Underpinning: Good practice guidance


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Synopsis

Underpinning as a concept is generally understood by most people, but its mechanics and feasibility is less so. This document provides the reader with the key information necessary when underpinning is being considered on a project. Ultimately, the success of any project lies in proper planning, allowing sufficient time to gather the right level of information and appointing experienced specialists. This is especially true for underpinning where the consequences of getting it wrong can be catastrophic.

Disclaimer

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Photos 1 and 2 - Examples of good shoring to access pits for underpinning to external walls

1.0 Introduction

1.1 Whilst the concept of underpinning is generally understood by most construction professionals, its feasibility is less so.

1.2 The aim of this guidance is to provide a first point of reference where underpinning is being considered on a project (see Photos 1 and 2).

1.3 The target audience is those involved at project conception: Planning Consultants, Architects, Consulting Engineers; Developers, Principal Designers (PDs) and lay clients.

1.4 However, Contractors, Groundworks Specialists, Temporary Works Design Engineers, Temporary Works Co-ordinators (TWCs), Health and Safety Consultants, Party Wall Surveyors and Building Inspectors may also benefit from its reading.

2.0 Scope

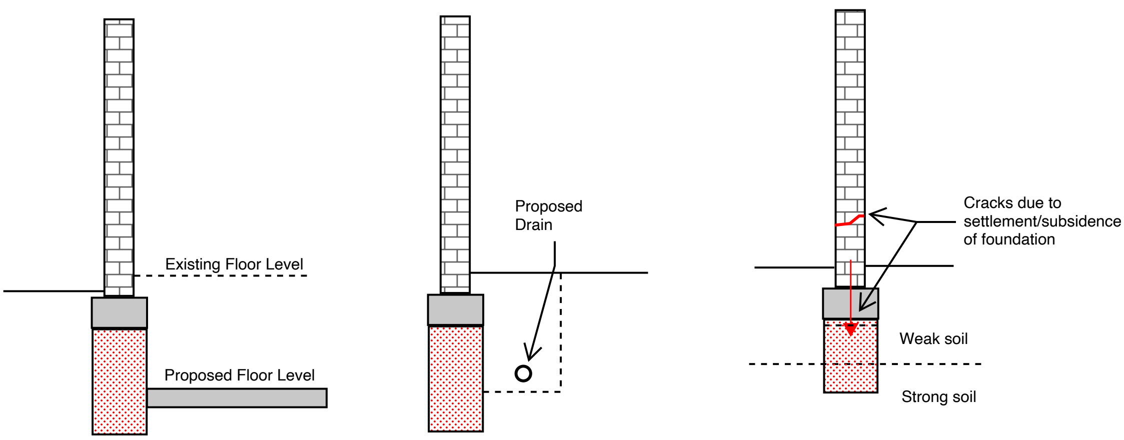
2.1 For the purposes of this document underpinning will be defined as:

"the downward extension of existing foundations using a method of staged excavations and replacement of soil with concrete (reinforced or unreinforced)"

2.2 Underpinning is often required in the following situations:

a) Lowering of ground levels adjacent to existing structures, e.g. lightwells, lift pits, which would result in undermining or de-stabilising foundations nearby (Figure 1);

b) Accommodating the installation of deep drainage or other services close to existing foundations (Figure 2);



Figures 1 to 3 – Typical underpinning situations

c) Remediation to address subsidence or excessive differential structural settlement (Figure 3);

d) Increase in load which requires founding in a stronger stratum.

2.3 Due to the upsurge in retro-fit basements, underpins are now commonly used as structural retaining wall elements.

2.4 This guide covers underpinning of **load bearing walls** whose length is at least **3m** with **relatively uniform vertical loading**.

2.5 In general, such structural elements are deemed to have sufficient robustness to allow staged excavation and replacement of soil with concrete beneath their existing foundations without causing harm to the structure above or overstressing the existing ground.

2.6 This guide **does not** cover underpinning of individual **columns or piers** where such robustness is lacking. In such situations, specialist engineering advice **must be sought**.

NOTE: It is hoped that future updates shall include more specialist forms of underpinning, e.g. piling, permeation grouting, stooling, etc.

2.7 The aims of this document are to:

- highlight the key issues and risks when underpinning is being considered;
- offer advice on how these issues can be addressed;
- promote best practice.

3.0 Health and safety matters

3.1 The Health and Safety at Work etc. Act 1974 (HSWA) [1.] sets out legal requirements on employers and employees regarding their duties to ensure the health and safety of those who may be affected by their operations.

3.2 The Construction (Design and Management) Regulations (CDM), introduced in 1995 and with its latest version published in 2015 [2.], were introduced to provide specific guidance and regulatory information to support parties responsible for managing and controlling health and safety, viz. Clients, Designers, Contractors, Principal Contractors and Principal Designers. All have specific actions that they must follow to discharge their duties under the regulations and subsequently the HSWA.

3.3 Clients and designers should recognise that the decisions made when selecting underpinning as the method to form a basement, or when extending foundations, impact on the health and safety of those persons subsequently employed to implement those decisions and designs. The following are specific regulations to be aware of.

- Regulation 4, Client duties in relation to managing projects
- Regulation 9, Duties on designers
- Regulation 11, Duties of a principal designer in relation to health and safety at the pre-construction phase
- Regulation 15, Duties of contractors

  NOTE: A Contractor must plan, manage and monitor construction work undertaken either by themselves or by others under their control, to ensure that it is carried out without risks to health and safety, so far as is reasonably practicable.
- Regulation 17, Safe places of construction work
- Regulation 22, Excavations

3.4 Regulation 9(2) states that designers must consider the following:

When preparing or modifying a design the designer must take into account the general principles of prevention and any pre-construction information to eliminate, so far as is reasonably practicable, foreseeable risks to the health or safety of any person—

(a) ***carrying out*** *or liable to be affected by construction work; …*

3.5 Self-evidently, underpinning is a high-risk activity, but it is not precluded by the Regulations. It can be classified as 'temporary works' or 'permanent works' but, irrespective, there is a legal requirement imposed on all those involved in the design process to consider the risks and eliminate them at source where possible.

3.6 To help contractors fulfill their duties under Regulation 15 and with particular respect to the management and control of temporary works, the recommendations of BS 5975: 2019 [3.] should be followed.

4.0 Key risks

4.1 The key risks associated with underpinning that should be considered and addressed at the outset of a project are:

- ground collapse;
- structural failure/collapse;
- unacceptable ground or structural movements.

4.2 Despite legislation, failures resulting from poorly planned or executed underpinning are still reported in the press. The impact of these occurrences is far-reaching affecting not only the property owner but also neighbours and surrounding assets. Some cases have also accounted for fatalities. (See Photos 3 to 6.)

5.0 Planning

5.1 The success of any underpinning scheme is dependent upon proper planning (see Figure 4, Planning Flowchart). As a minimum requirement the planning phase should include the following activities:

- a full ground investigation (GI) to ascertain the site stratigraphy and water levels;
- structural appraisal to understand the structural form, condition and load transfer paths;
- dilapidation survey(s) and history of existing structures;
- site survey to determine the proximity and nature of neighbouring buildings, existing services, public utilities, highways and other transport assets;
- further research, as required, to address any other identified risks, e.g. underground tunnels, unexploded ordnance, etc.

5.2 As a result, there may be a need for a Party Wall Award to be served or an Approval in Principle (AIP) to be agreed with the Local Authority or other Public Service entity, e.g. Network Rail, London Underground, Transport for London, Water Authorities, etc.

