Paper

Role of the structural engineer in demolition

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Synopsis

This paper is intended to help other structural engineers as well as construction and health and safety (H&S) professionals appreciate some of the common structural issues encountered during demolition. The content is equally relevant to refurbishment projects where demolition is a necessary process but one not always fully appreciated by a construction industry that focuses on new-build. The text provides an insight into the role of the structural engineer working for a demolition contractor.

Introduction

'*Although HSE statistics show that demolition is a high-risk activity, it would appear that it is either not given much consideration or is included at the end of the planning process and given whatever time is left in the programme. The avoidance of accidents depends on the quality and thoroughness of the Designer's plan for the project*.' *CDM Guidance for Designer*, Construction Industry Council, Fig 1.

According to the HSE Statistics Unit, reportable injuries in demolition are twice as high as those in construction. For the 12 month period 2007 – 2008, there were 10 reportable injuries for every 1000 demolition workers (of 18 000 total) as compared with five reportable injuries for every 1000 construction workers (of 500 000 total). Clearly, demolition is still a relatively dangerous industry to work in. Risks associated with the industry not only impact on demolition contractors and their staff, but can also affect the building owner, developer, local authority, government agencies and the wider community.

The Health & Safety and CDM regulations are an essential aspect of demolition and much has been written from these perspectives but this paper focuses more on the structural detail.

Role of the structural engineer

There are many hazards associated with demolition, refurbishment, dismantling and decommissioning for the spectrum of structures requiring demolition is wide, ranging from power stations to tower blocks and from bridges to Victorian institutional piles. Conditions vary from the robust and modern to the crumbling, damaged and ancient, and from city centre buildings trapped between other buildings to those on greenfield sites. Correspondingly, the potential range of risks is wide and structural engineers can play a crucial part in reducing them via the planning and design work they do to facilitate the demolition process. Obviously identifying structural risks at the beginning of a project can reduce accidents and save time and money. Thereafter, good communication should ensure that the potential hazards are understood by the client team, site managers, supervisors and the workforce themselves, Fig 2.

Although the paper deals predominantly with buildings, its content can be equally related to many other types of structure.

Demolition in practice

Demolition may be viewed as the poor cousin of construction, but an experienced demolition contractor will often know more about the real ultimate strength of materials and building collapse mechanisms than many structural engineers, for during demolition, the true strength of a structure and its components are revealed. Experienced demolition engineers will have physically worked with, manipulated and pulled apart more buildings than probably most structural engineers will ever design in a lifetime. Thus they will intuitively understand plastic and elastic behaviour, serviceability and ultimate limit states, even though they can perhaps not recite the relevant formula.

Demolition scenarios are often complex and getting the demolition sequence right can be like a game of 3D chess, thinking many moves ahead. The structural engineer charged with advising must be able to visualise the part-demolished structure and its stability within each phase.

Demolition should not be thought of as de-construction. In construction, there is relatively little choice for the building methods and sequences available. In contrast, many alternative methods and sequences for demolition can be employed. Different contractors have different plant and equipment, different skills and specialisms and different learned experiences. Collectively, these factors will greatly influence the cost and chosen method proposed. Moreover, with this variety of methods on offer there are also varying hazards and degrees of risk to consider. There may be a best solution in terms of programme or hazard reduction, but this may not necessarily be the cheapest solution. For example, remote demolition, such as long-reaching or by using explosives, is often safer because the number of man-hours working at height can be considerably reduced.

1 'Danger Demolition in progress' signage
2 Drop balling was the wrong method
3 Overloaded slab or poor sequence

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To obtain a better understanding of the demolition process it is essential to recognise potential hazards at the planning stage, for these are not always obvious to those who are in a position to influence decisions made on site. If they were obvious, then demolition would be a much safer industry, Fig 3. The principle concern of the structural engineer planning demolition is avoidance of uncontrolled collapse. In demolition, only planned collapse is acceptable and an unplanned collapse of elements greater than 3t should always be reported to the HSE as a dangerous occurrence.

Causes of uncontrolled collapse can include:
– overloading of floors by machines or debris;
– unexpectedly weak connections;
– unexpected voids and hidden basements;
– the incorrect demolition sequence;
– ignorance of stability issues;
– instability in high winds;
– the discontinuity of structure at movement joints;
– over-stressed elements caused by an altered load path;
– excessive commercial pressures leading to corner cutting;
– individuals taking risks.

