

# Temporary Works Toolkit

## Part 19: An introduction to the demolition of large structures

The Temporary Works Toolkit is a series of articles aimed primarily at assisting the permanent works designer with temporary works issues. Buildability – sometimes referred to now as ‘construction method engineering’ – is not a new concept and one always recognised as vital to the realisation of one’s ideas; it ought to be at the forefront of an engineer’s mind.

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### Introduction

This article provides a brief introduction to demolition practice in the UK, addressing the more technical aspects which require engineering input. It will focus primarily on the demolition of large structures.

Demolition covers a wide spectrum of work, from simple ‘cut and carve’ to the total demolition of large and complex structures across a multitude of disciplines. These include transport, nuclear, oil and gas, industrial, commercial and residential schemes.

The effect of this is that demolition is becoming an increasingly complex and technically challenging sector of the construction industry. Recent years have seen demolition contractors developing and using highly specialist plant and techniques to assist in these challenging projects, alongside complex temporary works designs. Specific highlights with which the author is familiar include:

- high-reach excavators capable of demolishing structures up to 70m tall (developed by DSM for the demolition of Tottenham Hotspur FC’s White Hart Lane ground)
- the ‘megamuncher’ (as it came to be known) – a remotely operated 25t excavator developed by Mace, Coleman &



Figure 1 Specialist cranes developed by Coleman & Co and Andun for Birmingham New Street station project

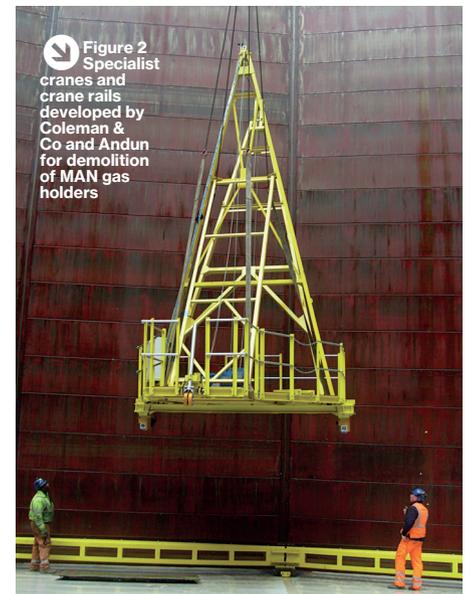


Figure 2 Specialist cranes and crane rails developed by Coleman & Co and Andun for demolition of MAN gas holders

- Co and JCB specifically for the Birmingham New Street station redevelopment
- gantry cranes erected within the structure at Birmingham New Street station (Figure 1) to facilitate the removal of one floor (developed by Coleman & Co and Andun)
- cranes and associated crane rails (Figure 2) for the demolition of MAN gas holders at Battersea, London (developed by Coleman & Co and Andun)
- partial demolition of the 33-storey Centre Point tower in London by John F Hunt, requiring the removal of the majority of the top five floors of the tower while maintaining the facade. This

required significant temporary works and sophisticated analysis to confirm the stability of the structure<sup>1</sup>.

All demolition work can be considered as falling under one of two broad categories:

- progressive demolition
- deliberate collapse mechanism.

The former is the most common. Partial demolition works will be progressive demolition work.

### Progressive demolition

Progressive demolition involves the controlled



Figure 3  
Dismantling of shopping centre

## "PROGRESSIVE DEMOLITION INVOLVES THE CONTROLLED REMOVAL OF PORTIONS OF THE STRUCTURE"

removal of portions of the structure while ensuring the remaining structure remains stable. In general terms, the demolition is carried out working from the top to the bottom of the structure, usually working towards the structural core to ensure that stability is maintained. Partial demolition of a structure will follow similar constraints. However, the works will not necessarily be from top to bottom. Progressive demolition can be further subdivided into three broad methods based on the plant used for the works. It is not uncommon for a combination of all three methods to be used on a single project.

### Top-down demolition

If access to the structure is limited by adjoining properties, roads or railways, then top-down demolition work will be undertaken. The plant will be lifted onto the roof and the structure will then be demolished floor by floor; to ensure stability, the core is generally left as the last section on each floor to be demolished. Rubble is generally cleared by skid steers.

As with most forms of engineering, the success of the project comes down to the engineer's understanding of the structure. The more information provided to the engineer, the better the assessment of the structure will be.

