisting steel frames and other construction forms. Nevertheless, the structural engineer should be able to demonstrate an understanding of risks arising out of:
  - missing, inadequate, uncertain, unrecorded or out of date structural information, together with the risks from unauthorised changes or modifications carried out during the structure's construction and life cycle.
  - degradation from recognised corrosion mechanisms that may affect the properties and behaviour of structural members.
  - the ways that certain structures were constructed e.g. thin-shelled cooling towers, water towers, bridges and arches. Some forms of construction will have required temporary works and elements of those works could remain as part of the built structure. Those details may not have been recorded as part of the permanent work record.
  - uncontrolled transfers of loads into parts of the structure that do not comply with the original design philosophy and calculations. This can cause redistribution of loads giving overstressing, rotations or collapse of structural members leading to structures falling or rotating in the wrong direction, partially failing or collapsing onto their foundations in "a sit down". Similarly, structural framing containing splices, joints, connections, stiffeners, tying members or compound sections that may unexpectedly either attract loading, become overstressed or fail when they become part of the temporary load paths should be identified and considered because they can adversely affect the collapse mechanism.

- failure of retained or pre-weakened sections of the structure that contribute to the development of the collapse mechanism. For example, assumptions made on the presence and extent of continuity of lapped reinforcement in reinforced concrete sections should be supported by robust evidence.
- the contractor's need to alter the existing structure to enable installation of explosive charges. The removal of member sections and cutting holes in webs or flanges to allow access needs to be recognised by the structural engineer and any requirement for strengthening should be included in the design.
- a failure to implement rigorous monitoring and supervision of any pre-weakening activities.
- the differences in the Codes of Practice and Standards used in the original design and construction, together with the recognised shortfalls or conservatism in the methods of structural analysis be that empirical or software based. There can be significant risks if modern design codes are used to model or analyse older structures where it would be more applicable to use the original design code and undertake a gap analysis against modern codes. A list of commonly used codes of practice, standards and guidance applicable to the demolition industry is available in the parent technical paper.

• The structural engineer should also be able to demonstrate that structures have been investigated to identify the means of construction and any consequential risks those means might present. The investigation process should consider what features and materials could be present in the structure that are not immediately obvious. Risks can arise from the presence of non-structural elements or features that would not be immediately recognised as having an influence on the structural behaviour during a blowdown. For example mechanical plant and services or ventilation ducts and shutes, cable trays and cables etc.
• The structural engineer should also identify and record the arrangements for cooperating with the project's personnel. Depending on the contractual arrangements, these could cover a range of roles including a Temporary Works Designer (TWD) and Coordinator (TWC) and the Principal Designer.
• There should be clear and demonstrable links to the work undertaken by the contractor's structural engineer in the demolition design and the contractor should provide and confirm details of how the structural engineers' design has been checked. In some cases, depending on project scale or complexity, this may be by retaining a competent independent third-party organisation. Alternatively, the client may choose to appoint that independent third party consultant for their own assurance. On a nuclear licensed site this would be in the form of an Independent Structural Assessment (ISA) together with an Independent Nuclear Safety Assessment (INSA). The check and any resultant changes should be recorded along with a discussion of how those changes have been assessed, approved and taken account of in the final design.
• The design should describe how the contractor intends to undertake the pre-weakening works on the structure. The details should be clearly stated on approved drawings showing the latest revisions. These drawings should be subject to robust change management procedures and should be regularly updated to record the date and scope of the completed work.
• All structural cut points or openings should be clearly marked prior to cutting or breaking out. When cuts or openings are made, they should be inspected to confirm that they are in accordance with the method statement and clearly identified as agreed along with the details of who was responsible for making it. It is good practice to record pre-weakening works such as the cut positions or openings before and after they have been made. This can be done using physical markings and records, digitally dated photographs or other suitable techniques. This visual evidence supports details recorded on drawings, sketches and schedules and allows ongoing assessments to be made of the stability of a pre-weakened structure. The client and contractor should agree the proposed technique to be used for recording this detail. Depending on the project scale and complexity, consideration should be given to recording and visualising the information within a BIM model or equivalent depending on the project scale.
• The contractor's explosive demolition design should describe the :
  - chosen demolition technique
  - approach to any pre-weakening not detailed above
  - the specification and quantity of all the explosives to be used
  - drilling patterns to be used for charge placement in concrete or masonry or
  - the location, orientation, and fixing methods of different types of charges for example cutting and kicking charges on steelwork
  - approach to securing explosives in place e.g. stemming of holes
  - type of initiation system for example nonelectric, electric or electronic
  - time delay sequence and backup systems
  - protection of the initiation system from damage due to shrapnel fly
  - provision of any visual indicators to confirm that specific sections of the works have been successfully initiated
  - arrangements for the delivery and return of explosives to an offsite store or storage of explosives on site
  - arrangements for security on site and accountability of explosives "in use" or being prepared on site.
• If the design requires cutting charges to be used then full details of the requirements for their specification, placement and initiation should be included. The explosive contractor's design