5.3 AIPs are now a commonplace requirement within many London Boroughs where works have the potential to cause damage to their assets, e.g. footpaths, highways, services, etc.

5.4 Adequate time and resource shall be allowed to complete the planning stage properly. For example, the minimum approval period for a Local Authority AIP is typically 8 to 12 weeks. Likewise, serving and agreeing Party Wall Award(s) can take several months especially in urban settings where there are often many boundaries, owners and tenants involved.

5.5 The early involvement of a **specialist consultant or contractor** who has experience in these matters is **highly recommended and good practice**. Their input should prove invaluable to the project team.

5.6 Using the information gathered during the planning exercise, both feasibility and scope of underpinning can be confirmed with a high degree of confidence.

Photos 3 to 6: Examples of failures caused by poorly executed underpinning works

5.7 Before commencing the detailed design stage, a movement monitoring regime should be considered and agreed with interested parties. This is usually a pre-requisite for Party Wall Awards and usually includes trigger action levels using a 'traffic light' system together with contingency measures.

5.8 It is emphasised that all underpinning works include risk of ground movement. A well-planned scheme seeks to reduce this risk to an absolute minimum. Movement monitoring of the affected buildings at regular intervals throughout the works provides the desired level of control necessary to achieve this goal. In addition, it provides valuable supporting evidence when contesting spurious claims.

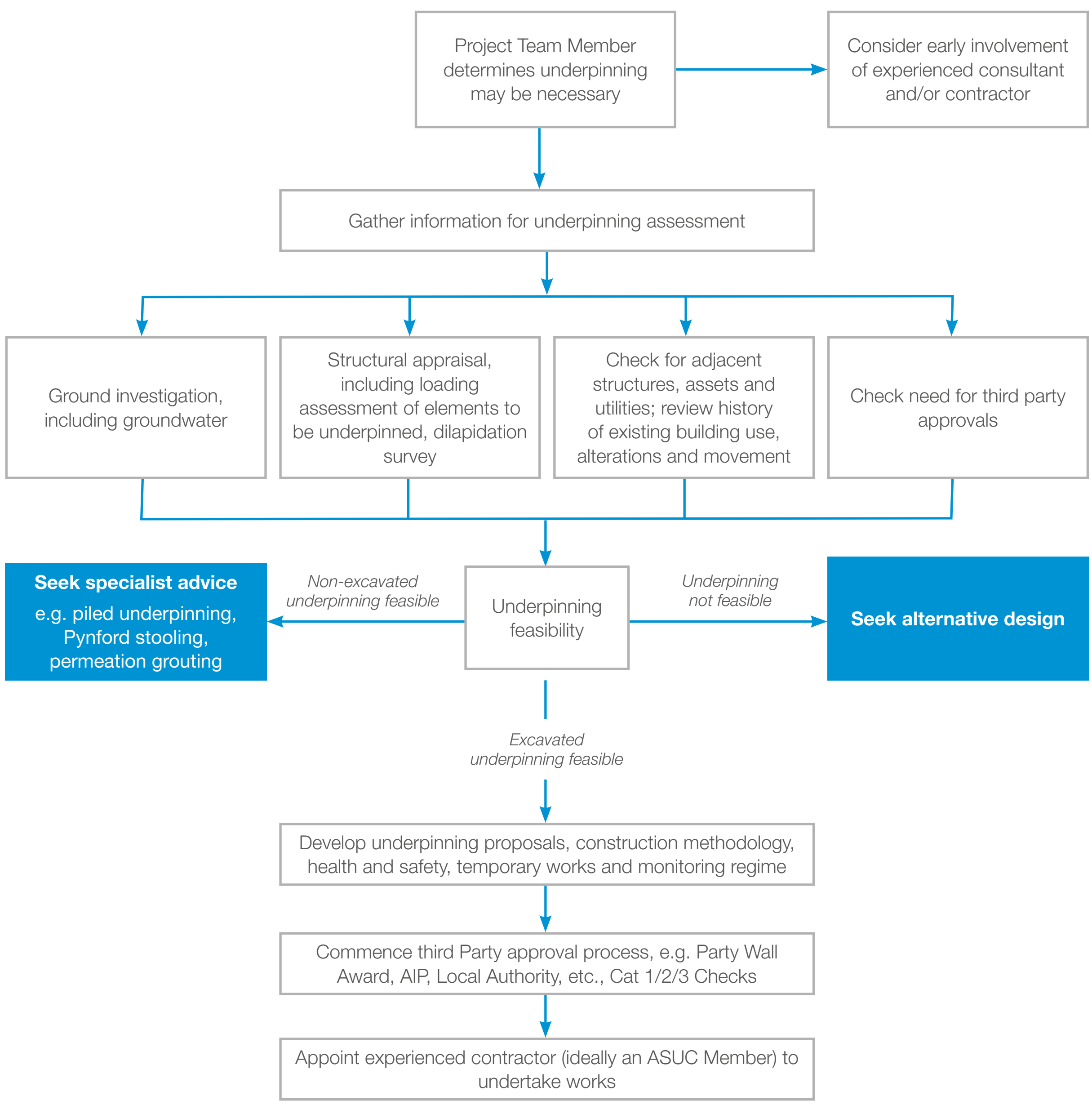


Figure 4: Planning Flowchart

6.0 Design requirements in underpinning

Summary of good practice guidance:

6.1 Underpin bays should not exceed **1.50m** in length, where structurally acceptable (otherwise, the norm is 1.0 to 1.2m), or exceed **2.50m** in depth. (See Figure 5.)

6.2 No more than **20%** of the wall's length should be unsupported at any one time.

6.3 The well-established '1, 4, 2, 5, 3, 1, 4, 2, 5, 3' underpinning bay sequence should be adopted. (See Figure 5.)

6.4 Underpin access pits should be large enough to allow safe access. A typical plan size is: width of underpin (1 to 1.50m) x 1.50m measured perpendicular to the wall being underpinned. (See Figure 6.)

6.5 Earthworks support would normally (subject to an assessment of the ground conditions) be provided to **all sides** of the underpin access pits and if necessary to the **rear exposed face** of the proposed underpin. (See Figure 7.)

6.6 Sacrificial support to the underside of the wall foundation being underpinned may be necessary. (See Figure 7.)

6.7 Underpinning in water-bearing granular soils **is not recommended** without a properly designed de-watering system or ground improvement process. These require the input of a specialist.

6.8 All underpins and/or access pits should be **re-propped and/or backfilled** with compacted granular material on completion. (See Figure 8.)

6.9 All underpins should be founded at least 300mm below any proposed reduced adjacent ground level. (See Figure 8.)

6.10 The minimum depth of underpin should be **1.0m**, for ease of access and safety considerations.

6.11 The minimum underpin wall/stem thickness should be **450mm**. (See Figure 8.)

6.12 Minimum curing periods should be:

- underpin concrete – 24 hours;
- dry-pack – 12 hours.

6.13 The dry pack gap between the top of the underpin concrete and the underside of the footing should be at least 75mm but not greater than 150mm.

6.14 Dry pack should comprise: 1-part OPC to 3-parts sharp sand by volume with an anti-shrink additive mixed with clean water to create a semi-dry mix.