But when the structural issues are understood, collapses can be prevented as the following examples of planning demonstrate (the objective being always to preserve a degree of global stability).

Planning

Making use of long-reach demolition has now become common place. Track-mounted plant with an extra long boom and dipper arm, sometimes telescopic, is available and can reach 40m easily. There are some giants that can reach 90m high. Even when long-reaching, it is good practice to follow a sequence that works back towards the stiff core so that the lateral stability of the structure is always maintained. The distance from the long-reach machine to the face of the building should preferably be a minimum of half the height of the building so that the operator is a safe distance from falling demolition arisings.

Un-braced frames

When working towards the end of a framed building i.e. an un-braced frame with no shear walls, it is sensible to leave a minimum of two bays intact. Clearly this framing is much more stable than one bay.

Cut lines

It is much better to pulverise and munch up to a cut line rather than prop and diamond saw cut since providing lateral stability to the propped element can be difficult. Also, to preserve stability, it is better not to munch up to the face of an *in situ* column, far better leave a stub of reinforced concrete beam protruding so as preserve the reinforcement anchorage.

Control of loading / arisings

Normally, when long-reaching in tower blocks, the floor slab will be able safely to carry the demolition arisings from the floor above. But if a floor is overloaded with demolition arisings from a number of higher storeys, a progressive vertical collapse can occur. Thus it is generally safer to long-reach bay by bay for full height rather than work floor by floor. This prevents excessive debris built up on floors and minimises the risk potential for a progressive collapse, Figs 4 and 5.

Control of progressive collapse

Large panel residential tower block system buildings can be at risk of a Ronan Point type failure (the full-height collapse of one structural bay) during demolition. These buildings have pre-cast concrete floors, walls, stairs and stair cores. The floors and walls are relatively slender and the fixity at the slab/wall interface is poor as compared to current practice. There is little slab end bearing and limited slab continuity reinforcement connecting adjacent pre-cast slabs across the wall support. Often remedial strengthening work was undertaken in later years but the effectiveness of such work can be variable and as-built records are hard to find. For this type of building, the long-reach method should be modified slightly by keeping a wider base area and controlling the arisings, Figs 6 and 7.

Control of arisings

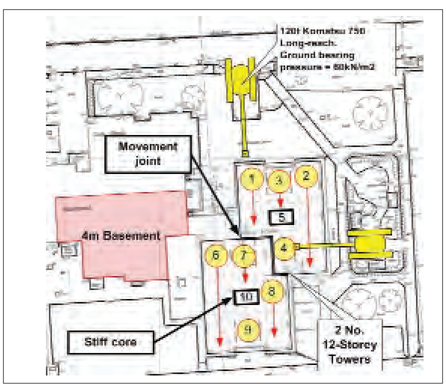
In all buildings, the amount of arisings permitted on floors should be controlled. But in system buildings, extra care should be taken to limit the weight of arisings on lower slabs. As the building is reduced in height, a relatively wide building base area should be maintained and the floors tiered back to preserve the overall lateral stability.

Basements

The presence and location of any basements should be identified in the pre-tender health and safety plan. This is to prevent heavy tracked demolition plant falling through basement roofs. It is good practice is to keep a marked up drawing on site recording the extent of the filled basement as the demolition front progresses.

Explosive demolition

A 'stand-up' can present a serious hazard if, after the charges have detonated, the structure does not fall or collapse and break



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4 Long reach sequence around core
5 Long reach sequence – working towards the core
6 Weak structure – high risk of collapse
7 Strong structure – low risk of collapse

up. As the risks associated with entering a partially collapsed structure are high, contingency measures should be provided wherever possible, for example, having long-reach plant on stand-by. Pre-weakening is often required to help the structure break up under gravity. But there is a fine balance between carrying out enough pre-weakening to avoid a 'stand-up' and too much pre-weakening making the building unsafe to work in, especially during high winds. The calculations which justify the extent of pre-weakening must also consider accidental damage and over-break. So the structural engineer has to work closely with the demolition contractor to produce the most appropriate pre-weakening arrangement. Special internal strengthening work can be designed to influence the direction of fall in conjunction with the delay sequence for the charges.

'*Commercial pressures imposed by the client to expedite work often impose severe limitations on the time available for a demolition contractor to investigate the design and construction features in detail and then to plan the demolition work carefully. Contracts tend to leave responsibility for investigation of the existing structure to the demolition contractor and then rely on cost penalties to enforce prompt completion. Contractual arrangements framed in this way increase the risks to both the general public and site workers, and limit fair competition.*' *8th SCOSS Report 1989*. This text was written 20 years ago yet is still pertinent today. The preparation time is so important that client pressures to reduce it should be resisted firmly.