Preliminary setting out of openings on masonry chimney.


Wall drilling to RC walls .


Steel section severed by linear cutting charge.

should demonstrate a clear understanding of issues around their use, such as the potential for liner or secondary fragment fly, and describe how the initiation system and timing requirements between cutting and kicking charges will be managed.

- The design should explicitly consider the protection requirements against the effects of debris fly, fragments, vermin attack or any other circumstances that may result in a misfire or a hangfire and where such a risk exists it should detail the preventative and mitigatory measures that will be employed. The design should also describe how:
  - any flying debris will be retained to ensure safety; and
  - what protection methods will be used to provide effective containment around the structural members to minimise both the transmission of fly and protect the initiation system.
- Recognised methods used for primary and secondary protection include chain link fencing and geotextile, geotextile screens, rubber matting or belting, sandbags, steel plates and water drums or similar.
- The design should include estimates of the levels of vibration and air overpressure that may affect neighbouring structures. These can be verified by the retention of competent independent consultants. Estimates can be calibrated from results obtained during test blasts to produce regression lines and be considered iteratively as the design progresses during the works.
- The method statement should provide details of reducing and controlling air overpressure, ground vibration and dust that cannot be eliminated in the engineered design. They should address the potential adverse effects on people, infrastructure, plant and equipment sensitive to damage or degradation due to dust ingestion or vibration. Examples are dust filters to hospital ventilation systems, vulnerable or sensitive buildings or infrastructure, dust settling on roads, drainage systems and surface water courses. Similarly, details should be provided for proposed control measures such as protection, water suppression from hoses, Intermediate Bulk Containment (IBC's) or other appropriate methods, and the clean-up of surrounding areas after the demolition. The design of the exclusion zone should allow for these environmental effects.
- **Environmental monitoring** usually involves subcontracting to a competent specialist environmental testing contractor and the use of remote or automated monitoring stations. Any hazards and risks arising from how the environmental monitoring equipment operates should be considered and incorporated into the relevant risk assessments and method statements. Remote monitoring for asbestos or other dusts provides public confidence that any previous decontamination works have been adequately undertaken.
- **Test blast** results should confirm deterministically if the proposed explosive design will generate a structural collapse. The contractor should detail any proposals for undertaking test blasts in their demolition design. These proposals should include including drawings and photographs, confirm the suitability of the proposed explosives and the reasons for this as well as the predicted failure mechanism of the structural element and the adequacy of the protection design. Reports should be produced following test blasts and provided to the project team. These reports should consider whether the test blast achieved its intentions and how the demolition design will be modified to take account of the results of the test blast. The report should also include results from environmental monitoring of vibration, air overpressure and witness materials, to give an indication of the expectations for the main blowdown. Any changes to the demolition design should be subjected to a formal change control process before demolition designs and associated method statements are modified. Where test blasts are precluded on the structure to be demolished or similar structures, alternative options such as using a mock-up or similarly constructed and loaded structural element should be considered. However, such test blast results generally require a cautious approach to decision making to be followed when assessing how the results of tests might influence the demolition design for the main structure.
- The extent, establishment and control of the exclusion zone are key elements of the demolition design and the associated method statements. The contractor should provide details of how the exclusion zone has been determined as well as how it would be expected to be established and controlled as part of the demolition design. The determination should consider the type of structure and the collapse mechanism, charge weights and placement, primary and secondary blast protection, and environmental considerations. This is important if public attendance is anticipated because dust and fly can travel over distances and present significant risks. Effective design of the exclusion zone should take account of the available space and any natural features such as roads, rivers or residential areas which act as boundaries. Guidance can be found in the HSE guidance document Construction Information Sheet No. 45[6], BS6187:2011, BS5607:2017 and NFDC publication Demolition exclusion zones DRG 110:2014[7].
- The design of the exclusion zone should also consider the residual risks to sensitive infrastructure, buildings, other structures or facilities and populations (including spectators) outside the exclusion zone. Similarly, arrangements for adapting to changing weather conditions such as thunderstorms, high winds or changes in cloud level and density.
- Arrangements and identification of who is responsible for the post blowdown clean up.