### Key points

- A proper engineering assessment should be undertaken. Partial load factors should be used as appropriate to the code in question, thereby ensuring a suitable factor of safety for the works.
- The assessment should use recognised engineering methodology, taking account of the likely operating loads imparted on the structure, i.e. plant operating on 'tiptoes'. It is here that experience of the realities of demolition work comes to the fore.
- Propping of the structure may well be required to permit intended plant to travel safely on the structure.
- Rubble should be included in the assessment, with suitable clear limits on permitted rubble build-up shown in the drawings.
- The structure should generally be encased in scaffold. The scaffold should be dismantled in tandem with the demolition works. One lift of scaffold should be permitted to project above the highest level of the structure, with ties removed in an agreed sequence. Ensure that the

scaffolding designer has considered this in their design calculations.

- If scaffolding cannot be erected, then suitable exclusion zones and edge protection should be provided. Further guidance on this subject can be found within BS 6187<sup>2</sup>.
- Site investigation should include breaking holes in slabs to expose the reinforcement, as well as breaking out sections of beams and columns to expose steelwork and/or reinforcement. This information will be the key input for design appraisal.

### High-reach demolition

In this method, a high-reach excavator on a suitable working platform is used to demolish the structure in a controlled manner. A number of floors will be tackled at the same time, leaving a staggered profile when viewed from the side. This allows the high-reach machine driver to see the work being undertaken and reduces the likelihood of rubble falling onto the machine.

### Key points

- High-reach excavators are large and heavy machines, which require working platforms to operate on. These should be designed and checked using the same methodologies as working platforms for any other plant.
- Particular care is needed when undertaking the demolition of large-panel system (LPS)

buildings, as they are prone to uncontrolled collapse due to latent defects.

- For the demolition of an LPS building, consideration should be given to the temporary restraint of panels and the provision of temporary bracing.
- Rubble should be cleared regularly; if rubble is allowed to build up, it can lead to unintended collapse.

### Dismantling

In this method, the structure will typically be dismantled using cranes (Figure 3) with cutting techniques to release suitably sized sections. In some cases, it may be possible to simply reverse the original construction methodology by undoing bolts; or in the case of precast sections, simply breaking out *in situ* concrete to release.

#### Key points

- Weights should be accurately calculated. Sufficient load factors should be applied to estimated weights in line with industry practice. Refer to BS 7121<sup>3,4</sup> and speak to an Appointed Person for further information.
- Consideration must be given to stability of remaining elements; temporary works may be required to provide stability.
- Proposed sections must be suitable for lifting, and the centre of gravity must be accurately assessed if required.
- Changes in wind loadings must be considered, particularly the effects of dominant openings being created. See BS EN 1991-1-4<sup>5</sup> and the National Annex<sup>6</sup>.

### Deliberate collapse mechanism

Typically, this is referred to as a 'blowdown' or a 'pull-down'. Many people mistakenly believe that an explosive actually blows the structure apart; in reality, it is used to trigger the collapse of the structure by weakening or removal of key structural elements, allowing gravity to do the rest. The mechanism for triggering the collapse can be either explosive charges or pulling with a wire or chain attached to an excavator.

Planning the deliberate collapse of a structure requires an engineer to have a very good understanding of the structure and experience of how structures behave in extreme conditions. Steel and concrete structures require different approaches.

### Steel structures

For the deliberate collapse of a steel structure, the structure is pre-weakened. This can include cutting out bracing and

secondary beams. Sit cuts and hinge cuts will be formed in the column sections to ensure that the structure collapses as required. The final cuts should be made only when everything is ready. Explosive or pulling with a wire rope is then used to provide the trigger to cause the structure to collapse, generally by knocking out columns.

These works need careful planning to minimise the risks of working in a weakened structure. However, the use of cutting charges (shaped charges) is becoming more common, reducing the risk of undertaking the final cuts.