Likewise, commercial pressures imposed by the demolition contractor can often complicate the required demolition solutions. Competitive tender pricing can necessitate imaginative solutions to avoid expensive methods. However, the demolition contractor must be able to clearly demonstrate that all the potential hazards have been considered and show the associated risks have been reduced to an acceptable level. Compliance with the CDM regulations should prevent excessive risk taking or inexperienced contractors slipping through the net.

The Code of Practice for Demolition (BS 6187) is an extremely good reference document providing an overview of the demolition process. However, the BS cannot be too prescriptive because every structure is different. That said, there are some regularly occurring situations where the following advice may be useful (Table 1).

Overall it should be noted that every situation is different and should be individually checked and assessed.

Plant	Small plant should be used wherever possible to avoid hand and arm vibration (HAV) caused when using hand held tools. When considering the safe size of small demolition plant to work on suspended floors, a starting guide is: – Residential 1t – Offices 2t – Shops 3t In the right situations, these weights can be increased using back-propping with calculations to prove the strength of the floor.
Debris	Getting the debris away efficiently to avoid a back-log of material which can overload floors is often the key to safe and successful demolition. This is particularly important on constrained city centre sites when the assignment of internal drop zones and openings through structural walls are often necessary to create a route to get the demolition debris material out of the building. Strengthening masonry walls to turn them into deep beams can allow new openings to be created underneath.
Scaffolding	A fully enclosed scaffold with reinforced plastic sheeting is used to surround a building during demolition when it is necessary to protect the public from any debris escape. A demolition scaffold is typically fully boarded with no gaps, sheeted or debris netted and carries $2kN/m^2$ at the top level. It is important for the structural engineer to consider the scaffold tie back fixings to the existing structure, which may itself be weak. The vertical scaffold cantilever must not be allowed to become too high as the demolition progresses.
Pre-stressed concrete	When working with pre-stressed concrete, the stressed tendons should never be cut. Generally there is no need. These elements can be demolished quite safely by destroying the concrete around the stressed tendons. Immediately the concrete fails and crushes, the tendons relax and become de-stressed. This is true for both grouted and un-grouted ducts.
Deep RC beams	Deep RC beams can be very difficult to demolish, particularly at height. One practical solution is to gradually reduce the beam's cross-section along its entire length with a hammer attachment. This can be much less hazardous than cutting and lifting.
Party walls	Demolition against a party wall is one of the most complex of operations undertaken. Sometimes pre-weakening the structure to allow hinges to develop whilst long-reaching can be used to fold the frame away from the retained building.

Table 1 Advice for common situations

Survey and Inspection

Surveys and inspections form an essential part of a preventative safety system, particularly at the planning stage for demolition operations.

Structural surveys are a form of detective work wherein structural engineers have to read the clues to determine how the structure was actually constructed. They have to look for tell-tale signs and evidence about connection strength and the general quality of workmanship and attention to detail.

The importance of the structural survey cannot be underestimated. Serious hazards are created if, for example, a movement joint or a narrow bearing detail is missed. So a detailed structural assessment should be targeted at identifying any weak elements, supports, connections or structural features which are stability sensitive. The maintenance of overall stability should be considered throughout the demolition process to avoid the danger of an unplanned collapse. As part of this process, load paths must be identified and it is important to identify the potential for hazards associated with hangers, ties, cable stayed roofs, barrels, arches and domes, space frames, retained façades, pre-stressed components, structures retained by ground anchors and structures that have been modified.

It should be noted that it is quite often difficult for the demolition contractor to supply a set of complete method statements before the structure is fully exposed, although this is often requested. Contractors need to be given the flexibility to modify their methods in the light of new found information during successive surveys and there are three main opportunities for demolition contractors to carry out such surveys.

Pre-demolition survey

A good time to carry out the first survey is during the Type 3 asbestos survey work when intrusive work is acceptable. This usually occurs after the building is vacated and before the soft-strip starts. This pre-demolition building survey should include identification of:
1. Structural form and movement joint locations.
2. A description of how lateral stability is maintained.
3. Any pre-stressed or post-tensioned elements.
4. Novel forms of construction.
5. Gross structural defects, cracks and signs of movement.
6. Hangers and ties.
7. A search for any existing drawings and calculations, noting that actual details may vary.
8. The building age and typical details to expect.
9. Recommendations for any local exploratory work.

