Temporary Works Toolkit

Part 10: Propping and needling

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

Many construction projects which involve partial or whole demolition, refurbishment, or working in close proximity to other buildings or structures are likely to require some form of temporary works. This may include: propping, needling, shoring, facade retention, crash decks, weather protection, temporary screens (to control noise or dust), etc. Temporary works are commonly the contractor's responsibility. However, the Construction (Design and Management) Regulations 2015 (CDM 2015) require that permanent works designers identify and communicate significant risks and take into account any temporary works that may be required during the construction phase[1]. This article focuses on propping and needling.

Understanding the structure

Prior to commencing any structural demolition or refurbishment work, it is important to have as thorough an understanding as possible of 'how the structure works'. This will involve researching any existing documentation (as-built drawings, original design calculations, soil investigations, etc.), checking for any planning constraints (as a result of listing or conservation) and carrying out on-site surveys.

Historic buildings and structures may have been built using traditional 'rules of thumb' which may not conform to modern building regulations, and as-built information often does not exist. Also, the state of repair needs to be considered – this can make the work particularly challenging and risky.

Adjacent property owners need to be consulted and party wall agreements obtained. Neighbouring properties may rely on the building or structure for support or stability and may require temporary structural support or temporary protection from the weather.

In order to carry out a structural survey, the site should be secured, with safe access established (some temporary works may be required to gain safe access). The survey should establish items such as: how overall structural stability is achieved, what materials have been used, the direction of spanning members, what loads are being supported, foundation details, the state of repair (including any maintenance that has been carried out), existing hazards, position of existing services, etc. The survey will need to be intrusive to see what is behind finishes.

Particular attention should be paid to any areas of visible distress (bowing, leaning, cracking, fire damage, water ingress, etc.) and areas where repairs or alterations have been carried out (why were they carried out, what workmanship was involved and has stability been compromised?). If areas are deemed dangerous and in imminent danger of collapse, these should be identified and addressed as a matter of urgency prior to the main works commencing.

BOX 1. GENERALISED PROCESS FOR DEMOLITION OR REFURBISHMENT WORKS

- **Secure the site and ensure safe access (may involve installing some temporary works)**
- **Understand how the structure works by researching existing information and carrying out on-site surveys**
- **Identify the need for temporary works and associated risks**
- **Obtain consent from owners of neighbouring structures that may be affected**
- **Use competent persons to carry out the design and design checking (permanent and temporary works)**
- **Make safe the existing structure (may involve installing some temporary works) in preparation for the main works**
- **Use competent persons to carry out demolition/refurbishment and rebuild in an agreed sequence (may involve installing further temporary works) and control the works by using a permit-to-load system**
- **Review and manage on-site alterations and changes**
- **Remove any temporary works in an agreed sequence so load is transferred to the permanent works and control the works by using a permit-to-remove system**

Surveys should be carried out by competent persons with relevant experience. If a building or structure has stood for many decades (or even centuries), it is likely that stability might not be compromised, provided that:

- the original support conditions remain unchanged and the materials are in good condition (the aim should be to retain the original supports or provide temporary supports which replicate the original supports)
- the loading and stress conditions (including those due to temporary loading and wind) remain unchanged
- vibration (due to demolition, pile driving, etc.) or weathering (the structure may require a new roof) during the construction process is carefully controlled.

Temporary works procedures

The need for temporary works and the associated risks should be identified from the planning/design stage through to the construction stage. On site, the principal contractor is responsible for ensuring that risks are managed and that the work is carried out by competent persons.

One way that the principal contractor can manage these risks is to have a formal temporary works procedure in accordance with the recommendations in BS 5975[2]. This should include: identifying temporary works and risks; ensuring temporary works design and design checking (unless standard details are used – see Table 1 of BS 5975) are carried out by competent persons; appointment of competent temporary works coordinators and temporary works supervisors; managing the erection, loading, monitoring and removal of temporary works.

Temporary works designers have the same designers' duties as permanent works designers. The design (and design checking) of temporary works may be carried out by a number of different organisations:

- principal contractor's in-house designers
- permanent works designer (structural engineer)
- equipment supplier's in-house designers
- specialist subcontractor's in-house designers
- independent specialist temporary works designers.