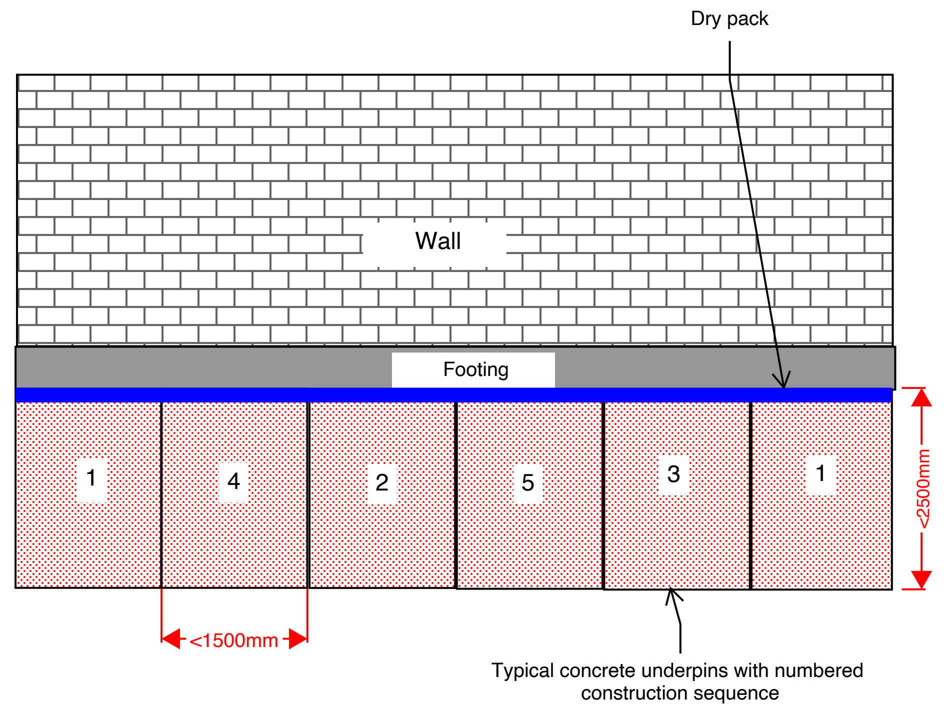


Figure 5 – Typical concrete underpins with numbered construction sequence

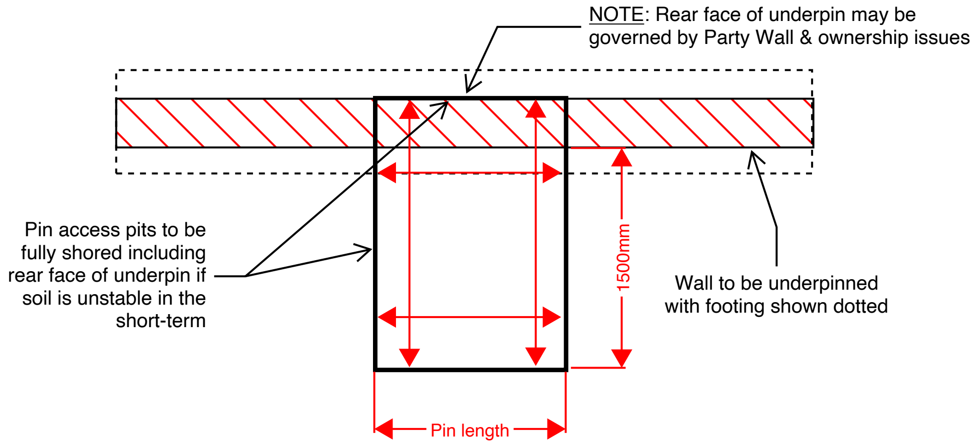


Figure 6 – Plan view on underpin access pit

NOTE: The extent of underpinning is often governed by party wall and trespass issues (see Para. 6.29).

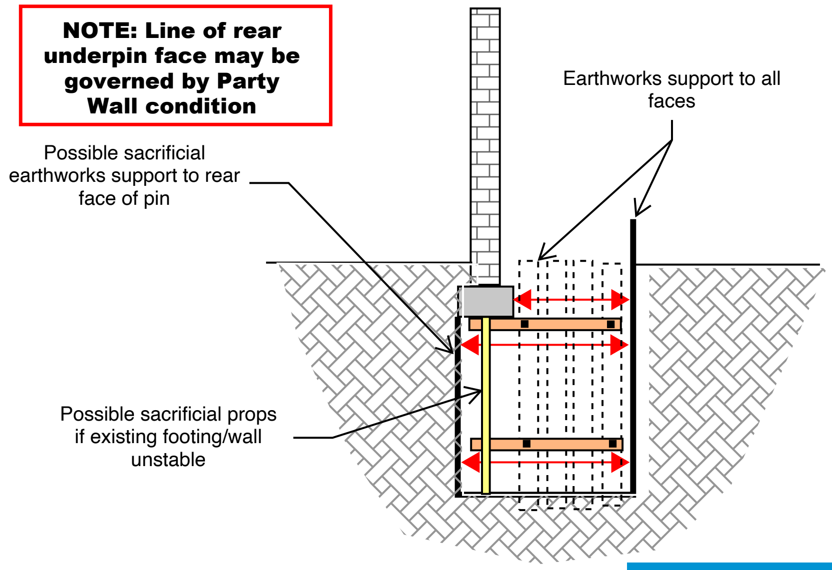


Figure 7 – Typical section showing temporary works

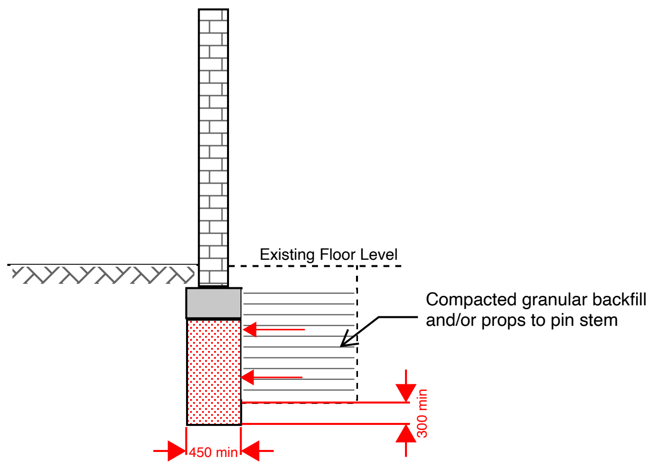


Figure 8 - Minimum underpin wall/stem thicknessworks

Photos 7 and 8: Examples of good shoring practice to underpin access pits

Shoring:

6.15 Ground conditions should be assessed prior to works commencing and appropriate shoring designed to support the retained soils during excavation work. The soils should be appraised continuously during the works and the temporary works design checked and modified accordingly. (See Photos 7 and 8.) Do not excavate for underpins in extreme weather unless precautionary measures are in place.

6.16 As a reminder:

"There is almost no ground that can be relied upon to stand unsupported in all circumstances and the risk is self-evident when you consider that it is quite common for one cubic metre of soil to collapse into an unsupported excavation, and this can weigh as much as one tonne."

Source:
Health and Safety Executive, HS(G)150 [4.]

6.17 There are several published authorities that offer guidance on excavation shoring and the detailing of standard waling, strutting and boarding ground support using timber and plywood as well as proprietary systems. (See References and Bibliography.)

6.18 BS 5930 [5.] and BS 5975 [3.] both give advice on the field identification of soils that can be used to assess soil strengths.