A good pre-tender H&S plan will have a pre-demolition structural survey included.

During soft-strip

Often the structure is not properly exposed until the soft-strip operation is completed. At that time, the original demolition method may need to be revised. As much of the floor and ceiling finishes will have been removed, signs of poor workmanship may be revealed, and generally the structure will be exposed to provide opportunities for a fuller understanding. More intrusive work can be carried out to expose connections and joints and locally check slab reinforcement. Overall, early investigation work can now be confirmed.

The condition of brickwork and timber is particularly important in refurbishment work. The mortar can vary from rock-hard and fully

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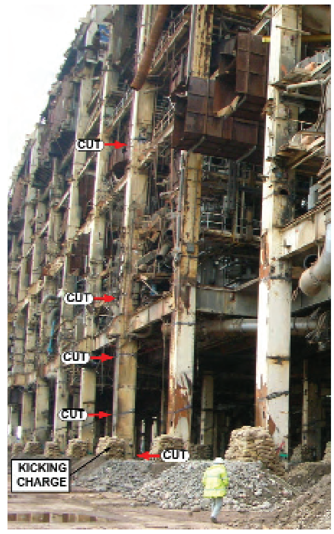

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8 Small plant demolishing multi-storey offices
9 Brokk 90 remote controlled breaker removing concrete
10 Steel pre-weakening for explosive demolition
11 Concrete pre-weakening for explosive demolition

11

bonded to being a loose sand that flows out of the joints with the slightest disturbance. It can also be patchy, depending on work carried out at different times or work by different gangs. Removing the plaster during refurbishment of old buildings from all faces is recommended to help determine the masonry condition.

During demolition

Site inspections by the structural engineer during demolition are a sensible precaution. This is an important opportunity for example, to spot hidden ties which hold a mansard roof together or to inspect a wall which is being subjected to high lateral loads from a rubble pile.

Design

During the appraisal of an existing building there are a few basic questions the structural engineer should ask.

Strength and robustness

It is a good idea to ask yourself how you would have designed the original structure considering the site restrictions, the use of the structure and any change of use. Historical plans and a knowledge of historical codes of practice can be of help. Then, whilst surveying the building, any deviations from your expected design can be further investigated to check for potential difficulties later. When considering the robustness of a structure, the strength and rotational stiffness of connections is key as to how the building will behave during demolition.

Collapse mechanisms

The structural engineer needs to think carefully about how the structure will behave during planned collapses as well as during any unplanned collapses. What will be the exact mode of failure: bending, shear, or excessive deflection? Will the failure be slow or sudden? Will there be any warning? Imagining the collapse second by second, in slow motion can be of great benefit. How much of the structure will be affected? There are many instances where a load-bearing wall can be removed with no effect because of redundancy in the structure and the existence of alternative load paths. Nevertheless, that cannot be always relied on and one must also consider the possibility of accidental impact by moving plant. Comprehension of key elements which, if damaged, could cause a progressive collapse or catastrophic failure is vital.

Building design details are often simplified during initial design to assist construction. For example, reinforcement or bolted connection details may be standardised. Such changes can provide extra load carrying capacity which the demolition structural engineer can take advantage of, even if only for increases in factors of safety.

Strength of elements

When assessing the strength of elements such as reinforced concrete slabs and beams, shear is often the most important failure mechanism to consider because shear failures are generally sudden and without warning: member stiffness and deflection is less important. Justifying member safe bending capacity can be difficult because reinforced concrete codes limit crack widths for durability which is not important during demolition. Consequently in the right circumstances, the demolition contractor will sometimes safely overload a slab or beam until it fails albeit the ultimate load can be many times greater than the predicted factor of safety would suggest.

