Precast concrete
Good practice and common issues in temporary works

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Temporary Works forum

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Synopsis

This guide provides information necessary for the management, handling, transportation and erection of precast concrete elements on site. It also highlights typical risks associated with using precast concrete and helps to reduce and control them.

Foreword

The Temporary Works Forum gratefully acknowledges the contribution made by members of the working group in the preparation of this guidance.

Readers should note that the documents referenced in this guidance are subject to revision from time to time and should therefore ensure that they are in possession of the latest version.

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List of abbreviations

3D 3-Dimensional
BIM Building Information Modelling
BS British Standard
CARES UK Certification Authority for Reinforcing Steels
CDM Construction (Design and Management) Regulations
CE Conformité Européenne
EN European Norm
ESO Early Supplier Orders
FIDIC Fédération Internationale Des Ingénieurs-Conseils (International Federation of Consulting Engineers)
GRP Glass-Reinforced Plastic
hEN harmonised European Norm
ICC Infrastructure Conditions of Contract
ISO International Organization for Standardization
ITP Inspection and Test Plan
JCT Joint Contracts Tribunal
NEC New Engineering Contract
NFDC National Federation of Demolition Contractors
PC Principal Contractor
PD Principal Designer
PWD Permanent Works Designer
RACI Responsible, Accountable, Consulted and Informed
RAMS Risk Assessment and Method Statement
RC Reinforced Concrete
RIBA Royal Institute of British Architects
RRV Road Rail Vehicle
TVCB Temporary Vertical Concrete Barrier
TWC Temporary Works Coordinator
TWD Temporary Works Designer
UK United Kingdom
UKAS United Kingdom Accreditation Service
VE Value Engineering
WwTW Wastewater Treatment Works

1 Introduction

1.1 There is an increased use of precast concrete structures. These bring a number of benefits, including increased speed of construction; risk mitigation (e.g. reducing working at height, etc.); the use of concrete as a finished surface; tighter dimensional tolerances; off-site construction. Although there are benefits in using precast concrete it generates different safety risks; not always identified by the client, permanent works designers (PWDs), specialist sub-contractors or the site team.

1.2 This guidance has been developed to provide generic, practical guidance for the design, management, handling, transportation and erection of precast concrete elements on site. It covers the steps to be taken from manufacturing through to final placement or demolition, but it is not intended to cover every situation or component. The guide's aim is to improve site management, highlight the typical risks associated with using precast concrete and help site teams to identify and control these issues from an early stage.

1.3 The control measures presented are examples and do not preclude the use of alternative solutions based on sound engineering judgement in their design.

1.4 It is acknowledged that there is a design interface between the client's engineer and a sub-contractor undertaking design prior to manufacture, e.g. the provision of loads and moments. Likewise, there is a detailing interface between a client's engineer who has detailed an element in insitu reinforced concrete and those designing the precast element that is supported from it. This should be coordinated and is particularly important when both elements are part of the provision for overall structural stability. This is important in the exchange of information, e.g. the BIM model.

2 Precast versus in-situ

This chapter considers the perceived benefits afforded by precast construction and the importance of early consideration.

2.1 When deciding on whether to use precast construction, the possible benefits (e.g. surface finish and durability) and disadvantages should be thought through at an early stage.

2.2 The contract works information may specify precast of elements in the works. Alternatively, it may be seen by the contractor as an opportunity to address time, cost, logistic and quality concerns. There may be a contract incentive, e.g. value engineering.

2.3 Often, the perceived benefits afforded by a precast opportunity are the early driving force. However, careful consideration should be given to the engineering through all stages, from concept design, procurement, manufacture, planning and initial installation through to final installation. Some works may require a combination of precast and insitu concrete – the same stages apply. There should be early consultation with precast suppliers at concept design to ascertain what could be precast, the design approach (including the provision for overall stability), envisaged construction methodology and the approach to detailing (especially if the intention is to detail part or all of the precast elements in a BIM model).

2.4 It is often only at the installation stage that aspects are uncovered that have not been reviewed thoroughly and planned for. The consequence of this way of working can be on-site compromises. Accordingly, the role of the client and its professional advisors is important in addressing programme issue affecting the procurement of (for example) cladding, mechanical and electrical contractors, assemblies, etc.

2.5 Experience has shown that the temporary works associated with installation often receives a cursory review only: "all looks fine". It can be some time later, after there has already been a commitment to a precast solution, that the detail of an installation scheme is looked at and issues are uncovered, e.g. temporary stability and support. These can become much more complex when other variables within the temporary works designer's brief are examined and solutions considered. In short, do not fall in to the trap of an insufficiently detailed review of the requirements before committing. It can be both an expensive and frustrating mistake to make.

2.6 Early and detailed planning is key and throughout all phases of a project. Responsibilities should be clearly set out and communicated. There should be peer reviews, a consideration of whether the right decision is being made for the right reason. There is benefit in using people not directly connected to the works to examine any thought processes, logic and reasoning. Impartiality can be important in Identifying where benefits may have been overstated and also, conversely, provide confidence that a decision is the right one.

2.7 If the planning is detailed it should eliminate the last-minute surprises that undermine the decision to use precast as a preferred solution. The 'devil is usually in the detail' especially in the scheduling of reinforcement for fixing, connections and laps.

2.8 If there are areas that can't be completed then caution should be exercised until such time as the issues are understand and an informed decision made.

Put simply: Failure to plan is planning to fail

3 Procurement/ Project requirements

This chapter considers the issues to be taken into account when procuring precast concrete solutions.

3.1 Introduction

3.1.1 The procurement of precast concrete elements is a relatively frequent requirement. Precast items may be required as part of the permanent works or as part of a temporary works scheme. Items generally fall into the following categories:

a) external supplier (standard), e.g. offsite manufactured catalogue items such as manhole rings, culverts, pipes, retaining wall units, bridge beams, floor units, etc.;

b) external supplier (bespoke), e.g. offsite manufactured bespoke items such as cladding panels, parapet units, arch units, etc.;

c) cast on site, self-delivered items or catalogue items modified on site.

3.1.2 This guidance is aimed at the procurement of b) and c) and is prepared as an aide-mémoire to assist in gathering, appreciating and understanding the information required to enable successful pre supply chain engagement; supplier contract negotiations; and post enquiry pre sub-contract award

3.2 Design

3.2.1 It is good practice to nominate a design manager who should oversee the following:

- Identifying who is responsible for the permanent works design as well as any elements that have a temporary configuration prior to being completed as the permanent configuration.

NOTE: The use of responsibility matrix is a good tool for planning the management of design. See ***Section 16****, RACI matrix.*

- Ensuring that the designer has considered any temporary loading conditions to which any elements may be subjected (whether during fabrication, transportation, storage and stacking, handling, offloading and installation at the site, lifting points and methods of handling).

NOTE: The consideration of lifting points and methods of handling is often left too late in the works and can cause difficulties requiring late changes.

- Ensuring that the need for, and categorisation of, independent design checks is undertaken in accordance with company procedures (including risk classification).
- The content of design briefs.

NOTE: Ensure that there are no areas of design that have not been allocated to a party and that responsibility for the overall design is assigned to a single party.

- The principles of prevention and protection are clearly communicated to, and understood by, designers.
- That the competencies of any designers in all aspects of the design are checked and validated.
- The consideration of stability at all stages, particularly during the construction phase.
- That designs are coordinated and communicated.

NOTE: This may be best captured using a marked up drawing or a simple matrix, which helps to prevent items 'slipping through the net'.

- Ensuring that the designer identifies the execution class for any precast elements, e.g. BS 13670 Execution Class 1, 2 or 3, and that design checking and third party sign-off is considered, where appropriate.
- The approach to detailing the structure to avoid ambiguity between the client's engineer and any specialist precast subcontractor(s), especially if undertaken in BIM.

3.2.2 More detailed and comprehensive notes on design inputs can be found in **Section 4**.

3.3 Design inputs review

3.3.1 Typical design considerations are shown in **Figure 3.1** and **Section 16** and - in addition to the requirements of CDM2015 - includes consideration of:

- The influence of the form of contract used, e.g. RIBA, JCT, NEC, ICC, FIDIC, etc.
- Whether specification are in place (These could be designer or contractor generated).
- The origin of any specifications, e.g. UK standards or non-UK, and whether these are acceptable, and whether the latest edition of any standard referenced in the specifications are still current.