Design responsibility may be split between different organisations, e.g. the structural engineer calculates the magnitude of the load to be supported and an acceptable deflection limit; an equipment supplier may then be responsible for ensuring a suitable structural item is provided. Whichever organisation carries out any design, the principal contractor should ensure that any 'grey areas' of responsibility are appropriately managed.

Even though thorough surveys have been carried out, not all details may have been established and, once site work commences, some items may be found to differ from what was expected. The design and site management process should anticipate dealing with unexpected items.

In order to prevent partial or full collapse of the structure (or adjacent structures) during construction, careful thought must be given to correctly sequencing the demolition and rebuilding, ensuring that critical supports are not removed without temporary support being provided.

Installing and removing temporary works can be challenging, as generally they are installed prior to main demolition and remain in place until support is provided by the new permanent works. The temporary works need to be positioned to provide the required amount of support, while allowing the work to be carried out with as little obstruction as possible.

Often, it may be of economic benefit to delay certain parts of the demolition until part of the new structure is built. This could allow savings on temporary support requirements, but may make the sequencing more challenging. Limiting deflection and movement is essential to prevent cracking and other significant damage.

The principal contractor should always have overall responsibility for ensuring the works are carried out safely.

The process that should be adopted when considering demolition or refurbishment work is summarised in Box 1.

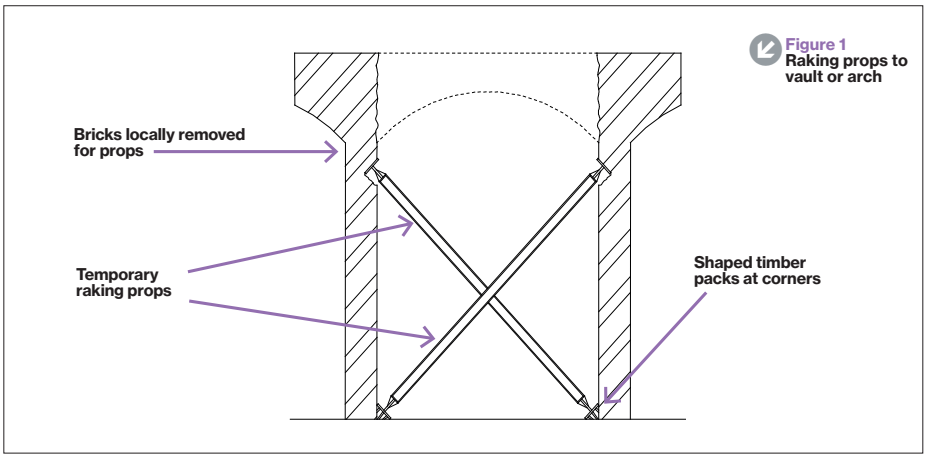


Figure 1 Raking props to vault or arch

Temporary vertical propping

Propping (for this article taken as provision of vertical support to a building or structure rather than support to an excavation) is likely to be required:

- when existing supports are removed or are replaced/strengthened because the supports are no longer capable of supporting the existing or new loads
- to provide temporary support until any new structure becomes self-supporting (e.g. concrete curing)
- to limit deflection which may cause damage
- to gain access for work
- to provide temporary support beneath a slab or floor, to allow for construction plant, labour, materials or demolition rubble to prevent overloading. Backpropping subsequent levels below may then also be necessary in order to carry these loads through a structure to the foundations or to a more solid part of the structure[3,4].

CDM 2015 requires that foreseeable loads on any propping scheme be accurately assessed. Loads will generally comprise:

- self-weight of elements and finishes (including services that require support)
- live loading (Service Class 1 (access) is taken as 0.75kN/m^2; Service Class 2 (general construction) is taken as a minimum of 1.5kN/m^2)
- plant loading and material storage
- loading from other props or backprops
- earth and water pressures
- accumulation of demolition rubble
- accidental impact loading from falling demolition rubble
- vehicle strike (generally taken as 10kN or 20kN)
- environmental loading from wind, snow or rain.

For temporary works, the effects of thermal expansion and contraction are rarely considered (perhaps with the exception of large temporary props to a major excavation). Fatigue is also rarely considered, as the props should be inspected for signs of distress prior to use.

Once the magnitude of the load and effective length of the prop have been determined, a suitable structural member can be designed. The prop could be bespoke (timber, steel, aluminium, etc.) or proprietary propping equipment or scaffolding. Box 2 sets out considerations for the designer, in addition to supporting the vertical load.