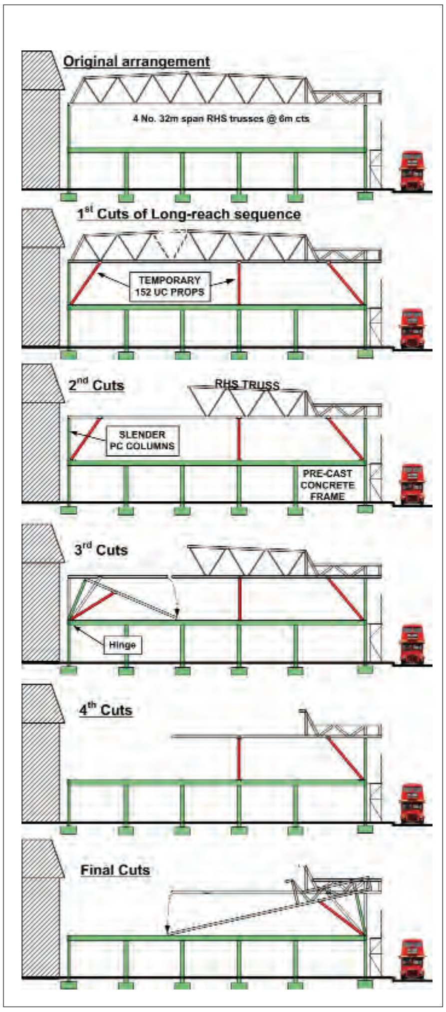
Adjacent buildings

An understanding of the sensitivity of any adjacent buildings, their structural frame and stability provision are important.

A structural engineer with the appropriate experience will provide the following services for a demolition contractor:

Planning

– Feasibility studies considering alternative demolition options and methods with recommendations that cause least risk to human life and least disturbance to neighbours.
– Advising on the most suitable methods for dealing with pre-stressed and post-tensioned structural elements and other ‘special structures’.
– Calculating the strength of existing floors and advising on the size, type and number of demolition plant that can be safely used. If necessary, advising on back-propping, type and layout, see Figs 8 and 9.
– Assist in the planning of demolition sequences and the preparation of detailed method statements and risk assessments. This is particularly important for complex structures and refurbishment schemes. The demolition of even simple structures can be made complex due to close proximity of adjacent buildings, where noise or vibration cannot be tolerated or where access for the removal of materials is particularly restricted.
– Work with the demolition contractor on alternative methods to pre-weaken a structure. The engineer will demonstrate by calculation the safety of a pre-weakened structure during its pre-weakened and part demolished condition see figs 10 and 11.
– Work with the demolition contractor to design safe, efficient and



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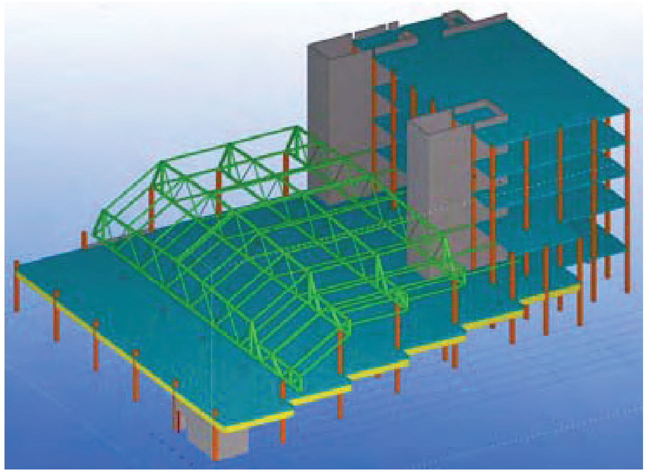

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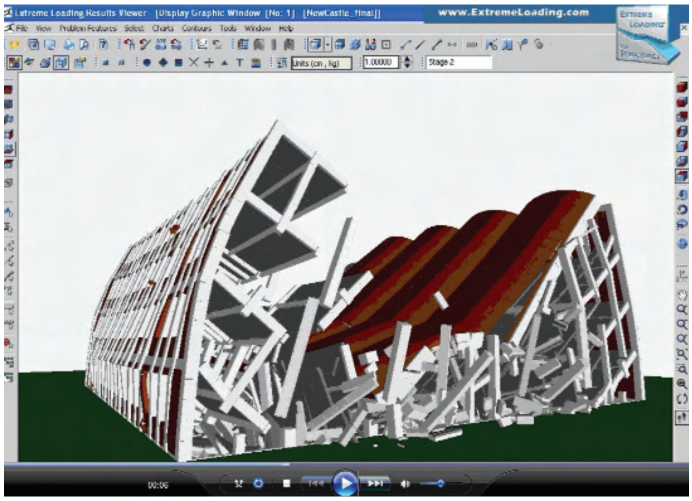

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12 Temporary props allow long reach operation
13 The 3D sketch also helps design development
14 3D collapse simulation movie in real time

effective collapse mechanisms such as hinging, launching, pulling or the controlled use of explosives and combinations of these.
- Produce lifting plans.
- Review demolition methods and sequences providing an expert opinion and confirmation that the proposals are safe.