#### Key points

- If shaped charges can be used, they should be used. They significantly reduce the hazards associated with the works, although the risk of damaging adjacent buildings with the air overpressure needs to be given careful consideration.
- The deliberate collapse of structures can be completed within a few seconds; however, it should be borne in mind that the preparation of these works can take a long time.
- The simplest collapse mechanism possible should be used to ensure the lowest risk; as is often the case with any design: 'keep it simple'.
- Design should utilise the minimum of pre-weakening necessary. Positioning of the cuts should be considered carefully.
- The works should be planned by a suitably experienced engineer with a track record of undertaking similar works.
- Calculations should be sufficient to justify the design.
- The age of the structure must be recognised and appropriate design factors and material strengths incorporated.
- Clear drawings should be provided detailing all cuts and locations, and workmanship tolerances.
- Stability must be maintained; release cuts should be made only after all preparations are completed.
- Accurate setting-out of the cuts is critical and must be given particular attention.
- Workmanship is critical when pre-weakening a structure, and only suitably qualified and competent burners should be permitted to undertake this work. There should be a clear specification and method statement.
- An exclusion zone(s) should be planned and enforced, based on the worst-case collapse radius. See BS 6187<sup>2</sup> for detailed guidance on exclusion zones.

### Concrete structures

To prepare concrete structures for deliberate collapse, key structural elements are weakened. Explosives are typically placed in holes pre-drilled into the key elements that are to be fragmented. Once detonated, the solid explosive converts instantly to a gas of much higher volume, which effectively blows the concrete off the reinforcement; gravity does the rest.

#### Key points

- These are similar to the key points presented earlier for pre-weakening a steel structure.

### General considerations

#### Key information

The availability of original drawings of the structure can give the engineer a head-start when working out how a structure behaves. However, the information contained in the drawings should be verified on site by carrying out opening-up works. If all is well, the capacity of the structure can be ascertained using traditional design formulae suited to the material in question. Suitable design formulae can be found within the Eurocodes or British Standards.

If the original drawings are not available, then the assessment of the structure will require site investigation. This will require opening up the works following the completion of the soft strip. This should include breaking holes in slabs to expose the reinforcement, as well as breaking out sections of beams and columns to expose steelwork, connections and reinforcement. This information will be the key input for design appraisal.

#### Key points

- It is worth considering that the design codes in use at the time the structure was designed and constructed are likely to differ significantly to those in use today. In addition, the materials will be different; concrete strength is likely to be lower, reinforcement may well be mild steel, the yield stress of steel lower. There is guidance available on this subject from numerous sources<sup>7-9</sup>.
- Any historical information or site investigation of the structure should be passed to the engineer planning the demolition works.
- Beware of using the latest design codes to analyse older structures; they are not necessarily the correct choice. In particular, Eurocodes specifically exclude the use

**CASE STUDY: WHITE HART LANE – DEMOLITION OF SOUTH STAND PRIMARY TRUSS**

**Method:** Demolition by deliberate collapse mechanism  
**Demolition contractor:** DSM Demolition

**Background**

During the demolition of Tottenham Hotspur FC’s White Hart Lane stadium, the south stand primary truss was the final truss to be removed. The truss was approx. 110m long, 8m high and 3.5m wide; its estimated weight was approx. 250t. The truss was set 26m above pitch level.

The truss was initially to be subject to a blowdown using shaped cutting charges to sever the supporting chords. However, concerns regarding blast overpressure resulted in this proposal being dropped.

The second proposal was for a tandem lift using two large crawler cranes. However, when examined closely, the works required became prohibitive. The cranes were currently being used for construction of the new stand, and to reconfigure them for the truss lift would require significant work. Boom changes, addition of a super-lift and other works would have denied the cranes to the construction works for at least a week, which would have had significant programme implications.

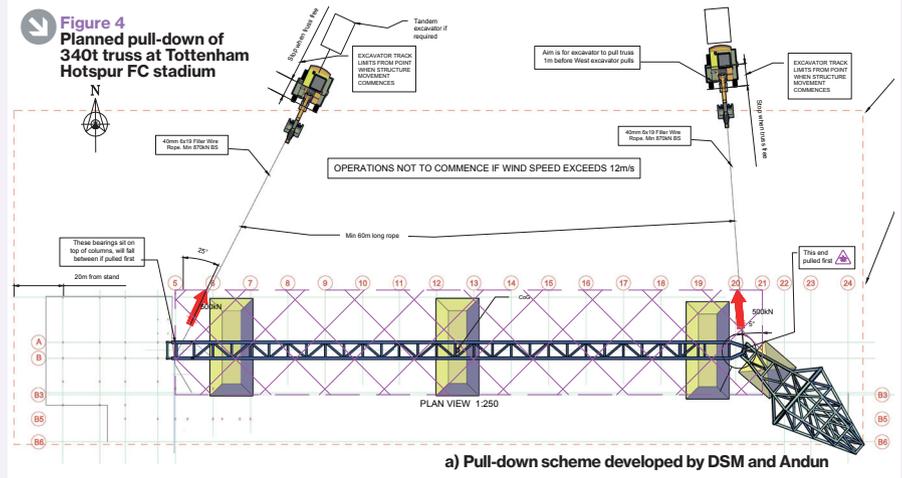
In addition, the principal contractor’s engineer had concerns regarding the lift and required a cradle to be designed and fabricated for the lift. Again, this would involve a significant amount of additional work and would delay the demolition works, which were on a very tight schedule.