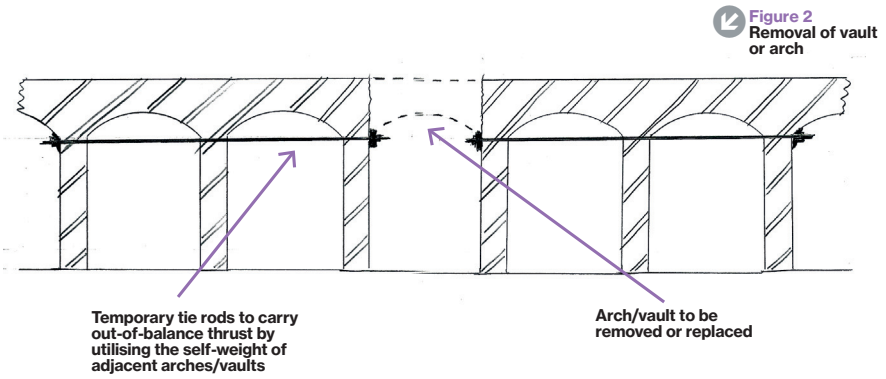


Figure 2
Removal of vault or arch

Removing arches

An arch is a series of wedges in compression. These wedges have to be supported by a vertical reaction and also have to be restrained from spreading horizontally. The line of thrust must remain within the body of the arch; if the line of thrust is below the bottom of the arch, tension is developed and the arch potentially becomes unstable. Figures 1 and 2 show two possible options for providing temporary support to carry any out-of-balance thrust when vaults or arches are removed.

Forming openings in loadbearing brickwork

Minor openings may be required for services such as extractor fans. The brickwork will arch over the new hole and a lintel or temporary supports would not be necessary. Larger openings may be required for a new door or window, to enlarge an existing door or window, for new large services, or to open up a space for more light.

The new opening will have to be permanently bridged, typically by using a steel beam, precast concrete lintel, *in situ* reinforced concrete beam, timber beam, or by forming an arch. The loading should be calculated as shown in Figure 3 by considering the full weight of brickwork within the 45° load triangle, plus an allowance for any additional loading from floors or beams within the 60° interaction zone (unless these are supported separately).

Existing openings or columns above a new opening need to be identified (they may be partially obscured by an existing floor), as these will affect the ability of the masonry to arch.

If a single or double skin of brickwork requires support, there are two commonly used simple temporary works solutions:

- Proprietary horizontal steel frames (e.g. 'no more props') can be cut into mortar joints above the new opening and then bolted in position. The frame is tensioned and acts as a temporary lintel to support the brickwork until the new permanent lintel is installed, after which the frame is removed. This type of system does not require props and is normally suitable for openings up to around 2.5m wide.
- 'Strongboys' are steel plates (approx. 150mm × 350mm) that fit onto the head of an adjustable steel prop ('Acrow'). The plates can be cut into the mortar joint above the new lintel. They will be positioned at relatively close centres (around 750mm) and rely on the brickwork arching between them. They can typically support loads of around 350kg (as the applied load is eccentric to the prop) and are generally used for openings up to around 3m wide, with heights less than around 3m.

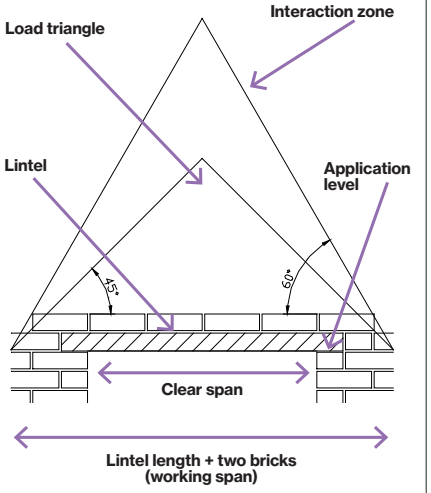


Figure 3
Lintel design to BS 5977[6]

If an opening is to be formed in a thick wall, or the opening is wide, then a designed needling scheme would be required. The needles should be positioned not more than 1m apart and the load on each needle should be calculated as shown in Fig. 3. Figures 4–6 present three examples of needling techniques (brickwork or stone walls).