Temporary works

- Temporary works design for floor strengthening for machine and debris loads or for the breaking-out of temporary openings to allow debris removal and machine access.
- Temporary works design for shoring basement walls and under-pinning.
- Temporary works design for propping and needling for wall removal or for temporary bracing systems for stability in refurbishment and demolition.
- Design of working platforms for tracked plant (typically a compacted hardcore embankment, several storeys high, which will allow a long-reach machine to reach the top of the building). These are most commonly constructed using the demolition arisings. Loose and compacted pulverised brick and concrete has a very high angle of internal friction and there is no problem maintaining 45° slopes in this material.
- Design of temporary ramps for moving plant from floor to floor inside buildings.
- Provide advice and assistance on site during complex procedures.

Often the temporary works structural engineer is only commissioned to design the temporary works required for demolition and not to inspect progress. Thus a temporary works design needs to be very clear so that it cannot be misinterpreted. But ideally the engineer should inspect the temporary works *in situ* to confirm the correctness of assumptions and application. At that time, any potential hazards should be brought to the attention of the site manager immediately.

To give an example of temporary works design for demolition, a long-span trussed roof in a city centre location requires a 500t crane to lift down each truss to ground level and all the associated working at height cutting and slinging operations. The alternative was to prop the trusses so that each truss could be safely long-reached *in situ,* Fig 12.

Communication

Collapses are often the result of failure to use information that is available somewhere. Unless you are used to demolition, it can be difficult to visualise what a structure will look like during the demolition process. Overall, providing structural engineering advice is a waste of time if it cannot be understood so a simple sketch which can replace sides of text, which in reality few people take the time to read, is to be preferred. Such sketches can also be easily copied into method statements and thus make approvals easier to obtain, Figs 13 and 14.

Preferably nothing should be so complicated that it cannot be explained to non-experts. If it is that complicated, one should try to make it simpler. There is much more risk of an incident occurring because, for example, a machine operator or scaffolder has not understood. Equally, explaining the reasons behind methods can make them easier to understand and easier for others to remember and this also allows methods to be improved upon and developed by others in the chain.

There are three levels at which communication is important:
- The client's team need to communicate its views on any assumed demolition sequence to the contractor. It should highlight known hazards and any assumptions made about the existing building that will need to be confirmed by the contractor.
- The contractor has to communicate their demolition sequence proposals to the client's team for approval.
- The contractor has to communicate the approved method and sequence to the workforce.

3D drafting software such as Revit and Tekla is being used increasingly to clearly demonstrate complicated demolition sequences, for which they are invaluable tools, particularly where there are a number of different sub-contractors working in the same area at different stages.

3D collapse simulation software such as Extreme Loading from ASI is an impressive tool that is going to become more prevalent, particularly for 'pulling' structures (this is where a structure is weakened and pulled to the ground) and for 'blowdowns' (demolition by the controlled use of explosives).

ASI's Applied Element Method (AEM) based technology is the only current analysis method for accurately analysing the behaviour of a structure during a critical failure and the resultant progressive collapse. The software will analyse and predict the linear, nonlinear, and failure modes of structures in a 4D environment. It will analyse and play out different 'key element' removal scenarios. Collapse simulation is an excellent way to demonstrate to clients exactly what to expect and it can be used during the demolition design process to check and refine collapse mechanism assumptions.

The position of structural engineer can be immensely satisfying when, through good communication, s/he is able to combine the knowledge of experienced construction and demolition professionals to produce innovative, simple and safe solutions to complex and difficult problems.

Sustainability considerations

Designing attractive, high quality new buildings that are built to last and can easily be adapted for change of use will produce the most sustainable buildings because they will not require demolition. Demolition contractors have always been efficient at recycling because it makes commercial sense to sell and re-use as much material as possible; typically 90% of the demolished building is recycled. The 10% that goes to landfill is generally carpets, curtains, blinds, false ceilings and roofing felt.