NOTE: Where non-UK standards are used, it is recommended that compatibility with UK standards be demonstrated.

- Whether specifications are suitable, sufficient and complete (and whether particular test methods and acceptance criteria should be defined in the specifications, or by making specific reference to existing standard clauses or appendices).
- Whether the design, as detailed, is satisfactory and whether it could be improved.
- The level of design check required; who will be undertaking this work; and whether they are competent.
- Whether the site temporary works team has reviewed the proposed arrangements to identify any potential provisions that the design does not include.

3.4 Quality assurance requirements

3.4.1 Precast product should meet the client's specifications. The need to provide detailed documentation, providing traceability of both raw materials and products, has become a key - and sometimes onerous - contract requirement.

3.4.2 The collation of this level of detail should commence at an early stage, in order to ensure that work/product can be assured at the point of delivery and meet programme requirements. Careful consideration should be given to any surface finish requirements and the issues that could affect this, e.g. casting orientation and lifting eye location.

3.4.3 The contract should identify which products require CE marking. Where precast products are covered by harmonised European standards (hEN) - denoted as EN or BS EN or BS EN ISO (See: http://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/construction-products/) - then the precast product can be CE marked. This provides the end user with a product that is subject to robust production checks by a certification body. Preferably, any supply chain company should be certified to ISO 9001. If not, a high degree of surveillance may be required during the product's manufacturing stage.

NOTE: Inspection and test records from the manufacturer should be made available to the client for review and acceptance of product prior to delivery.

3.4.4 Where such harmonised standards do not exist, for example where a product is of bespoke manufacture, consider the following:

a) Are the component materials to be used subject to hENs?

b) Are there alternative assurance schemes which are applicable, e.g. CARES, UKAS, etc.

c) If a) and b) is not available, what level of production third party surveillance is necessary?

d) Is there a need to engage a professional surveillance resource through a specialist consultancy?

NOTE: Reference can be made to BS 8297:2017, Design, manufacture and installation of architectural precast concrete cladding. Code of practice.

3.4.5 When placing an order with a precast supplier a contractor should be satisfied about the ability of that company to supply products complying with the specification. A pre-order visit is recommended.

3.4.6 Where a sub-contractor is contracted to install a temporary works solution some issues should be addressed:

a) The sub-contractor should have the necessary engineering experience to provide a robust solution.

b) The competence of any proposed temporary works design organisation should be checked (due diligence).

c) After a check on a) and b), arrange a physical site visit as this is invaluable to any designer.

d) There should be a formal contract in place, specifying the scope and responsibilities.

e) Dialogue should be established and maintained with the Principal Contractor's TWC.

3.4.7 Experienced and competent specialists should be used for the inspection of Execution Class 3 items.

3.5 Installation of precast elements - Engineering evaluation

3.5.1 The decision to take a precast route to delivery may be taken for a number of reasons:

- high quality is required;
- consistency of finish would be hard to achieve with in situ concrete;
- programme savings can be made in terms of time;
- it can take important items of work out of the critical path;
- cost savings are available;
- there may be safety related advantages;
- it can improve logistics on some restricted worksites.

3.5.2 It is necessary, however, to take a detailed view of the planned installation method from a temporary works perspective (and, if this varies from the envisaged construction method specified by the client's engineer, the permanent works design be checked to ensure that it can accommodate the temporary works method). An assessment should be made of the viability of any initial precast options. This may identify unforeseen issues that can affect the option(s) chosen and lead to complicated and costly temporary works solutions, outweighing any savings. This should reinforce the need to thorough and honest in considering any initial options.

3.5.3 Early consideration and resolution of issues relating to installation should take place during the planning stages. Engineers, supervisors and the client's team can all contribute to developing good ideas. It's no use critiquing the first solution into oblivion after something hasn't worked as planned. Involve the precast company at this stage - the sooner the better. Also, logistic teams should plan any traffic routes in detail (and check these when on site, to see whether they need adapting).

3.5.4 When a preferred supply chain partner has been engaged they are likely to bring ideas of their own. Be open to reviewing these and, where improvements are spotted, be prepared to embrace these changes through a review, validate, peer review and implement cycle.

3.5.5 When a plan has been agreed try a 'dry run' at the precast company's yard, e.g. practice lifts, temporary works propping, load stacking, storage of units, reinforcement fixing to insitu stitching between precast units, etc.. This should help in avoiding future delays on site (and can take place in a much safer setting).

3.5.6 **Remember:**

- Plan in detail, early.
- Don't start on site until a sufficient number of units have been manufactured (to allow for continued installation).
- The site installation schedule should drive the design, detailing and manufacturing schedules.
- Ensure the site delivery team input into the solution.
- Engage impartial peer reviewers to validate solutions, where required.
- Have a 'Plan B' available to mitigate the 'unforeseen'.

3.5.7 More detailed and comprehensive notes on installation can be found in **Sections 10** and **11**.

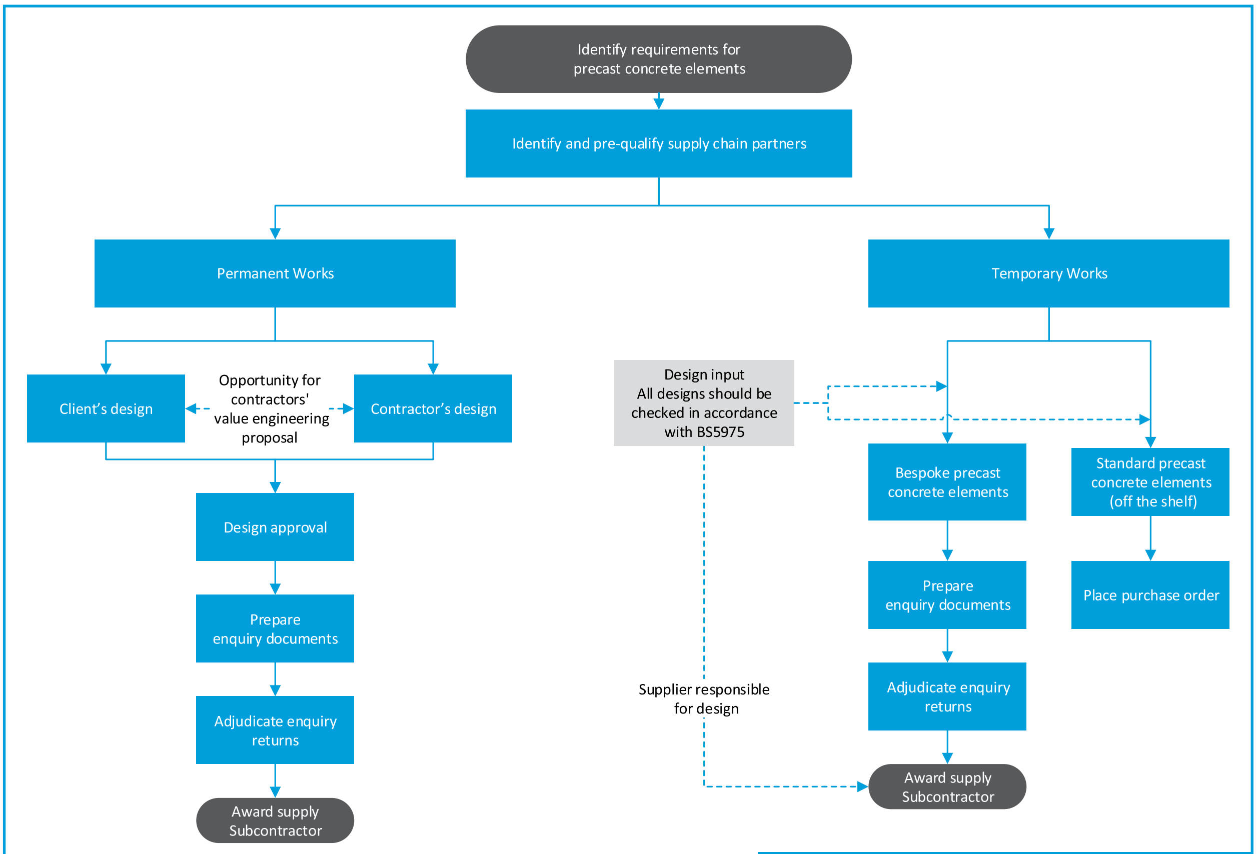


Figure 3.1 – Procurement of precast concrete

4 Design intent/ Design coordination

This chapter considers some of the common design issues when adopting precast solutions and the importance of getting things right.