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

Safety management system (SMS)

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

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

This process of recording should be audited at an appropriate frequency to suit the scale, complexity, risks and consequences of failure for the works. These audits should be undertaken not only by the contractor but also the project team, the client, and if appropriate, independently by a separate body within the client's or Licensee's organisation or an independent 3rd party acting on behalf of the client or Licensee. HSE's guidance document HSG159 Managing contractors: A guide for employers[8] provides a useful framework for managing the work of contractors in a high hazard environment and can be used to supplement the arrangements expected by CDM2015. Similarly ONR guidance document TAG 76 Construction Assurance NS TAST GD 076 (Rev 4)[9] provides additional guidance for nuclear licensed sites.

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

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

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

The contractor should detail proposals for dealing with foreseeable emergencies that may arise on site during the works. Proposals should include a communications plan for liaison with the client and the project team as well as all the emergency services. The client and project team should have arrangements for communicating with external stakeholders where that would not be part of the contractor's role and responsibility. The plan should be clear in the roles and responsibilities of all parties.

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

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

The client may choose to have a permanent presence on site and this is accepted practice on nuclear licensed sites. Arrangements for supervision should identify roles and responsibilities in the client, project team and contractors and describe the chain of command, the methods of communication, and mechanisms for liaison with third parties. The extent of the arrangements should reflect the complexity of the project and the extent of the hazards and risks it involves.

Security of explosives

The contractor may choose to store explosives on site or more usually have them delivered on a daily basis as charging requires. The requirements for the secure and safe storage of explosives, including the permissions required and the prevention of access by prohibited persons are provided in the Explosives Regulations 2014 (ER 2014) with additional guidance available in the HSE publications L151[10], and L150[11] and relevant subsector guidance[12]. On a nuclear licenced site such arrangements will require the involvement of the Civil Nuclear Constabulary (CNC) and the Office of Nuclear Regulation (ONR). Away from nuclear licensed sites regular contact with the relevant police force's explosives liaison officers will be key to ensuring the arrangements for security are proportionate and effective.

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

Blowdown day

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

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

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

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

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

Conclusion

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

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

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

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

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

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

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

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

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

Disclaimer

The content of 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).

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References

1 BS 5607:2017 Code of practice for the safe use of explosives in the construction industry
2 BS 6187:2011 Code of practice for full and partial demolition
3 BS 5975:2019 Code of practice for temporary works procedures and the permissible stress design of falsework
4 https://ukbimframework.org/
5 https://www.standardsforhighways.co.uk/dmrb/
6 Establishing exclusion zones when using explosives in demolition https://www.hse.gov.uk/pUbns/cis45.pdf
7 https://demolition-nfdc.com/download/exclusion-zones/
8 https://www.hse.gov.uk/pubns/books/hsg159.htm
9 http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-076.pdf
10 https://www.hse.gov.uk/pubns/books/l151.htm
11 https://www.hse.gov.uk/pubns/books/l150.htm
12 https://www.hse.gov.uk/explosives/er2014-commercial-manufacture-and-storage-of-explosive-articles-and-substances.pdf

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