Loads:

6.19 It is of critical importance that the loads in the ground or superstructure are properly assessed.

6.20 These loads are both vertical or horizontal (or often a combination of both) and, depending on the circumstances, cause sliding, overturning or settlement or a combination of these.

6.21 The applied loads should be properly assessed at **all** stages of the underpinning activities and the shoring and temporary works designed accordingly. This should be undertaken by an experienced Engineer who is well versed in soil mechanics and temporary works design.

Vertical – Failure mechanism: Settlement

6.22 The design should consider the live and dead loads to be supported as well as how these vary with piers, chimneys, point loading, openings, perpendicular walls, etc. The bearing capacity of the soils should then be appraised according to the various loading scenarios. If the bearing capacity is insufficient, soils compress and cause the structure above to settle and rotate. (See Figure 9.)

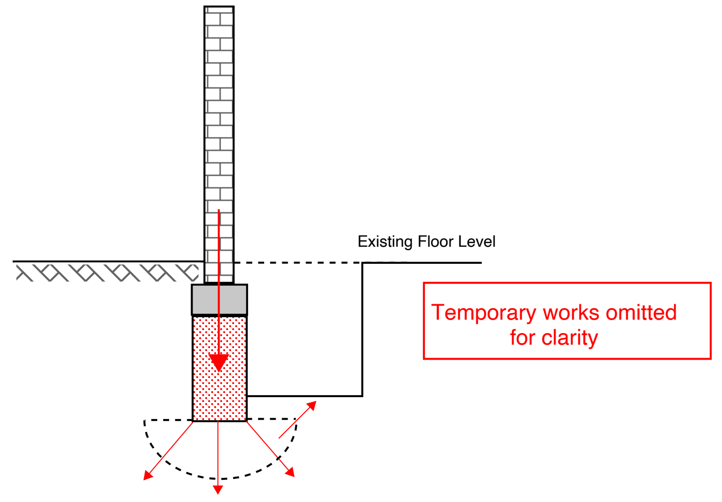


Figure 9 – The consideration of bearing capacity

6.23 The distribution of forces during each stage of the individual and group underpinning construction should be considered. The bearing capacity below existing walls adjacent to an individual excavation might be exceeded due to the redistributed load or the bearing capacity of the soil at the base of the underpin(s) may not withstand the applied loads. In each circumstance there might be settlement as the soils below compress.

Horizontal – Failure mechanism: Sliding/ overturning

6.24 The surcharge dead and live loads should be calculated and the soil parameters in the excavated ground identified. These provide the horizontal loading during the underpinning process. It is also important to note that soil characteristics and loads may change during the works. An example of this might be moisture content, i.e. drained or undrained and water level. Both can have a significant impact on the stability of an excavation, shoring and underpinning in the temporary condition. (See Figure 10.)

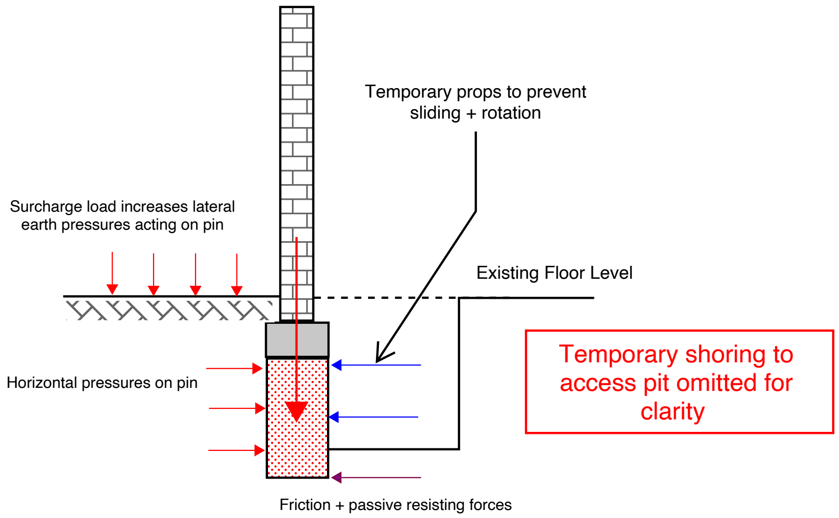


Figure 10 – Considering dead and live loads

NOTE: The loads may change during the works due to modifications in the building and adjacent structures, temporary works or live loading from the public or site operations. These structures should also be assessed for inherent defects or remodelling that may lead to them being more susceptible to movement when underpinned.

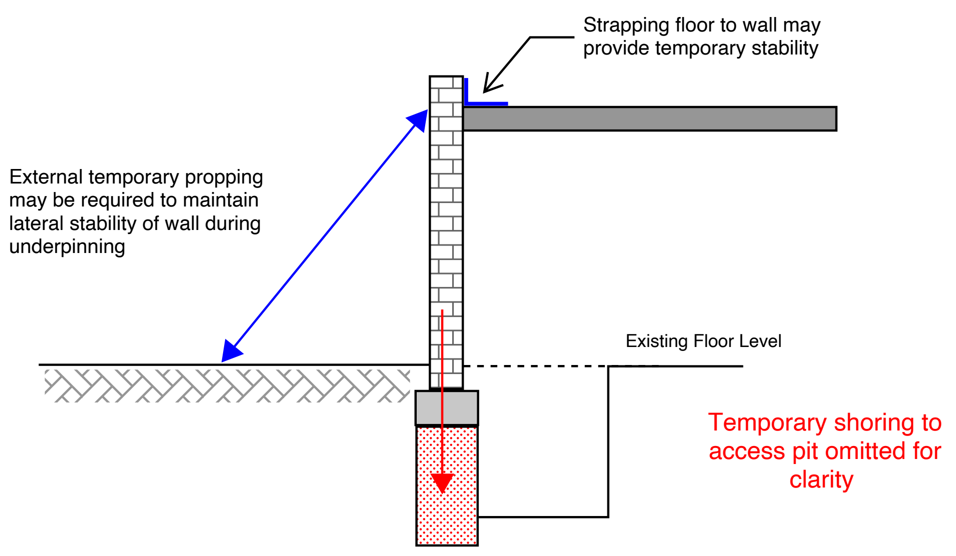


Figure 11 - Considering the effects of movement

6.25 The effect of movement that may occur should be considered and the secondary impact that this has on unstable elements of the superstructure. An example of this may be lateral movement of a gable end wall where the floor joists are not tied into the brickwork. In such instances, it may be prudent to introduce straps between the joists and the wall to be underpinned or where this is not feasible, to prop the wall externally. (See Figure 11.)

Adjacent structures

6.26 The excavations required to construct underpinning bases may affect the stability of adjacent structures. This may be from a reduction in soil bearing area when a pressure bulb is intersected or when restoring forces confining cohesionless soils are removed. (See Figure 12.)