4.1 Common Issues

Consider the following when considering the adoption of precast as a solution:

- The choice to use precast is often made after the detailed design has been undertaken. This can result in the modification of some details, as it is not always possible to have all details available during the tender (and many assumptions may have to be made). Accordingly, consider designing from a precast perspective, i.e. a modular or prefabricated design.
- Precast is sometimes adopted on the assumption that it is always a safer option. However, there should be due consideration for the practicalities of site installation.
- If an in-situ design is difficult to build it may be better to revisit the overall design rather than try to use precast to solve the problem (See **Section 14**, Case Study 2).

NOTE: Under CDM2015 the designer should consider how their design is to be constructed.

- There is often a lack of clarity between various parties for the design responsibilities, e.g. principal designer, permanent works designer, precast sub-contractor, reinforced concrete sub-contractor, temporary works designer).

*NOTE: A responsibility matrix is helpful (see **Section 16**).*

- There is often a lack of clarity over which party is designing which aspect of any precast. Often the permanent works designer (PWD) will design for the permanent situation but there is less clarity over who designs for temporary stability, initial striking (i.e. strength and time), lifting/handling at the precast yard, transportation, lifting and handling on site, lift points, etc.

NOTE: Precasters should be sufficiently experienced and competent to demonstrate that they can manufacture and deliver units to meet any performance requirements.

- There should be clarity on the responsibility for the design of any connection details between the precast unit and the permanent works. This should be established at the earliest possible stage. Likewise, design coordination between the precaster and the TWD should also be established at the earliest possible stage.
- The detailing of stitches between precast units, and at connections to cast in-situ concrete, needs attention. It should be clear which party is designing what, e.g. whether a particular surface preparation is required.

NOTE: Close cooperation over design detailing is required between the precast and insitu designers.

- It should be clear whether a precast unit, and the works on which it bears, has been designed for installation on shims, in the temporary state. Determine who decides on the shim pattern and any possible reduction of friction (see **Section 14**, Case Study 2).

NOTE: If a unit sits on a trowelled surface the surface finish should be specified.

- There is often insufficient space around bridge beam bearing plinths for adequate temporary support. Precast bridge beams need lateral support until they are connected together by the insitu diaphragm or deck concrete regardless of whether they are landed on temporary supports or the bearing itself.

4.2 Getting it Right

4.2.1 Consider the following when considering how to get things right:

a) Ideally, the construction method should be decided upon as early in the design process as possible. The earlier it is introduced the easier it will be to get the best design.

b) The reasons for using a particular solution (e.g. precast or in-situ) should be assessed. Don't use precast purely on the assumption that it is better. If a change is being proposed from the concept design, establish why the particular solution was chosen previously.

c) Prepare a high level installation methodology and share it with the various parties to the design. Include the follow:
   - Limits of unit size and/or weight.
   - The location of the crane to be used for lifting (and its type).
   - The sub-contractor undertaking the installation.

- The type of temporary works which will be used to provide stability to any units

NOTE: Temporary works is often required, regardless of a precast manufacturer's claim to produce freestanding units.

- The edge protection required during installation.
- How any formwork required for stitches is to be installed.

d) Use the coordination process between the precast company, the temporary works designer (TWD) and the temporary works coordinator (TWC) to produce solutions. For example, cast-in sockets, which enable installation of edge protection, props, etc. to be carried out at ground level before the unit is lifted into position.

e) Decide on which party is responsible for the following elements of the design:

i) striking strengths and times (e.g. the strength at which the precast sub-contractor needs to strike to suit their processes);

ii) lifting and handling in the precast yard (e.g. lifting points and the overall structural strength);

NOTE: Items i) and ii) are governed by the strength required for cast in lift points (as specified by the manufacturer of lifting points). Careful consideration should to be given to the turning of units (as well as the storage of units at the yard).

iii) transportation;

NOTE: The precaster is responsible for ensuring that units arrive on site with no damage. The precaster and the site team need to liaise/agree on any load sequence, the access to any load and the stacking of units on a load in order to avoid damage during off-loading.

iv) lifting and handling on site (e.g. lifting points and overall structural strength). The lifting method can affect the design;

NOTE: The design of lifters should be considered at an early stage. The precaster will design to information provided to them from site. Close attention should be given to the reinforcement needed, especially if units are pitched on site from horizontal to vertical.

v) stability of any units whilst they are being stitched;

vi) the shimming arrangement and the local loads on any supporting structure;

vii) an assessment of any supporting structure to withstand loads in the temporary situation;

viii) preparation of construction joints;

ix) design of stitches;

x) detailing of formwork for stitches;

xi) permanent works reinforced-concrete design;

xii) fire and durability design;

xiii) robustness/tying (disproportionate collapse).

f) Decide what information is needed from each party and how this should be communicated.

g) Manage the design process rigorously, with regular meetings between parties. This may be achieved through the appointment of a design manager.

h) Agree on how important information is communicated to the construction team(s), e.g. limits on the design of lifting points, shim patterns, installation sequence, etc. The lead designer should consider preparing a drawing to illustrate the information provide by various parties.

i) Early supplier engagement enables early design collaboration and integration.

4.2.2 **CAUTION:** When designing precast columns there is the potential for the construction load case may require more reinforcement that the permanent load case. If a supported slab relies on moment-distribution into the columns both above and below then, during casting of the next floor above (which typically pushes the newly cast floor slab up to its design limits), the column below can experience greater moments but also at much reduced axial force. Depending upon where the design lies on the N-M (load/moment) chart the column could fail. This is not an issue unique to precast columns, but can become more pronounced due to the division of design responsibilities.

4.2.3 Refer to **Section 17.2** for a list of design requirements.

4.3 Postscript

Should the final output be a decision to proceed with precast, early engagement with the precast manufacturer is important as the time from placing an order to the commencement of casting can be lengthy. A decision to precast should happen sooner rather later, otherwise any time saving element is squandered.

4.4 Flowchart

An example design input is shown within **Figure 4.1**.