A typical installation sequence for the scheme shown in Fig. 4 would be as follows:

- Check for existing services.
- Erect scaffold tower (or adjustable props and backpropping – which may need some additional bracing for stability) with an access platform for workers. If the new lintel is large, then remember to position it on the floor inside the line of the props or scaffolding prior to their installation.
- Form holes through the existing wall (at maximum 1m centres) above where the new lintel is to be placed – this can be done with a hammer and bolster or coring machine.
- Thread needles through the holes and support them on the props or scaffolding. The props or scaffolding should have screw jacks for adjustment.
- Dry pack between the tops of the needles and the brickwork above, and allow curing time.
- Use the screw jacks to remove any slack from the support system and form a slot for the new lintel.
- Attach blocks and tackles to the needles to lift the new lintel into position.
- Position the new lintel and dry pack between the top of the lintel and the brickwork above, and allow curing time.
- Form the new opening below the new lintel.
- Remove the needles and then the supports.

BOX 2. CONSIDERATIONS WHEN DESIGNING A PROP

- Consider the eccentricity of the load (for temporary works 25mm is typically used), which will cause a moment in the prop unless concentric loading can be guaranteed
- Consider the prop being installed 'out of plumb' (for temporary works 1.5° is typically used)
- Establish exclusion zones for safe working and protection measures to prevent significant accidental loading
- Ensure the sequencing of the works includes a means of adjustment so that props can be installed and removed. For complex systems, a load-transfer system (from temporary props to permanent supports) should be considered. Generally, the removal of temporary props should follow the load path of the permanent works
- Consider excessive stress between the top of the prop and the member being supported. Punching shear could be an issue – packing and spreaders will help, but if timber is used then crushing should be considered
- Check the capacity of any existing connections
- Determine a safe means of releasing the load from the temporary props, especially when the applied vertical loads are large
- Determine whether crash decks will be required for any falling items during demolition and how rubble will be removed
- Assess the foundation options. Existing foundations may be utilised or new temporary foundations may be needed. When the prop is positioned above a suspended slab or floor, backpropping may be required
- Consider elastic shortening of the prop and foundation settlement leading to movement in the item being supported; this movement may be significant enough to cause damage. The degree of acceptable movement should be agreed by the parties involved. Deflection can be minimised by using stiffer supports and pre-loading by using the mechanical advantage of threads or jacking systems. In general, the author uses a maximum pre-load of around two-thirds of the applied vertical load. The likely deflection limits and facade/building movements are discussed in more detail in CIRIA publication C579[5]
- Consider how the props will be handled (if lifting equipment cannot be used, then props need to be 'manhandled'), and provide sufficient working space and safe access for any work at height
- Consider the stability of the item being supported (e.g. deep beams may become unstable) and overall stability of the structure if shear walls are removed. Propping systems should be braced to provide the required stability
- Ensure any temporary works are robust and designed so that progressive collapse is prevented