Water and air pollution is controlled by good site practice, by the contract specification and legislative requirements. When considering the reduction of carbon emissions during demolition operations, diesel fuel is by far the largest single contributor to the quantity of CO_2 emissions produced. Every 100 litres of diesel fuel consumed results in 268kg of CO_2 being emitted. It is in everybody's interest to reduce this as much as possible and there are various methods by which this can be achieved:

- Using modern and well-maintained demolition plant and choosing plant with low fuel consumption rates will save fuel. So will reducing transport distances, including those of plant to site, waste to the processor and operatives' commuting distances.
- Separating and re-cycling the elements of the demolished building reduces the carbon footprint. Every 0.34t of waste that is recycled and not sent to landfill will save the greenhouse gas equivalent of 1.0t of CO_2 production.
- Recycling can be made more efficient if building designers consider material separation initially. For example, by specifying dry linings rather than using wet applied plaster which is difficult to separate from masonry. Another example is composite cladding panels, where recycling is now becoming a problem because the insulation is so well bonded to the steel. In addition, the insulation can contain CFC gases or, latterly, pentane-based products which are highly flammable.
- Comparing alternative demolition methods, for example, the controlled use of explosives can reduce the contract period, it can reduce the amount of demolition plant required and, most importantly, the amount of diesel consumed. As an example, a typical 20-storey tower block blow-down process will produce 15t of CO_2 emissions. The same block demolished by traditional work-down methods, using 5t or 7t machines, over the longer period will produce 80t of CO_2. Thus the blow-down method would save 65t of CO_2 from being discharged to atmosphere.

Design for future demolition and refurbishment

The more as-built information there is available, the closer demolition tender sums will be and the less opportunity for additional costs arising through unforeseen difficulties. The use of CDM health and safety files and operation manuals for new buildings should improve this aspect and help reduce hazards for future generations.

The following design considerations may not be at the top of most designer's or client's 'to-do' list, however, they would make future demolition safer and the provisions do assist the creation of robust and adaptable buildings:

1. Stiff connections and built-in redundancy allow alternative load paths and will make demolition safer, with fewer uncontrolled collapses. Recent revisions to design codes have improved continuity ties for *in situ* concrete and precast concrete design which is of assistance.
2. Adopting a robust minimum size bolted end connection detail for steelwork.
3. Providing a 50mm air gap at party wall junctions, instead of 10 or 20mm.
4. Using wider staircases and landings (1500mm) to avoid the necessity for cranes to lift small plant onto the upper floors will allow small plant to access all levels without the need for a crane.
5. Avoid designing massive structures carrying heavy plant and tanks on the top floor of multi-storey office blocks and flats. (It's difficult getting a 20t machine onto the roof). Dealing with these roof top structures is often the most hazardous operation.
6. Use a design live load allowance of $4kN/m^2$ which is adequate to support 2 or 3t demolition plant and provides the added bonus of reasonable flexibility for change of use and refurbishment to extend the useful life span of a building.

Conclusion

The structural engineer combines technical knowledge with management and communication skills. With his/her knowledge of the demolition industry and its practises, the structural engineer can contribute and add value to demolition works from all perspectives – whether the client is a contractor, building owner, developer, local authority or government agency. Demolition, like most other branches of engineering, is becoming increasingly complex due to factors such as commercial pressures, health and safety, sustainability, community interest/concern, new technologies, new materials, new construction processes and so on. But the structural engineer can help clients address these issues and can help the demolition contractor improve productivity and health and safety outcomes through engineering analysis and design. Engineering analysis and visualisation with CAD provides an opportunity for demolition contractors to improve record keeping and knowledge management, so that practical experience can be passed on to junior staff. The structural engineer can assist with communication to stakeholders and regulatory authorities.

Cost efficient, safe and sustainable demolition depends on:

- a good quality pre-demolition survey;
- good communication between all parties involved;
- the assessment of the strength of connections and continuity ties;
- identification and communication of stability and robustness systems and assumptions;
- as with construction, access to move materials can be crucial to the success of a project;
- most importantly, keeping it simple.

Employ expert advice every time. Early input will reduce costs, financial and Health and Safety risks, contract duration and improve sustainability.

Useful links and references

Institution of Civil Engineers: www.ice.org.uk (Demolition Protocol 2008.pdf)
National Federation of Demolition Contractors: www.demolition-nfdc.com
Health & Safety Executive: www.hse.gov.uk
Institute of demolition engineers: www.ide.org.uk
Confidential Reporting on Structural Safety (CROSS) scheme: www.scoss.org.uk
Corporation of London: www.cityoflondon.gov.uk (Demolition-control_and_advice)
BS 6187-2000 – *Code of Practice for Demolition* Synopsis