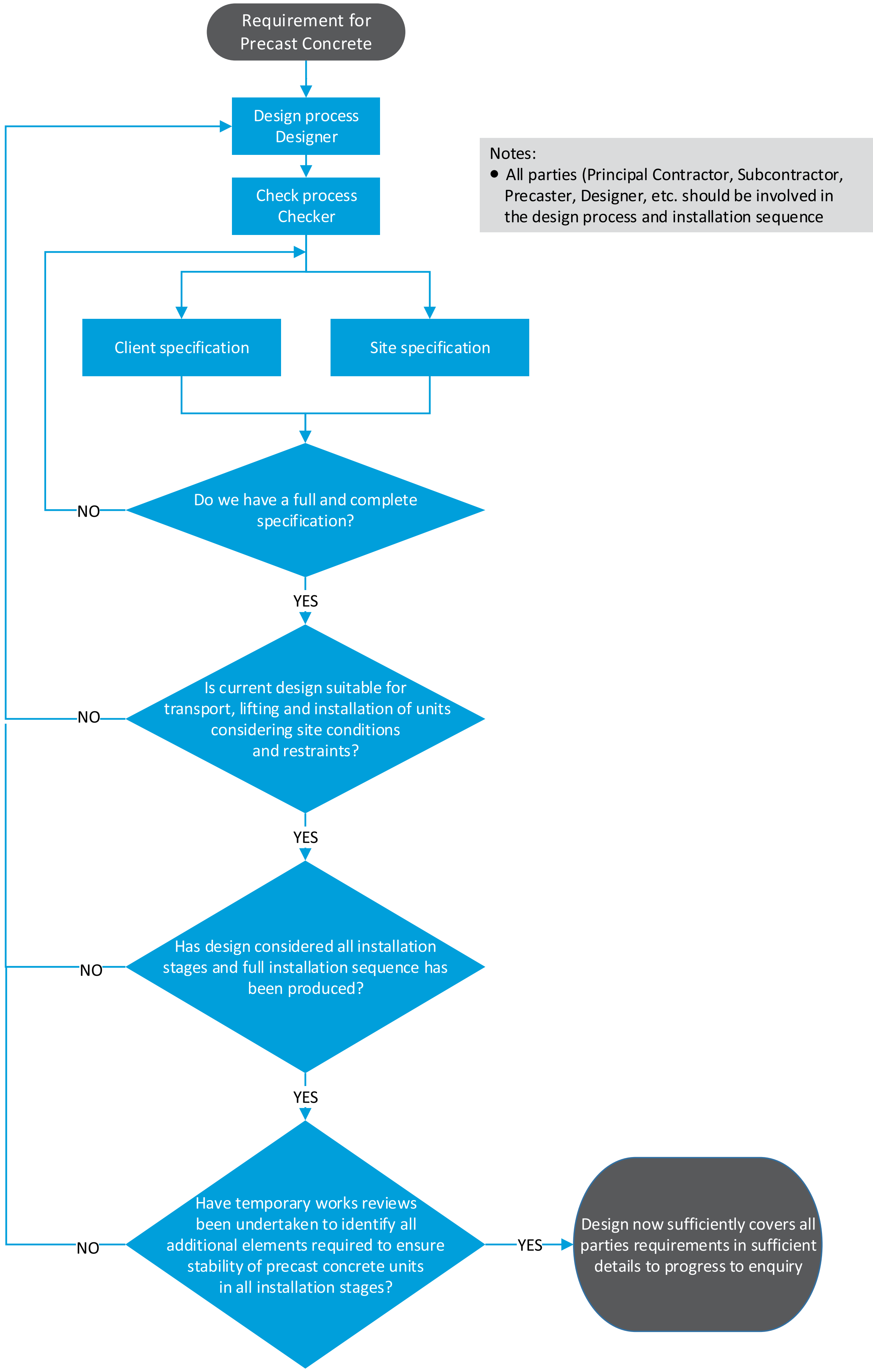


Figure 4.1 – Example design input

5. Quality/ Inspection and Testing Plan (ITP)

This chapter consider the quality checks that should be implemented when handling and installing precast concrete because it assures quality and minuses the risk of rework.

5.1 Manufacture

Consider the following (for both off-site and on-site manufacture):

a) Designs should be approved – and have been considered for installation sequence; with stability checks at the delivery, temporary and final positions; and considering the loads imposed during transportation.

b) Lifting points should correctly cast, e.g. depth, additional rebar, cover, etc. (See **Section 6**).

c) Adequate and approved concrete, rebar, concrete placement, etc.

d) Type of surface finish (e.g. basic; ordinary; plain; special [1 2]) and the faces on which this this finish will be seen on; the casting orientation may need to change to suit these requirements.

e) Cube strength [3] prior to lifting, as well as during transportation and installation.

f) Risk assessment for lifting.

NOTES

(i) The risk assessment for lifting must be carried out by a competent person.

(ii) The designer's risk assessment should state the tolerance on lifting angles, directions, limitations of lifting points, different load paths from final position, etc.

g) Tolerances

NOTE: Build in additional tolerances which make allowances for manufacturing and site tolerances, i.e. cleats with elongated holes, well voids slightly oversized. Let the precaster know which tolerances are critical.

h) Lifting method and whether turning is required (It must not weaken freshly cast concrete, or induce any crack, torsion or instability).

i) Units prepared for transport so as to avoid damage or cracking, adequate temporary supports and ties (including transportation frames to prevent buckling in slender precast members).

j) Load check, i.e. confirm final weight.

k) Pipe couplers cast into wall units and whether they are out of tolerance, damaged and/or out of position.

l) Wall units (out of tolerance, warped).

m) Roof units including the position of openings and the fixing of protective covers over openings.

n) Manufacturing errors in units resulting in them being made incorrectly. See BS EN 13670:2009, Execution of concrete structures.

5.2 Delivery

Consider the following:

a) Units arriving on site need to be identified for traceability. Labels should include the unit weight, manufacturer's name and date of manufacture. The location of labels on units should be agreed beforehand, e.g. unit type, location in works, etc..

b) Lift plan for off-loading, including appropriate equipment/rotation/slewing and access to load.

c) Loads transferred due to method for turning, stacking, etc.

d) Designer risk assessment reviewed with respect to using lift points; minimum angles; different load paths from the unit in its final position; etc.

NOTE: Designer risk assessments should be reviewed by the principal contractor, installation contractor and lifting contractor; as well as the principal designer.

e) Visual check of units: signs of cracking, distortion/damage of lift points.

f) Temporary works design and check for temporary storage, stacking, temporary stability, packers, point loads, etc.

g) Ground stability at storage location or other risks of damage or interference.

h) Route planning in order to understand any highway restrictions/limitations. Off-site temporary works may be required to support any additional loading on existing highway structures.

[1] BS EN 13670: 2009, Execution of concrete structures

[2] Table 2, Formwork - a guide to good practice, 3rd edition, CS030, Concrete Society

[3] e.g. BS EN 12390-2: 2009, Testing hardened concrete - Making and curing specimens for strength tests

5.3 Installation

Consider the following:

a) Installation procedures – risk assessment and method statement (RAMS).

b) Designer's risk assessment reviewed with respect to using lift points; minimum angles; different load paths from the unit in its final position; shimming; loads on permanent structures from temporary works schemes providing stability to precast units, etc.

NOTE: Designer risk assessments should be reviewed by the principal contractor, installation contractor and lifting contractor; as well as the principal designer.

c) Temporary stability reviewed; skewed lifts; slanted lifts – temporary works check.

d) Installation and sequencing of packers, bracing, chocks, supports and subsequent elements.

e) Imposed and dynamic loads in its temporary state to be clearly identified.

f) Limitations on using packers, size, type, wedges, etc.

g) Grouting and removal of packers, temporary supports or jacks.

h) Review sequence of removal of temporary works.

i) Understanding the effect of point loads during handling and installation; explain clearly.

j) Finish of in situ stiches

NOTE: Usually, unit manufacturers do not supply in-situ concrete for stitches, etc. The site's own concrete supply attracts risks on quality, e.g. water test failures.

5.4 CE marking

See **Section 3** (3.4).

6. Lifting

This chapter considers the issues to be taken into account when lifting precast units.

6.1 Common issues – 'getting it right'

6.1.1 Cranes lifting precast units should be managed in the same way as any other crane operations on site. As always, additional care should be taken with tandem lifts.

6.1.2 There are a number of common issues that should be considered when planning lifts:

a) Any operation which is likely to lead to the crane slings being inclined (e.g. turning units or slings at an angle) should be planned carefully and often requires additional reinforcement for lifting anchors. Where lifting anchors are also used to pitch units, appropriate anchors and suitable clutches should be chosen. Any manufacturer-detailed reinforcement around these anchors should be retained.

b) Precast units should be assessed by the PWD and/or TWD for all lifting arrangements as these often vary from the support arrangement in its final position and can changes the load paths.

c) When precast units are incorporated into the permanent works by using in situ stiches, special consideration is required to the fixing of insitu stitch reinforcement following the placement of any precast units.

d) It is important to assess the centre of gravity of all lifting arrangements prior to lifting in order to determine an effective slinging arrangement and to assess the lifting points. Sometimes, precast units can be lifted into final position with temporary items attached to them (e.g. edge protection, temporary supports/restraints, etc.). Often, precast units have protruding rebar for tying with a stitch.

NOTE: Consider a visit to the precast facility by the site erection team in order to establish good practice.

e) When units are lifted straight from the delivery vehicle to their final position, care should be taken to ensure that any loose packing or protective materials have been removed and that any fittings are secure.

f) Special consideration should be given to lifting precast units together with any supporting structure, e.g. lifting precast planks together with steel bridge beams (See **Figure 6.1**). It is recommended that precast units be secured for lifting by tying them to the supporting structure.

g) Special consideration should be given to lifting used, old precast units (such as 'Kelly blocks', temporary vertical concrete barriers (TVCBs), etc.). The condition of any lifting points should be assessed carefully to see whether they are still fit for lifting. If there is any doubt other means of lifting (e.g. post drilled lifting anchors, lifting cradles, etc.) should be used instead of lifting eyes.