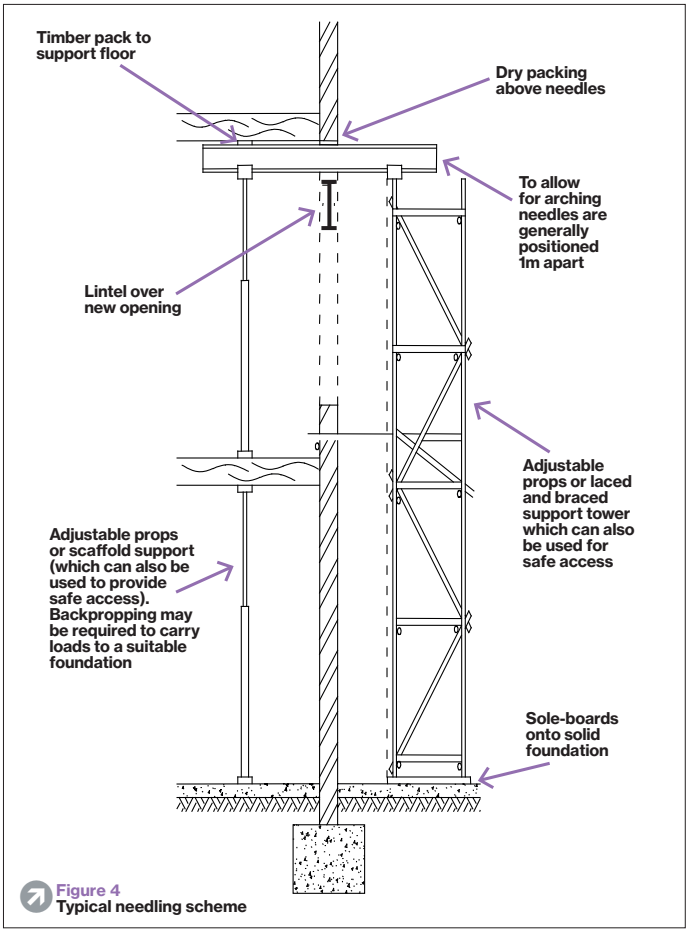


Figure 4
Typical needling scheme

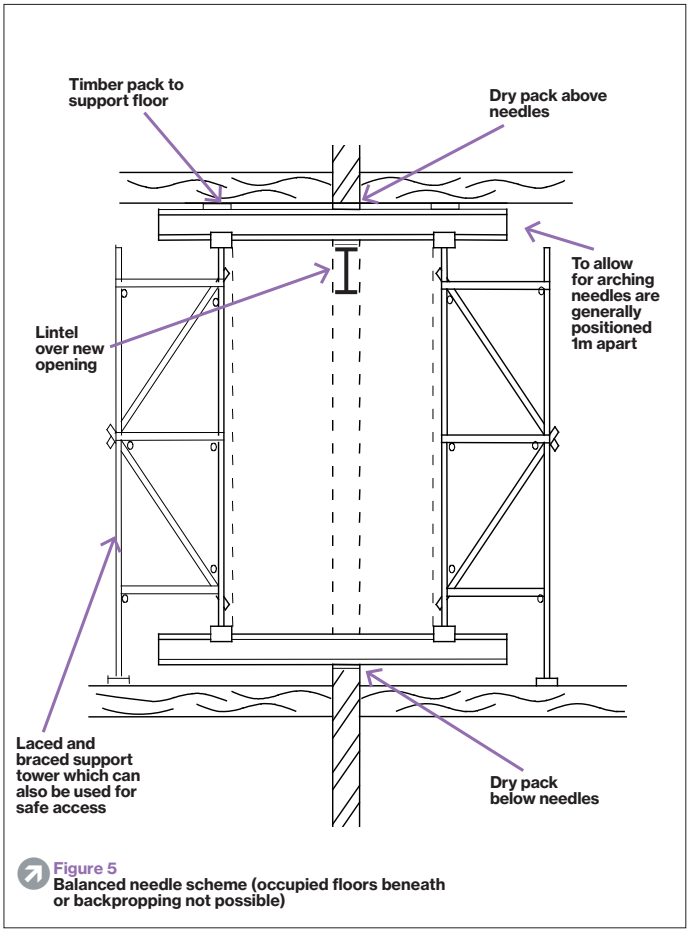


Figure 5
Balanced needle scheme (occupied floors beneath or backpropping not possible)