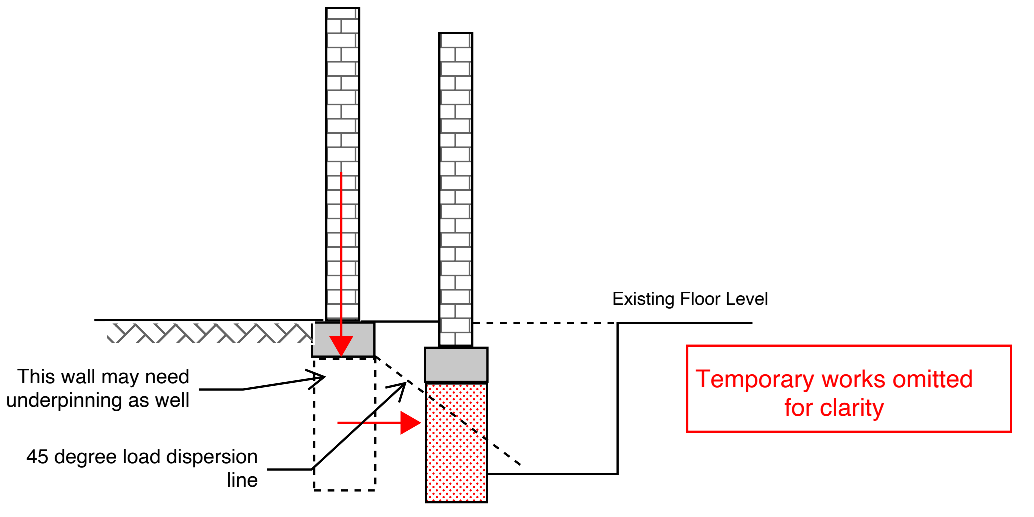


Figure 12 – Adjacent structures

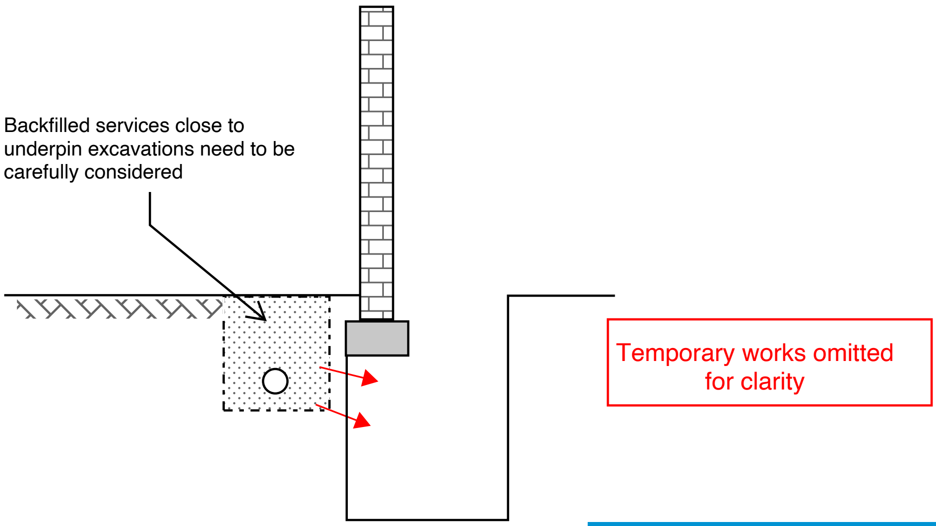


Figure 13 - Excavations near buried services

6.27 Excavations near buried services that have been backfilled, perpendicular wall foundations and nearby infrastructure have in the past caused instability, catastrophic failure and death. These situations should be carefully considered and managed. (See Figure 13.)

6.28 Underpinning wall stems should not usually be less than 450mm thick as this is the minimum width achievable when working in such confined spaces. In addition, it is good practice to ensure that the formation of the underpins is at least 300mm below any excavated level. (See Figure 8.). This ensures that the base of the pin has some degree of lateral passive resistance and counters the risk of settlement due to potential ground disturbance and weakening. It is important to keep the area dry. Water ponding in the 300mm deep zone is likely to weaken the soil, reduce the ground bearing pressure and increase settlement.

Design safety considerations

6.29 Wherever possible the use of rear heel projections from the underpinning base should be avoided because these increase the risk of ground collapse behind the pin. If rear extensions are required to satisfy design load criteria, then the whole stem thickness should be increased over the full height of the pin. (See Figure 14.) Asymmetric pin widths may give rise to unacceptable eccentricities. These should be assessed.

NOTE: This may not always be possible in Party Wall situations where the rear face of the pin usually aligns with the neighbour's wall face to avoid trespass issues.

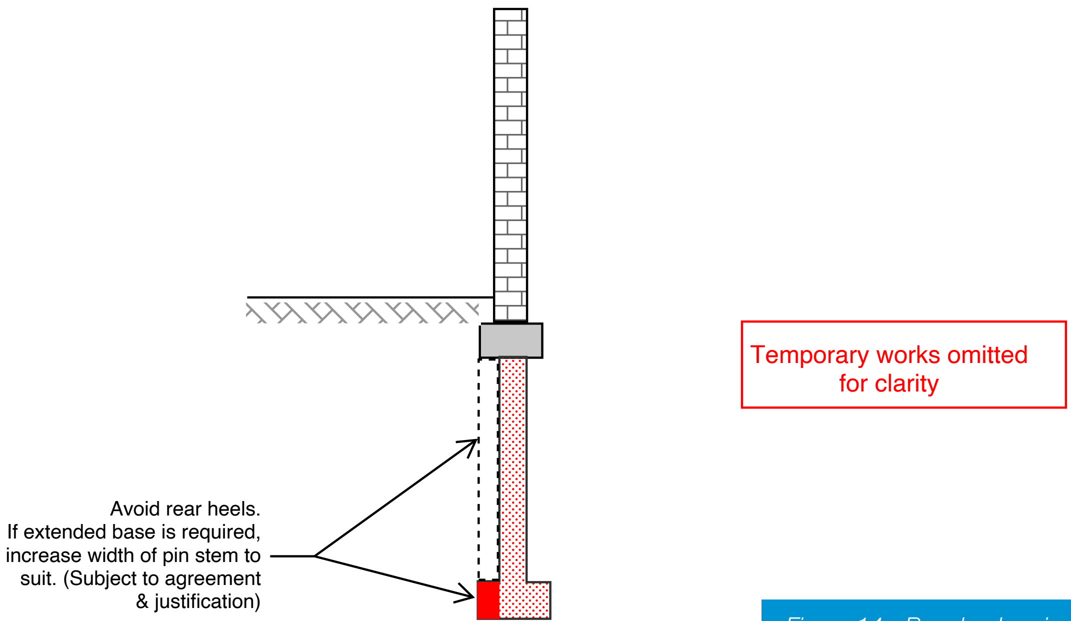


Figure 14 - Rear heel projections

Figure 15 – Plan view of underpins with vertical shear key connections

6.30 Where possible the use of reinforcement between bases should be avoided and replaced with shear keys to reduce the risk of injury during excavation work. Alternatively, use of proprietary reinforcement continuity systems comprising pull-out bars or couplers may be used. (See Figure 15.)

Underpinning as part of retaining wall construction – Basement construction

6.31 These are more likely to experience sliding and overturning as individual pins become wall sections and the soil is removed from one side.

6.32 To resist the horizontal loads without excessive temporary propping, it is possible for elements of the permanent structure to be constructed. For example, floor plates can be installed to prop the head of the retaining wall or a section of floor slab at the base of the wall to resist sliding and overturning or improve the temporary bearing capacity of the soil.

6.33 In some instances, the lower most section of the underpinning can be deepened to embed the base of the wall in undisturbed soil or a keel may be added. This may reduce the need for temporary propping at low level. (See Figure 16.)