NOTE: Kelly blocks should be assessed to ensure that there is no chance of fragmentation and disintegration due to lifting geometry or, indeed, any existing damage.

h) Strategically, consider the use of 'MBT' mechanical rebar couplers to avoid entanglement between protruding starter bars and lifting chains.

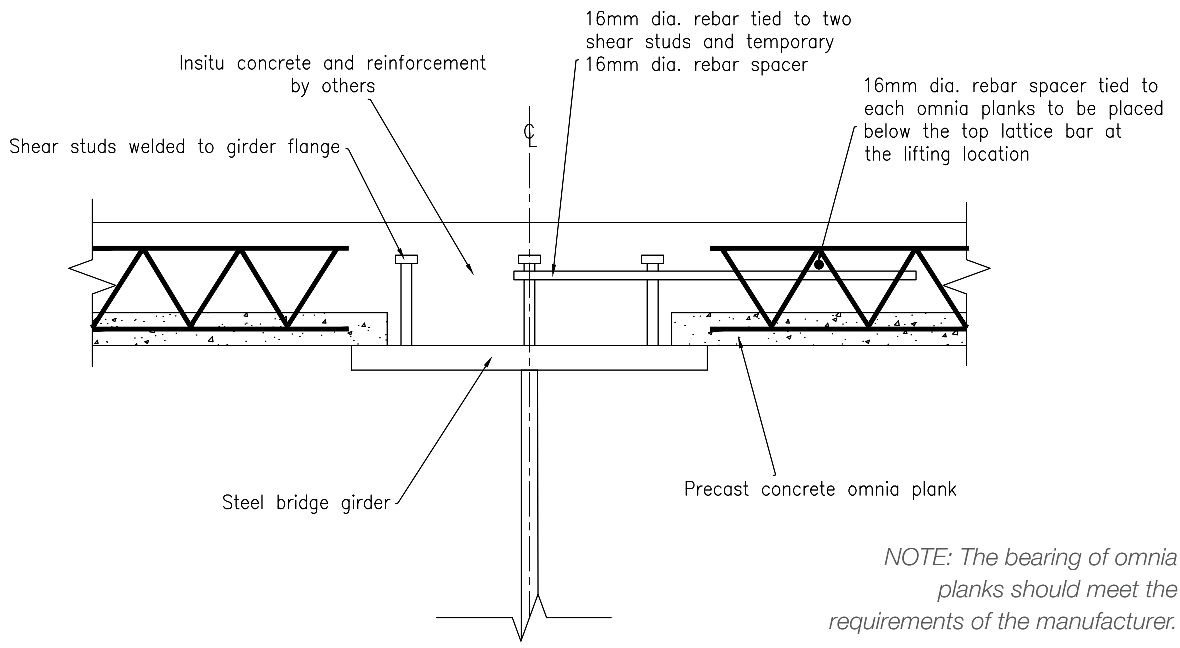


Figure 6.1 – Typical temporary anchorage to be fixed at each end of omnia planks

6.2 Lifting points and slings

6.2.1 This is probably the biggest single cause of failure during the erection of precast units. Lifting points provided by the manufacturer may suit the handling of units in the precast yard only. If these lifting points, provided by the precast supplier, are to be used then checks should be in place to verify that their design and installation is adequate. Remember, the lifting arrangements can differ at each stage and may require the turning of precast elements. Mark the units to indicate which lifting holes are for the manufacturer's use only and are not for installation lifting.

6..2.3 The design of lifting points is normally based on the use of specific lifting equipment, e.g. slings, chains, shackles and lifting beams. It is important that any restrictions are communicated effectively to site via drawings (see **Figure 6.3**), risk assessment and method statements (RAMS) and inspection and test plans (ITPs). The load at each lifting point will depend partly on the angle and length of the slings. In a four point lift it is common to design each lifting point for at least half of the total load due to diagonal spanning (caused by unequal chain lengths).

6.2.4 Some important considerations for lifting points and slings are:

a) Precast units, both collectively and individually, should be designed and detailed to allow for adequate and safe handling, including the safe removal of lifting slings after the units have been placed.

b) When using multiple-leg slings, it is important to assess the centre of gravity of a component prior to lifting in order to determine an effective slinging arrangement.

c) It strongly recommended not to use a single lifting point; at least two lifting points should be used.

d) Soft slings (e.g. webbing slings) and edge protection may be used to avoid causing any damage to precast units and need to be restrained from sliding during the lift.

e) Sometimes, lifting points can be used after final placing as the fixing for edge protection. **Plan ahead**!

f) All lifting anchors must be used strictly in accordance with the anchor manufacturer's recommendations.

Figure 6.2 – Incorrectly designed lifting eyes (rear)

6.2.5 The use of reinforcement as lifting points should be avoided (unless specifically designed for lifting purposes). Several failures have been reported where rebar used for lifting has failed. Common causes for this include:

a) Reinforcement that has been bent to a radius, thus causing brittle failure (For this reason, purpose-designed mild steel bars are preferable to high yield steel);

b) Reinforcement deforms when loaded and this results in brittle failure;

c) Insufficient anchorage length, poor concrete or thin sections resulting in the rebar pulling out;

d) Poorly positioned bar, again resulting in pull out;

d) Rebar that is undersized for the lift.

6.2.6 In **Figure 6.2**, the beams were delivered with high yield hoop lifting eyes (rear). These had to be modified with a welded steel plate in order to make them suitable for use on site (front). The hoop were designed by the beam's designer but the manufacturer obviously didn't use them in the yard (otherwise failure would have occurred). Production inspection upon casting ought to have resulted in this problem being spotted and is an example of how early supervision and inspection of work undertaken by the precast manufacturer can prevent problems.

6.2.7 Where proprietary lifters are unsuitable, bespoke lifters can be designed. These should be supplied with full design calculations and, where appropriate, proof loaded.

6.3 Lifting eyes in precast concrete components

6.3.1 Several CROSS reports detail failures with lifting eyes in precast concrete components:

637 Failure of cast-in lifting anchor on precast twin-wall

The failure of a designed cast-in lifting anchor which suffered a brittle failure, resulting in the panel swinging from the remaining lifting anchor causing minor damage to the panel, during the lifting of a precast reinforced concrete twin-wall panel from the tilting frame.

638 Failure of cast-in lifter on L-shaped wall

The failure during a routine lifting operation of an L-shaped wall unit, when a cast-in lifter on one of the legs on the cast-in lifter (located on top of the unit), pulled out of the concrete.

642 Toppling of precast concrete unit during lifting causes serious injury

An L-shaped precast concrete unit, during a routine lift, tipped over while a worker was un-slinging the top sling points for the unit using a ladder and caused serious injury to a worker.

749 Failure of prestressed hollow-core units during lifting

Issues with the failure of lifting clamps, choke hitched chains, lifting hooks and cast-in lifting anchors.