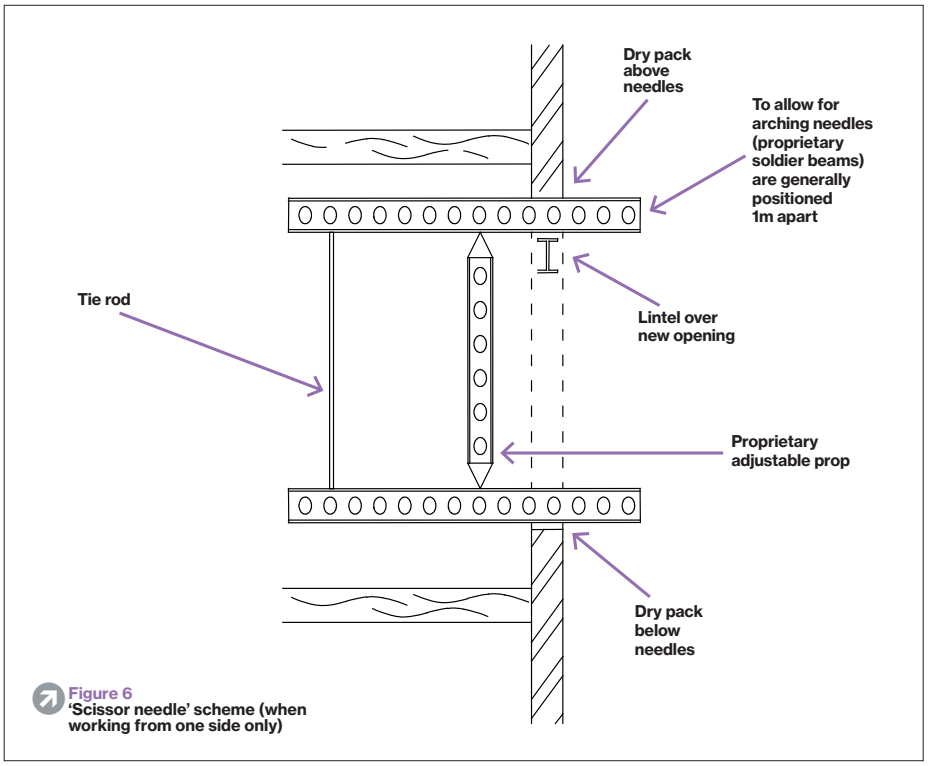


Figure 6
'Scissor needle' scheme (when working from one side only)

Needle beams can be timber, proprietary soldiers or steel beams (depending on the magnitude of loading) supported on timber props, adjustable steel or aluminium props, scaffolding, proprietary soldiers or steel column sections. They are positioned above the new lintel through holes which are formed in the existing wall, generally not more than 1m apart to allow for arching. Dry pack (a dry sand/cement mix) is placed between the needle beam and the wall above to ensure even bearing. As with propping, deflection (due to beam bending, elastic shortening of props, foundation settlement) is a significant issue to prevent damage to the structure being supported. Pre-loading or using stiffer supports will minimise deflection.

When needling upper floors, backpropping may be necessary. If the new lintel is within the depth of the existing floor, then it is likely that the needles will have to be placed above the floor and the floor will have to be supported independently. A useful 'trick' is to place the new lintel inside the line of the props before the props are installed, otherwise access becomes difficult. When forming new openings in shear walls, any temporary works must allow for the transfer of horizontal loading.

When backpropping is not possible, 'balanced needles' are used, whereby the vertical load is carried back into the loadbearing wall by the lower needle beams (Fig. 5). Similarly, 'scissor needles' can be used when the work is to be carried out from one side of the wall only (Fig. 6). With this scheme, bricks should be prevented from falling outwards by using netting or similar.

The 'Abbey Pynford method' (Figure 7) can be used to avoid needles and props. Small holes are formed through the brick wall (as described earlier), with steelwork 'stools' (which become sacrificial) installed into the holes and dry packed above and below. The holes are joined together to form a 'slot' and

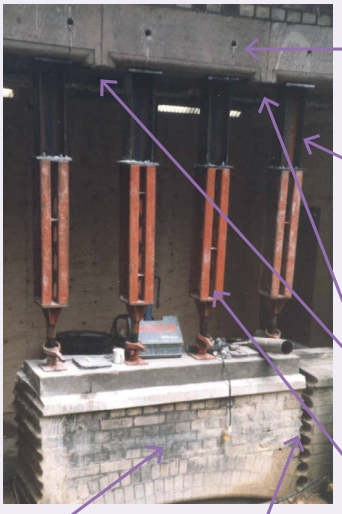
CASE STUDY: NATIONAL PORTRAIT GALLERY, LONDON

A new large door opening was to be formed in the position of an existing window. The window opening comprised a large stone lintel which was in three sections, supported on stone mullions which were supported on brickwork below.

The solid brickwork was 18in. thick and in good condition. The new opening was to be supported by a new *in situ* reinforced concrete beam formed beneath the existing three-section stone lintel and supported on reinforced concrete columns at each end.