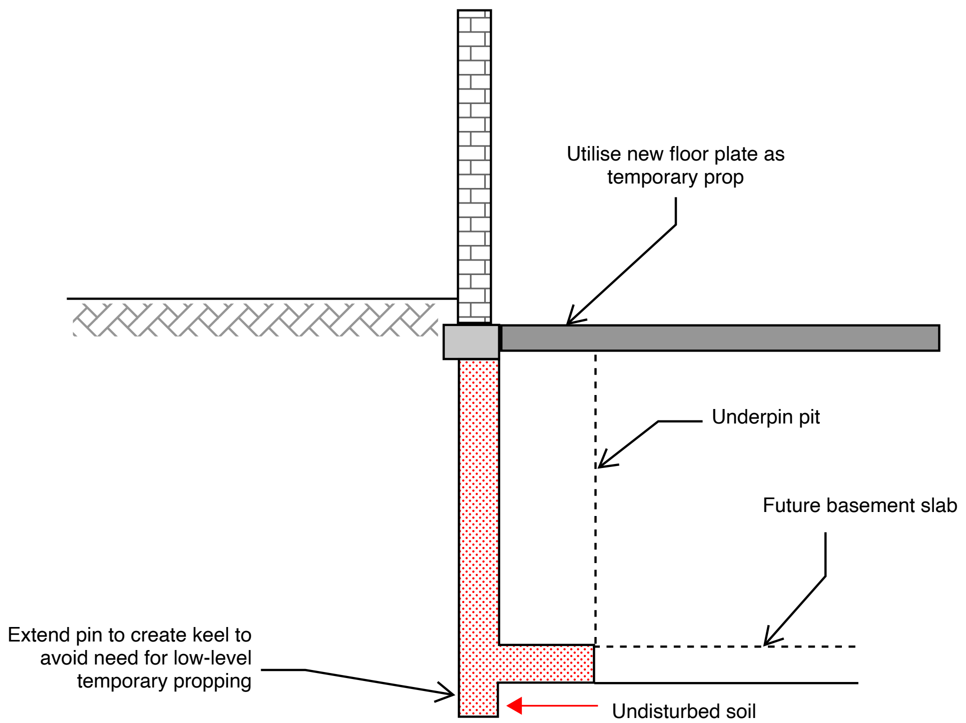


Figure 16 - Reducing the need for temporary propping at low level

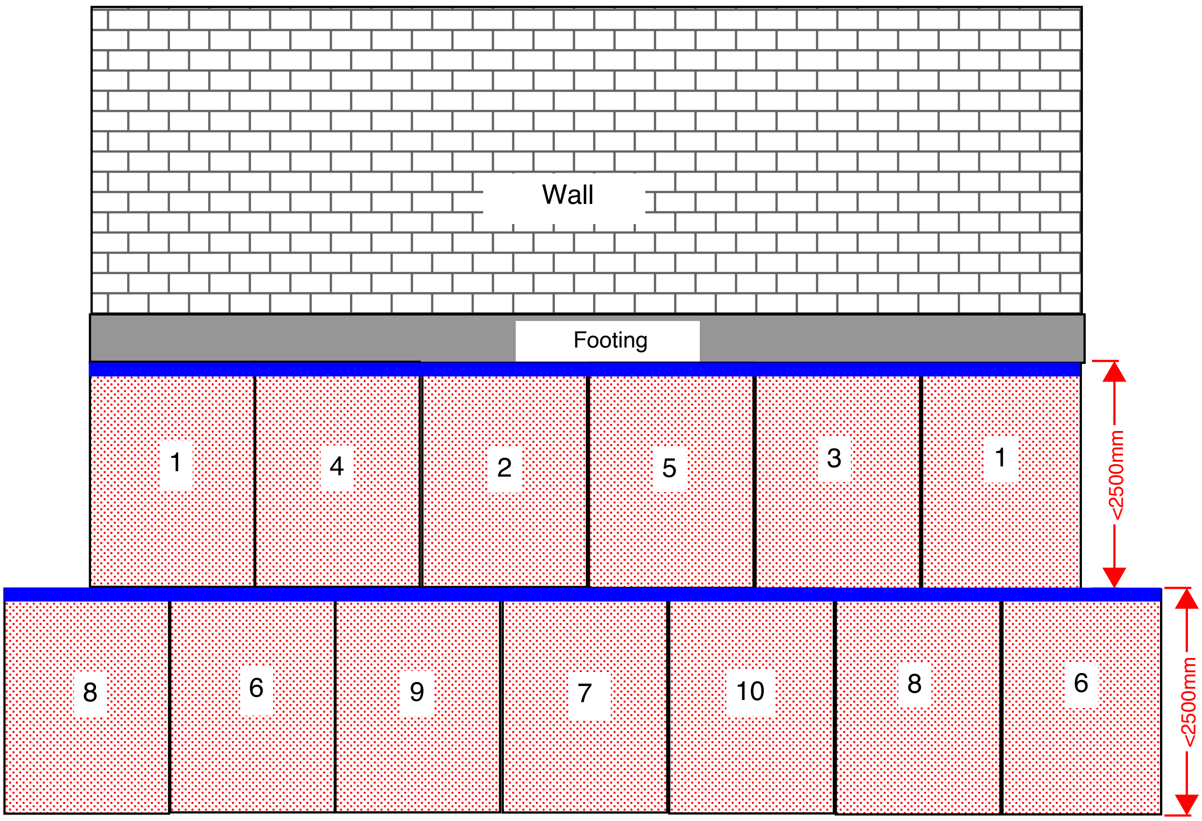


Figure 17 – Multi-stage underpinning with staggered vertical joints

Deep underpinning, retaining walls and multi-level underpins

6.34 Wherever possible hand excavation in deep excavations should be avoided through design. If very deep underpins are required, a piled solution should be considered as an alternative.

6.35 If the deep underpinning is part of a retaining wall, the excavation depth can be lessened by breaking a deep underpin into more shallow sections that are underpinned in turn. A single 5m deep underpin may be come 2 No. 2.5m deep pins.

6.36 It may be necessary to offset the underpinning stages so that a lower underpin is centred on the joint between two upper pin. (See Figure 17.)

6.37 The base of the first stage underpins and access pit excavation may be blinded to reduce the risk of the soils changing characteristics (becoming wet and softening or excessively drying out) which may lead to unacceptable movement.

Vertical loads

6.39 The bearing capacity of each underpinning stage should be checked (see 6.18). If there is insufficient capacity to resist the loads, temporary toe sections can be considered. These spread the load over a larger area and can be demolished once the full depth underpin is installed. (See Figure 18.)