6.3.2 Further detail can be found at: https://www.structural-safety.org

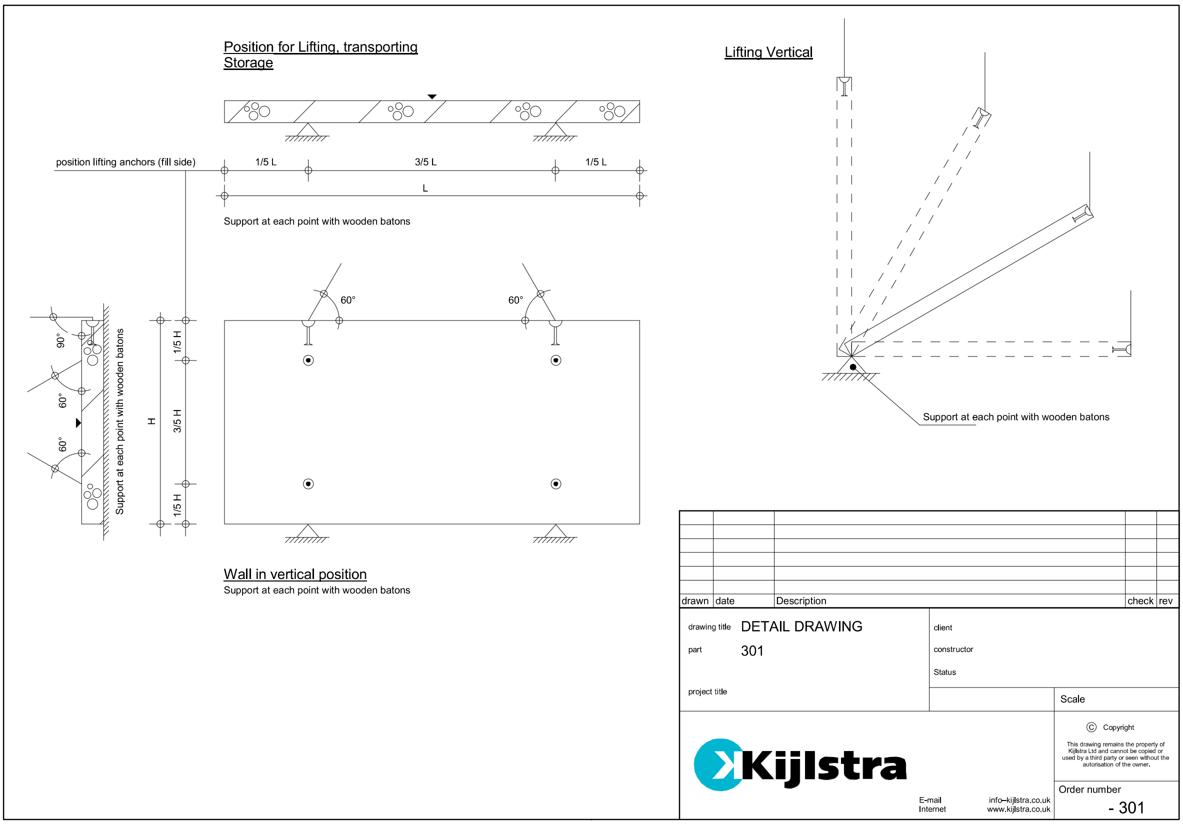


Figure 6.3 - Example precast panel with lifting eye detail

7. Transport

This chapter considers common issues to take into account when transporting precast units.

7.1 Common issues – 'getting it right'

There are a number of common issues that should be considered when planning transport:

a) When planning precast units, it is important to limit the dimensions and weights of any units to suit road transport. Some precast units are handled in multiples, e.g. precast tunnel linings (where the whole ring may be lifted in a single lift).

b) Consider casting units on site, within radius of a single lift to their permanent location.

c) Over width elements require police escort and road management. These units should be inspected prior to dispatch as rejection by site on quality issues and return to precaster are not a simple matter. There should be a 'Plan B' so that any over width loads unable to unload, due to unforeseen circumstances, can be held on site.

d) A fundamental concern when loading delivery vehicles is to ensure an even weight distribution and load stability. The weight of precast elements (and their centre of gravity) should be checked and confirmed prior to loading. Loose and extraneous material on any precast unit should be cleaned off prior to dispatch. Lifting anchors should be checked for functionality.

e) When considering the loading of precast components, it is important that the loading arrangements allow maximum protection against damage or breaks. Cut widths, or slabs that have details, e.g. holes, may need to be placed at the top of the load in order to avoid damage during transportation. Check for any damage during transport.

f) Components must have bearers placed at suitable positions along their length, in accordance with the precaster's recommendations. Where components are stacked in layers the bearers at each layer should line through vertically, so as to avoid shear planes. The material used for securing the components should be reviewed and approved by the purchaser.

g) The contractor's duty is to ensure that all delivery vehicles are offloaded safely. A major issue is work at height. Therefore, use measures such as platform gantries, handrails, airbags, personal work restraint systems, personal fall arrest, etc.

h) For improved safety during installation, it is important that units are loaded so that unloading can be carried out in the appropriate sequence. However, this should never be at the expense of the safe transport. Therefore, some double handling may be required at the point of installation.

i) There are dedicated specialist trailer units that can be used for the delivery of unusually-shaped elements (see **Figures 7.1** to **7.6**). Slender beams can buckle (e.g. SY bridge beams). The manufacturer should use transportation frames to stiffen the top of the beam to prevent buckling.

Figure 7.1 – Precast units loaded onto a flatbed

Figure 7.2 – Use of a transportation frame

Figure 7.3 – The use of a rearing frame

Figure 7.4 – The transportation of precast units [4]

[4] NOTE: The load on the front drop legs requires a check on punching shear.

Figure 7.5 – U-beam on a trailer

Figure 7.6 – Transport A-frame with centre access

8 Storage

This chapter considers the storage of precast units, in order to avoid damage.

8.1 Common issues – 'getting it right'

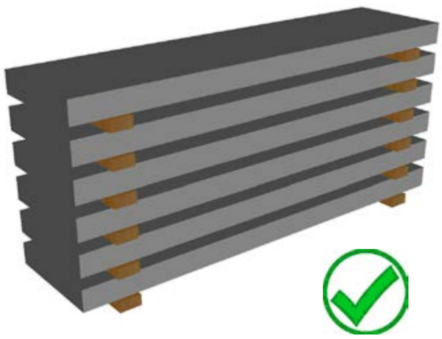
There are a number of common issues that should be considered when planning transport:

a) As with transport (see **Section 7**) precast units should have bearers placed at suitable positions along their length, in accordance with the precaster's recommendations. Where components are stacked in layers (see **Figure 8.1**) the bearers at each layer should line through vertically, to avoid shear planes.

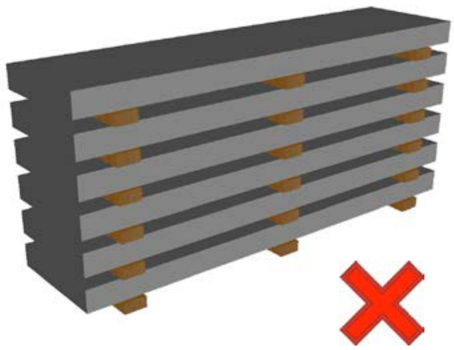
b) Unusual shapes (e.g. manholes, curved parapets and tunnel segments) require more complex storage arrangements and these should be individually assessed.

c) Storage areas should normally be overlain with a granular working platform and may be topped with a suitable slab to minimise the foundations required under the stored units.

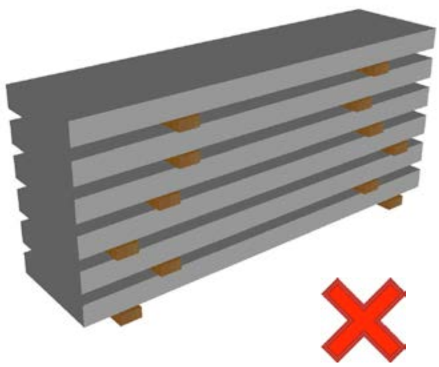
NOTE: The ground bearing capability of the storage area should be reviewed for suitability to safely store the precast units for the required length of time. Also, consideration should be given to the duration and protection/handling requirements.



Stacking method and packers or support spacers vary according to the types of precast concrete elements. Horizontal stacking of slabs/beam/column units can be done with suitable packers or support spacers as shown above. As a guide, the storage support position for beams/slabs elements should be within 100mm from the lifting points.



Do not use more than two support points in particular for prestressed elements like hollow core slab etc.



The packers or support spacers should not be misaligned as shown above.

Wall panels should be stored vertically and braced in position by A-frames or a racking system.

Figure 8.1 - Stacking in layers

d) With no need for storage, immediate installation is good practice.

e) Careful consideration and advice from the precaster should be taken when considering protection of the units, either when in store or erected. The precaster should, as part of their package, detail how units should be stacked. Wrapped architectural precast units to protect them may cause staining and hydration marks. The material used for securing the components must be reviewed and approved by the principal contractor.

f) During storage, do not allow water to collect in recesses, pockets, lifting anchors (especially during the winter).

g) The height to which units can be stacked safely on site will be influenced greatly by the condition of the ground upon which they bear. An important consideration should be the height to which a slinger can reach in order to pass any lifting chains or slings around the units.