The sequence of works was as follows:

- **Carry out a structural assessment of the existing conditions and calculate potential loads to be supported.**
- **Check for any existing services and remove existing window frames.**
- **Bolt sacrificial steel universal column (UC) sections to proprietary adjustable props (UC sections will be cast into the new reinforced concrete beam but do not contribute to the design of the beam).**
- **Install props with sacrificial UC sections either side of existing stone mullions. Adjust (tighten) props to remove 'slack' from the support system.**
- **Remove stone mullions.**
- **Core 100mm holes (using a proprietary coring machine) through the existing brickwork either side of the props to form the vertical slots into which the new reinforced concrete columns will be formed.**
- **Install basic timber formwork and reinforcement and pour concrete to form the columns. Allow curing time.**
- **Remove column formwork.**
- **Install beam formwork (supported on scaffolding which also incorporated a working platform and access) and reinforcement. Beam formwork was cut around the UC sections and made grout tight.**
- **Pour concrete beam to within 50mm of the brickwork above and allow curing time. Then dry pack between the top of the beam and the underside of the brickwork above and allow curing time.**
- **Unbolt sacrificial UC sections from props and remove props. Make good concrete beam soffit and then remove final section of brickwork beneath the props.**



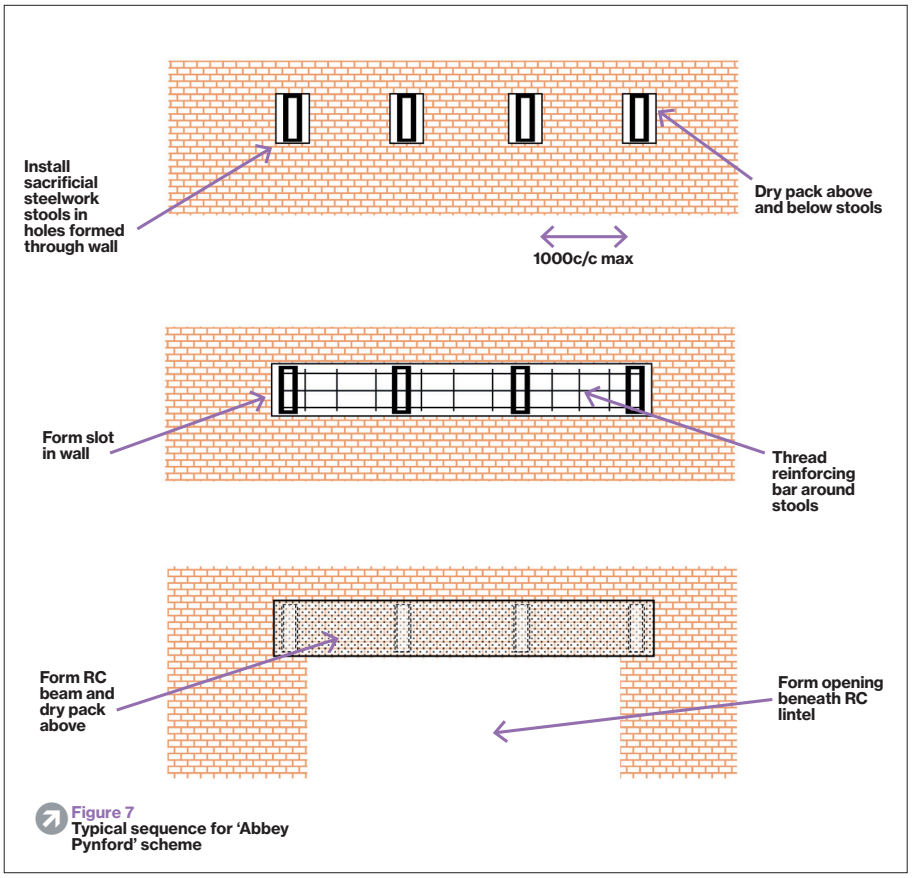


Figure 7
Typical sequence for 'Abbey Pynford' scheme

reinforcement bars are then threaded around the stools. Simple formwork is then used to allow a reinforced concrete beam to be formed (the concrete is poured to within 50–75mm of the existing wall above). The gap between the new concrete beam and the brickwork above is then dry packed and, once the concrete has cured, the new opening is cut out below this *in situ* reinforced concrete lintel.

When forming an opening in a wall, in addition to the considerations mentioned previously for propping, the designer should:

- check for existing services
- consider the overall stability of the structure when significant openings are formed in a shear wall
- be aware that load interaction triangles can affected by corners, expansion joints and openings above
- position needles where the load is applied, i.e. generally not under windows
- consider independently propping beams that carry significant floor loadings above openings
- ensure the span of the needle beams and the positioning of the props allows for working space
- check bearing stresses.

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