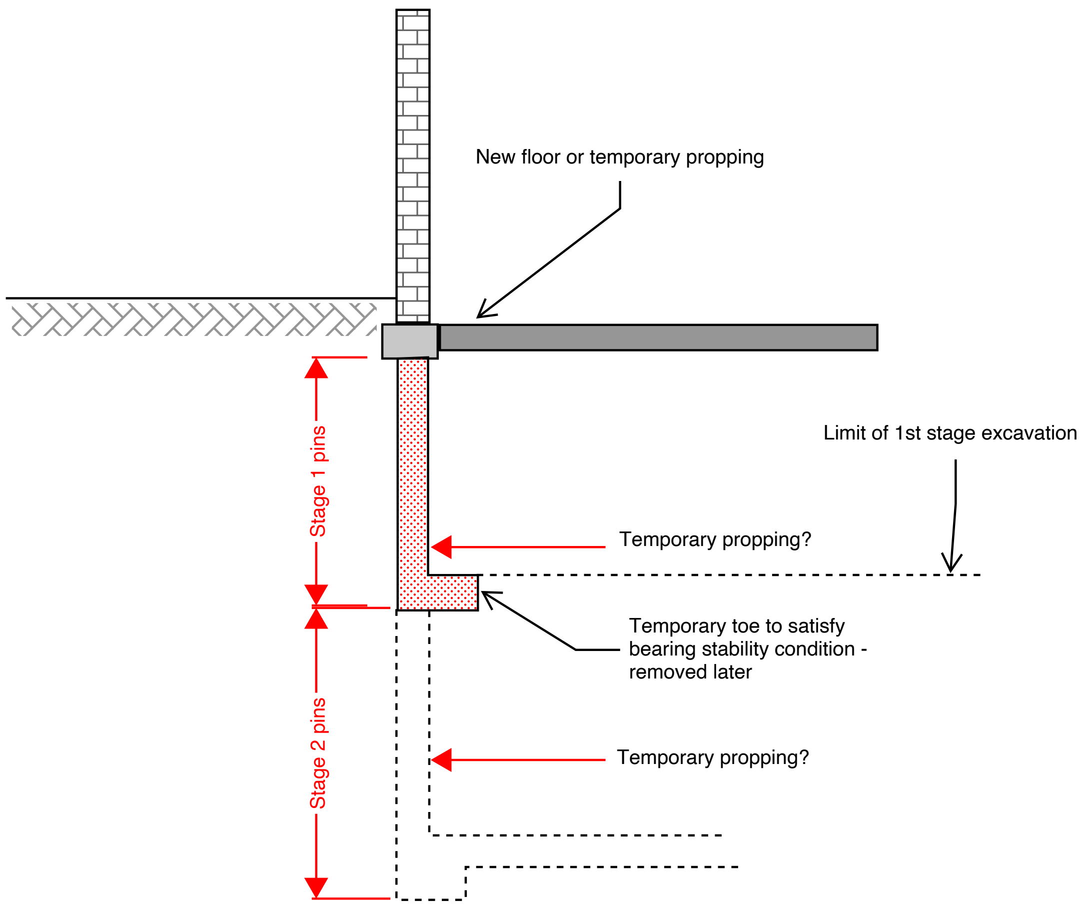


Figure 18 - Temporary toe sections can be considered

Load transfer

6.40 The transfer of load should be carefully completed to ensure that settlement is minimised and the aim should be to achieve an even bearing. Traditionally, this is achieved through dry-pack. In some instances, where the underpin is very thick or there is reinforcement continuity between an upper and lower pin, dry-pack is less feasible and a high strength non-shrink grout may be required. If the volume of the concrete is such that shrinkage is negligible and if a pressure head can be developed, the lower underpin can be 'flood-poured' to the underside of the upper pin. Where this is the case, the interface of the two pins must be proven to be adequate in adjacent excavations. (See Figure 19.) Trial cores may be used to inspect the contact interface. Flood pouring is dependent heavily on good workmanship and proof of full contact. Where there is any doubt dry pack method is recommended.

Pre-loading of ground, structures or propping systems

6.41 Pre-loading using hydraulic jacks may be employed to mitigate the risk of settlement and control load transfer by virtue of the following:

- compresses the structure above/below to create a more direct load pathway;
- pre-consolidates soils thereby minimising future settlements;
- pre-deflects structural steel/props minimising elastic shortening.

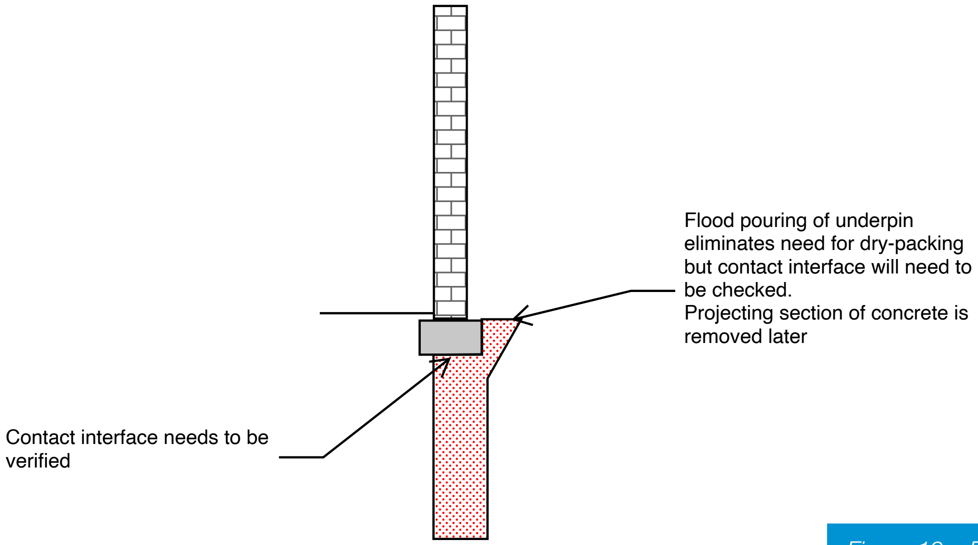


Figure 19 – Flood pouring

6.42 Deflection and ground movement may occur at each stage where load is transferred between structures. This should be considered as in each instance the movement may be negligible, but the aggregate may exceed reasonable expectations. The number of load transfers should therefore be reduced, or steps taken to mitigate the likelihood of movement. Pre-loading by the introduction of jacks may be a feasible option to mitigate risk of excessive accumulated settlements. (See Figure 20.) However, this is unlikely to be effective between multi-level underpins where vertical reinforcement continuity is present.