NOTE: The amount of precast that can be stored in a given area may also be limited by the load capacity of the surface upon which it bears. Specifically, suspended floor slabs should be assessed in order to determine a safe limit for loading.

h) Similar length beams should be stacked together. The need to climb onto stacked components to secure chains or other means of lifting should be avoided.

i) If units are to be left stacked for any length of time, consideration should be given to the practicalities and sequence of their installation. To avoid additional handling or transport hazards, units should be stacked as near as possible to their final position.

9. Turning

This chapter considers some of the issues associated with turning precast units, in order to minimise the risk of causing damage.

9.1 Precast wall units that are cast horizontally and then demoulded should be stored and placed for transport in the same orientation. When these units arrive on site they should be turned into a vertical orientation. This is a high risk operation and is frequently best accomplished using a "turning table" or "turning frames" (see **Figures 9.1** to **9.7**). Remember to secure the precast unit to frame.

9.2 Where cast in lifting points are used for both pitching and lifting it is very important to get the reinforcement detailing correct.

9.3 Wall elements can be subject to local bending from self-weight when being pitched and lifted and additional reinforcement may be required.

9.4 It is recommended that a dedicated risk assessment be undertaken to cover any turning operations.

Figure 9.1 – Precast parapet placed on turning table

Figure 9.2 – Unit being raised into the vertical position with lifting points at the top of the unit

Figure 9.3 – Precast unit in place ready to be propped

Figure 9.4 – Protection mats used whilst turning panels from a delivered orientation to installation orientation

Figure 9.5 – Precast wall unit placed on turning frame

Figure 9.6 – Unit being raised into the vertical position with lifting points at the top of the unit

Figure 9.7 – Precast unit in place ready to be lifted

10. Erection, temporary stability, propping and founding/shimming

This chapter considers the issues associated with the erection, temporary stability, propping and founding/shimming of precast concrete as there are often overlooked by the permanent works designer.

10.1 Basic concerns

10.1.1 There are some basic concerns facing those charged with the responsibility for erecting precast concrete units. These include the weight and size of the units; the type of connections; the temporary support required; and any site constraints.

10.1.2 In precast concrete, the structural and architectural considerations and designs are rarely overlooked as these are of concern to the designers developing the overall project. Too often however, the erection and temporary stability of precast units are not considered by the permanent works designer and, moreover, the precaster.

10.1.3 Detailed planning and preparatory work is fundamental to the safe installation of precast concrete units, ensuring an efficient and good quality installation is undertaken. Items that should be addressed include:

- method and sequence of assembly and erection;
- method of providing temporary supports;
- provision for final structural connections and joint details;
- erection tolerances; and
- handling and rigging requirements.

10.1.4 The verticality of units can be achieved by adjusting props. The line of units is often achieved by the physical pushing/pulling of units by the erectors whilst the unit is suspended on the crane. Sockets cast at low level, to which mechanical aids can be attached, give greater control of the unit and allow for easy adjustment.

10.2 Erection

10.2.1 Working to sequence

10.2.1.1 Prior to the arrival of the installation team, an installation sequence should have been agreed, in the form of RAMS (with records kept on site). This should include all delivery, access and plant requirements. Enough time should be allowed.

NOTE: It is recommended that a dedicated risk assessment be undertaken to cover erection (in addition to the lift plan).

10.2.1.2 It is the responsibility of the PC to ensure adherence to the agreed sequence. In circumstances where a deviation is unavoidable, the installation contractor - before altering the sequence - should seek advice and approval from the PC and/or the precast designer (in control of the safe system of work).

10.2.2 Pre-start checks

10.2.2.1 Before starting the installation of any precast units, the PC should be satisfied that all the agreed resources, plant and materials are available (and in accordance with the RAMS). Pre-start checks should be conducted with the contractor's workforce. To manage breakdowns and downtime, ensure that any back up plant is available (where appropriate).

10.2.2.2 If any item plant or material is found to be inadequate or missing, the installation contractor should highlight the problem and, if necessary, delay any installation until changes are sanctioned by the appropriate designer(s).

10.2.2.3 Forecast weather conditions, e.g. high winds, should be checked prior to the dispatch of precast units.

10.2.3 Supervision of installation

10.2.3.1 On all lifting operations, a qualified 'Appointed Person' should attend the site with the specific crane being used and assume the duties of 'Crane Supervisor' (providing that they are suitably qualified and competent).

NOTE: Reference should be made to BS 7121, Code of practice for safe use of cranes (published in several parts).

10.2.3.2 The installation contractor is responsible for the actual installation of the precast units. The PC retains overall responsibility and if they observe concerns they should be raised directly and immediately with the installation contractor.

10.2.3.3 Before placing units, the installation contractor should ensure that the crane (where applicable) is operating in a safe and proper manner, and that the 'Crane Operator' is fully aware of the nature of the work and can identify and understand the 'Slinger/Signaller'. It is also the responsibility of the installation contractor to ensure that the crane outrigger pad size and crane platform has been designed, approved and constructed accordingly. Overall responsibility remains with the PC.

10.3 Temporary stability/propping

10.3.1 There are a number of issues to take into account when considering temporary stability and propping:

a) Wherever possible stability and alignment props should be fixed to the unit beforehand, including elements such as cast in anchors, etc.

b) When it is necessary to attach such props after the unit has been positioned, the unit should be held safely by the crane whilst they are installed, using appropriate access equipment.

c) Generally, a minimum of two props should be utilised for all units (unless the TWD determines otherwise). Where units can be effectively coupled together, one central prop - to resist rotation or toppling - may be sufficient (subject to design by a competent temporary works designer (TWD)).

d) Props shall be attached to a surface that is capable of withstanding the applied loads. When the surface is a permanent structure (e.g. bridge deck, etc.) approval is required from the permanent works designer (PWD).

e) Props, including all their components, should be checked on site at regular intervals (as outlined by the TWD and agreed with the TWC).

f) Stability of the precast unit needs to be maintained during any translation or rotational effects.

g) Anchor specification, installation techniques, the use and re-use potential of prop anchors and the minimum concrete strength should be determined as part of the overall temporary works design.

h) In multiple anchor arrangements, any rebar location and positional tolerance should be considered. Templates should be used to cast in such anchor assemblies.

i) Precast component supports (e.g. steel beams, bridge decks, etc.) should be fixed securely and have adequate safe bearing at each end in order to avoid overturning, excessive deflection or collapse when the precast unit is placed. This should be assessed by the PWD and/or TWD.

j) When precast units are placed on them, consideration should be given to the asymmetrical loading of unrestrained walls or steel beams. For example, a steel beam shall be designed to resist lateral torsional buckling during the construction phase. This can occur when one side of a beam is loaded.

k) Any cantilever propping that may be necessary during construction should be clearly indicated on the installation drawings. The cantilever end of any precast member should be distinctly marked on the unit to avoid incorrect fixing.

l) The minimum bearing lengths and widths, in accordance with the recommendations set out in PW or TW design, should be met at all times. Allow for manufacturing and construction tolerances. Where shear studs are provided for composite action the bearing lengths may need adjusting with agreement from the designer.

m) Bearing surfaces should be clean, level and free of debris.

n) Load paths through a partially completed structure may be different for those in a completed structure. This should be assessed by the PWD and TWD.

o) Bracing/props should be left in place until the structure is stable in its own right, e.g. the insitu stitch concrete or insitu diaphragms/decks have been cast and reached the appropriate strength.

10.3.2 **WARNING:** Typically, floor slab falsework relies on a 'top restraint'. This is normally provided by any walls and columns. Depending upon the pre-cast connection at the bottom of units, i.e. if effectively a pinned connection, any temporary propping may need to be left in position and checked for the additional load case of providing lateral restraint when casting the floor slab above.

10.3.3 Some contractors use a 'gallows' type fall arrest system where sleeves are cast into the top of columns to receive the steel frame providing the fall protection systems. This should be coordinated in advance if chosen with a precast system.

10.3.4 Where precast panels do not have a slab adjacent to them, consider horizontal propping to adjacent panels or onto a platform within the void.

NOTE: Voids may require clear access for jump platforms, access, etc.