Up to this stage, Andun had had no involvement, but was now invited to attend site to see if an alternative solution could be developed. DSM proposed a cut and drop; however, a review on site indicated that this was not feasible due to truss geometry and the inability to time the works to give a clean drop.

A review on site confirmed the feasibility of a pull-down; however, there were a number of issues which required considerable thought. The east end of the truss was supported on bearings on a skew bracket supported on the gallows truss.

The west end sat on simple pot bearings supported on the east legs of the support tower. These were a particular problem, as it was feasible during the pull-down for the truss to sit into the tower and get trapped, with the potential to overturn the support tower and cause significant unintentional damage.

A further complication was the strain energy in the gallows truss: when the weight of the truss was removed, unintentional damage might result from the release of this energy.



a) Pull-down scheme developed by DSM and Andun

**Solution**

After considerable thought, a solution was developed which required pulling at various angles and timings (Figure 4). The plan was to release the east end of the primary truss from the gallows truss and then, as soon as it was free, to give a quick tug on the west end to ensure a clear drop from the west tower.

A weight would be attached to the gallows bracket on a steel wire, with the weight buried in a pile of fill. This system would act as a dashpot piston to slow the release of the strain energy from the gallows truss.

A 3D model was drawn up and a series of drawings prepared to illustrate the scheme.

Andun attended site on the appointed day to supervise the preparation works and the pull-down. Although there was a slight delay in completing the preparation works, the pull-down in front of a crowd of approx. 2000 people was undertaken successfully.



of low-yield (mild steel) reinforcement in concrete.

**Load-testing of slabs**

In recent years, load-testing of slabs within structures has become established, often driven by the contractor wishing to use larger plant on the structure. While this form of testing has its place, it can equally lead the contractor into a false sense of security. Where previously a smaller machine may have been used, a heavier machine may be used now; should the structure contain a latent defect (or have been adapted), it is more likely to lead to serious consequences.

If load-testing is to be used, it should ideally be undertaken only once the capacity of the structure has been calculated by traditional means. Failure to do so can lead to overloading of the structure. These load tests should be planned by an engineer, based on the identified likely failure mechanism of the structure: typically shear at the support in short-span structures and failure in bending in long-span structures. The results should be interpreted by an engineer to ensure that a sufficient factor of safety is in place for the intended plant loadings. Choosing the location of a load test is often difficult, as many structures have been adapted over the years and the changes may make determining representative locations challenging.

*Key points*

- A graph showing load applied against deflection should be provided.
- Loads should be held for a period of time and increased in controlled stages.
- There should be a fixed-level datum to ensure accurate deflections are measured.
- Loading should allow a suitable factor of safety; a minimum of two against failure load.

**Latent structural defects**

Load-testing a structure will not protect against latent structural defects. Experience shows that the best way to deal with such defects is to ensure that the equipment and methodology chosen are not challenging the structure. This means that a sufficient factor of safety should be in place, and a suitable exclusion zone enforced, should a failure occur.

*Key points*

- The quality of the structure can differ vastly dependent on the age of

**"DEMOLITION PROVIDES ENGINEERS WITH TECHNICAL CHALLENGES UNLIKE ANY OTHER FORM OF ENGINEERING"**

construction. LPS tower blocks built in the 1960s are particularly prone to latent defects such as missing reinforcement, loop and pin connections not being connected, etc.

- Car parks, particularly of lift-slab construction, are prone to failure during demolition.

**Conclusion**

Demolition provides engineers with technical challenges unlike any other form of engineering. It is one of the few remaining areas where design codes are not always directly applicable, and the engineer must often rely on engineering judgement and relevant experience.

**Acknowledgement**

This article draws on content from 'Chapter 34: Temporary works in demolition' of the forthcoming book *Temporary works: Principles of design and construction* from ICE Publishing.

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**FURTHER READING**

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