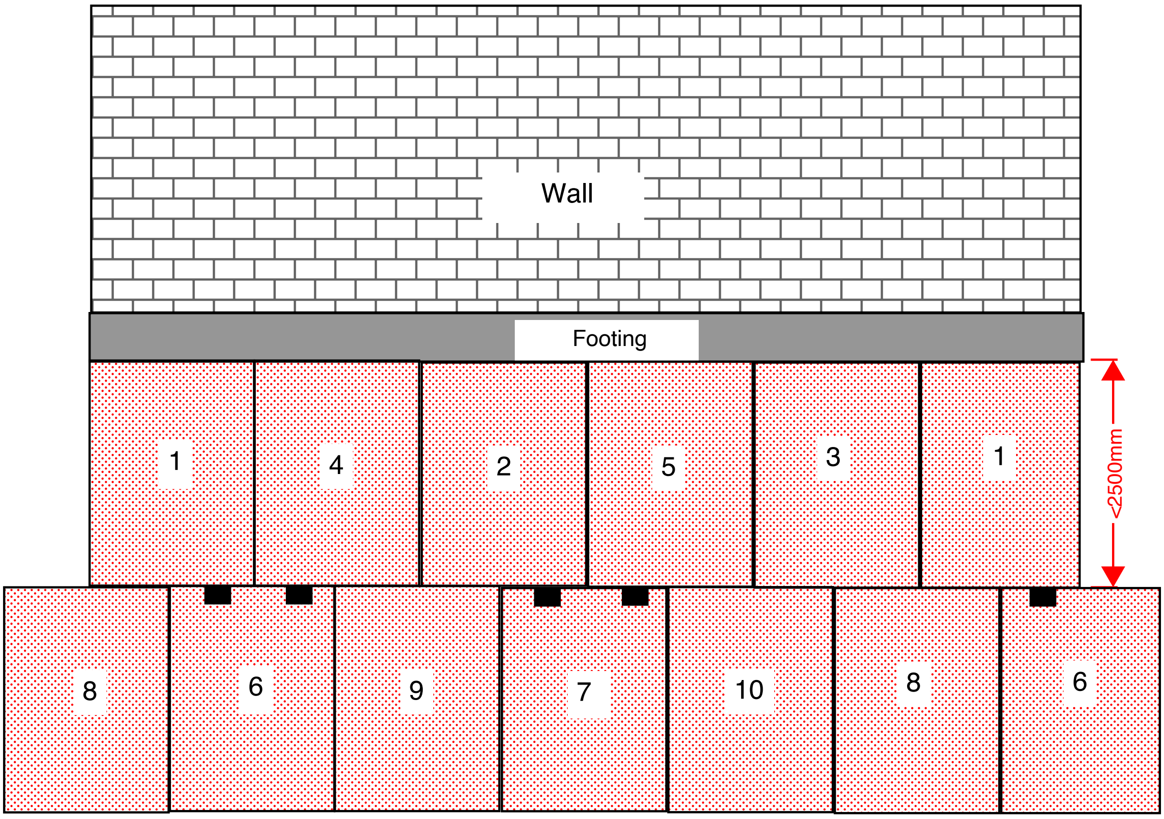


Figure 20 – Multi-stage unreinforced underpinning with provision for pre-loading for Pins 6 & 7

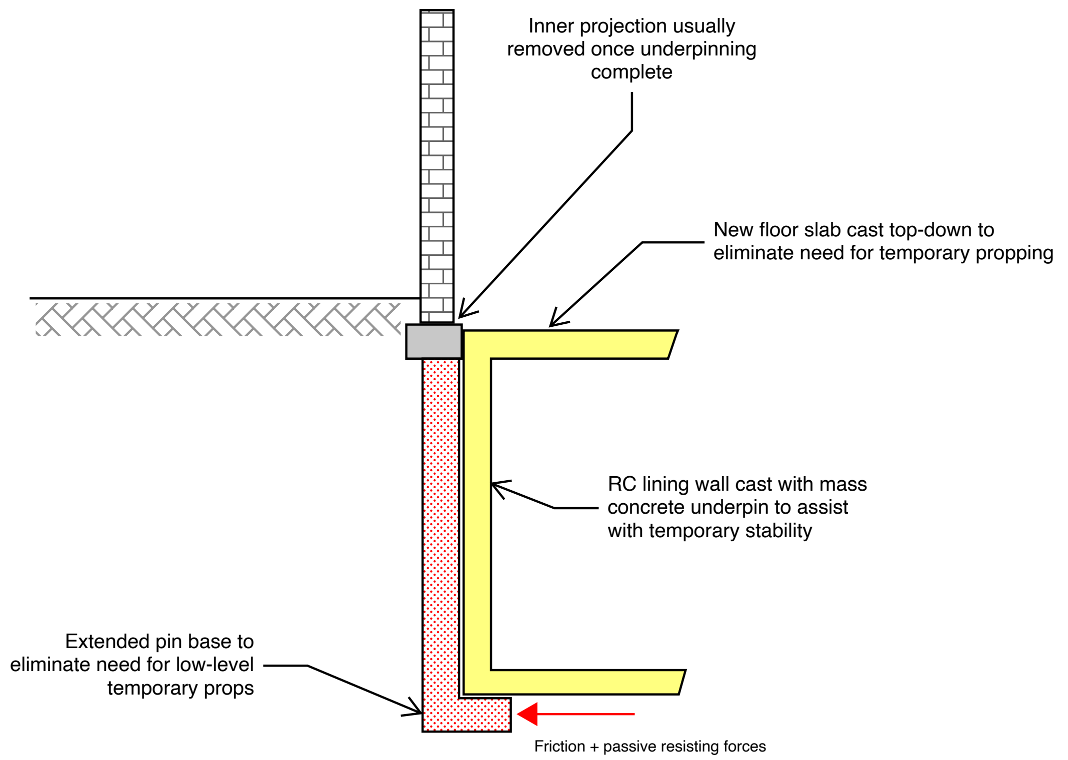


Figure 21 - Installing the permanent work items early in the sequence

Permanent works in the temporary condition

6.43 Installing the permanent work items early in the sequence particularly where basements are concerned offers several key benefits. Examples of this are floor slabs, beams and lining walls. (See Figure 21.)

6.44 Constructing these elements in a 'top-down' sequence:

(i) reduces potential ground and structural movements;

(ii) reduces the need for temporary works e.g. lateral propping;

(iii) improves safety by virtue of improved system 'robustness'.

6.45 When adopting this approach, consideration should be given to the impact on the waterproofing strategy (see BS 8102: 2022) [7.]. Early consultation with other design team members is essential.

6.46 Mass concrete underpins often have insufficient vertical loading to resist the applied horizontal loads. Due to their limited bending capacity extensive temporary propping will be required where such pins become exposed during excavation. This creates significant safety issues with manual handling and working in amongst props, issues with deflection when the props are removed and construction joints as the props prevent full lining walls to be cast. To overcome these issues, it is usually good practice to cast a reinforced concrete lining wall in front of the mass concrete pin at the same time. Use of this reinforced wall can then be made to reduce the amount of temporary works.

6.47 Where no lining wall has been specified, it may be feasible to add reinforcement into the mass concrete pin to satisfy temporary stability requirements. (Subject to agreement under the Party Wall, etc. Act [6.] this may be treated as a 'special foundation' and requires the adjoining owner's specific consent.)

Minimum underpinning depths

6.48 To facilitate access underneath foundations the minimum depth of underpinning should not normally be less than 1m. Where underpins are required to be wider than 1m then the minimum depth should match that width (i.e. if foundation width = 1500mm, then minimum underpin depth = 1500mm). The risk assessment and method statement (RAMS) should seek to limit access underneath to the minimum, ideally not at all. Consider carefully the excavation methods, e.g. excavate with an upturned bucket or suction methods, etc.

7.0 Conclusion

Underpinning is a high-risk activity with the potential to cause catastrophic damage and fatalities if undertaken incorrectly.

The key to its success lies in adopting the following approach:

- Proper planning at the outset.
- Seeking early specialist advice.
- Allowing sufficient time for proper investigations.
- Following the 'golden rules' of good practice.
- Employing a competent contractor (ideally an ASUC member).

References

[1.] Health and Safety at Work etc. Act 1974 (HSWA), https://www.legislation.gov.uk/ukpga/1974/37/contents

[2.] Construction (Design and Management) Regulations 2015, https://www.legislation.gov.uk/uksi/2015/51/contents/made

[3.] BS 5975: 2019, Code of practice for temporary works procedures and the permissible stress design of falsework, BSI (2019), https://knowledge.bsigroup.com/products/code-of-practice-for-temporary-works-procedures-and-the-permissible-stress-design-of-falsework/standard

NOTE: BS 5975: 2019 is being revised and at the consultation stage (June 2023)

[4.] HS(G)150, Health and safety in construction, Health and Safety Executive (2006), https://www.hse.gov.uk/pubns/priced/hsg150.pdf

[5.] BS 5930: 2015 + A1: 2020, Code of practice for ground investigations, BSI (2020), https://knowledge.bsigroup.com/products/code-of-practice-for-ground-investigations/standard

[6.] Party Wall, etc. Act 1996, https://www.legislation.gov.uk/ukpga/1996/40/contents

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Notes:

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