10.4 Founding and shimming

10.4.1 The practice of installing precast units on temporary bearings/shims should be used only after a full review of the bearing type, installation needs and agreement of all stakeholders. In cases where such measures are used, the requirement to land on temporary bearings should be identified at the design stage. Fixing should not progress until written confirmation has been obtained by the PC's site representative, from a competent technical authority, that any temporary structure has been suitably designed and the precast units assessed.

10.4.2 Shims are often used as spacers or as a means of levelling or aligning adjacent components. They serve an interim or temporary load-transferring function. Unless such temporary loading of units has been specifically incorporated into the project's contract documents, the installer is responsible for the temporary loading of the units and should ensure that any shims have been considered carefully by the PWD and TWD, as appropriate.

10.4.3 High density plastic and steel shims are used commonly to obtain the joint dimension specified. Shims should be positioned away from the edge of the unit in order to prevent spalling of the concrete in the case of excessive loading. They should also be recessed, out of view, as they can be unsightly and difficult to remove if exposed to view. Shims should be removed from the joints of non-loadbearing units after connections are completed and before applying sealants, unless the shim material itself is readily deformable. Plastic or steel shims usually significantly reduce friction resistance at the unit base.

10.4.3 When using shims for temporary load bearing, the platform on which the shims sit should be carefully considered for this point load (i.e. any base, be it concrete or another material, should have the capacity for punching shear taken into consideration by the PWD and TWD, as appropriate).

10.4.4 Any high wall units that require shimming to bring them into tolerance may require temporary works to provide stability. Ensure that any production tolerances and installation tolerances fit within any specified tolerances. For example, some tolerance may be 'standard' or 'bespoke'.

10.4.5 If there is a requirement to use folding wedges it is to use hardwood folding wedges recommended (see **Figure 10.1**). The slope of the wedge should not exceed 1 in 20. A minimum bearing area should be specified in the design. Consideration should be given to how the wedges are removed subsequently.

NOTE: Sustainability issues may restrict the use of tropical hard woods.

10.4.6 Ideally, bridge beams should be cast such that the bearing and subsequent jacking soffit faces are level in both planes.

10.4.7 Alternatives to hardwood wedges include concrete blocks (site-cast or proprietary supply) bedded in mortar with a plywood topping. These are broken out subsequently once the beams are permanently stabilised.

10.4.8 Any individual temporary support should be capable of supporting at least half the total beam weight until the permanent bearing becomes available to transmit load.

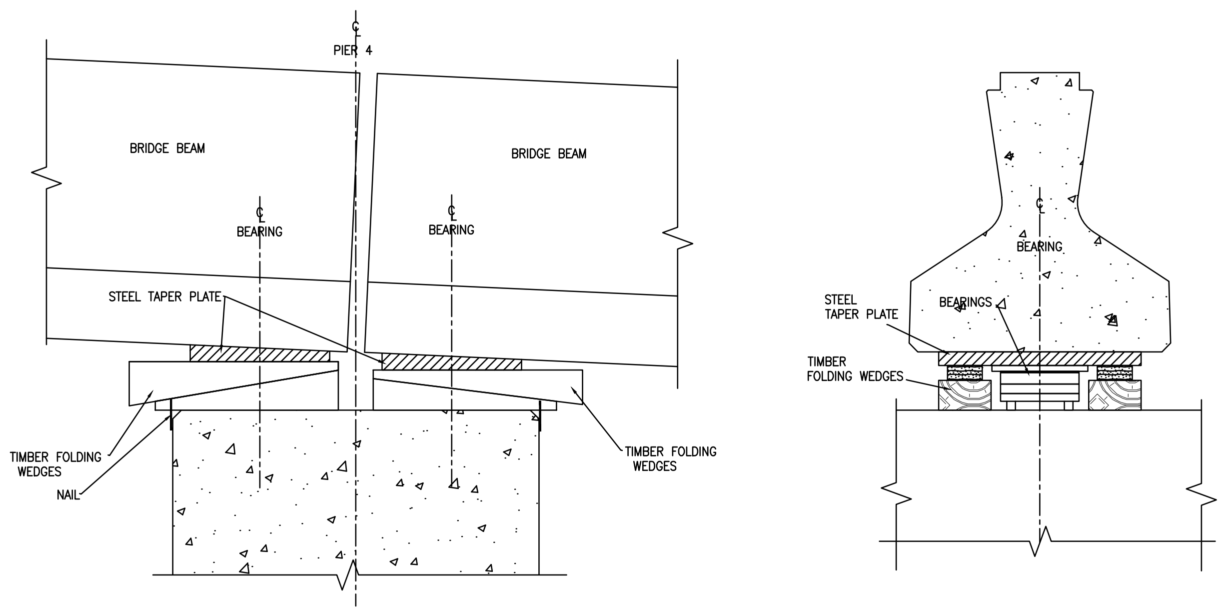


Figure 10.1 – Example precast beam bearing detail

11. Grouting and stitching

This chapter consider the key points to consider when grouting and stitching precast concrete.

11.1 Connecting precast units to any supporting and/or follow on works, or adjoining precast units, requires careful planning and controls to ensure the integrity of any joint. Particular attention is required for high performance joints with liquid retaining properties in tanks, walls, slabs, etc.

11.2 Key points include:

a) When designing temporary works to support the stiches between panels consider including support within the precast units.

b) The performance requirements for the stitches may need to align with the precast units, e.g. colour, texture, etc.

c) Hydrophilic strips should be fixed correctly and have the appropriate bearing surface and restraint.

d) Ensure that panels are aligned in all directions prior to final fixing, so that they will withstand any construction loadings in both horizontal and vertical directions, e.g. concrete pressure, plant loads, etc.

e) Assess friction carefully, so that conditions reflect the temporary works design, e.g. shims, concrete surface smoothness. Ensure no catastrophic failure is possible by using physical stops, e.g. upstands, in addition to friction.

f) Grout should be able to flow the required distance and thickness. Perform a trial, if required. Determine what surface preparation is necessary before grouting. Consider whether vents are required. Use a 'no/go' gauge for controlled water addition.

g) Ensure that shuttering is tight and grout flow controlled in order to prevent staining, damage, feather edging, grout loss, etc. A recessed joint may be more appropriate than a flush one.

h) Consider whether the positioning of the shims or temporary backing will influence the grouting and whether the load transfer can be achieved from the shims to the grout.

i) Ensure that samples of the grout are taken for compressive tests (as required by the project specifications and/or relevant standards).

j) Consider surveying and/or checking for protruding reinforcement and embedment clashes between precast units and any supporting concrete, e.g. parapet tie bars and bridge deck in-situ reinforcement.

11.3 On occasions a design detail calls for a dry packing to fill a void left from the installation of a precast concrete unit. Good detailing does not require dry packing and it usually occurs where there has been insufficient thought to the design. It can be engineered out, e.g. cast in grout tubes in the precast units. However, in the event that it is needed

11.4 From a quality assurance perspective, experience has shown difficulties in a number of areas:

a) Use pre-bagged materials whenever possible as this removes a variable.

b) Detailed records of material batch numbers and the volume of water added are crucial.

c) Don't make any test samples from the last part of the batch used in production. It's better to make up a specific control sample for filling and making cubes.

d) Keep cube samples small if possible, i.e. < 100mm. Ideally, 60 to 80 mm cubes are better.

e) Take sufficient cubes and allow for a rogue sample or two. Remember, the characteristic 28 day result is the mean of at least two samples; it's worth having spares in case of low strength results, so that samples can be tested in pairs at 56 and 90 days.

NOTE: A 28 day period is only applicable for 100% Portland cement. A longer period may be required for other cement mixes.

f) The water/cement ratio in dry pack and/or grout is particularly sensitive. Follow the manufacturer's instructions carefully.

g) Ensure that control samples are made and stored correctly. Once demoulded they should go into a temperature-controlled tank and not left to 'rattle around in the back of a van' for a number of days!

h) Ensure that control samples are made by a competent person, in line with the recommendations in BS EN 12390, and that the testing laboratory is certified by UKAS (or similar independently accredited authority).

i) If in doubt, seek expert guidance.

11.5 A simple jig allows the compaction of dry pack under an inverted base plate (Figures 11.1 to 11.3).

Figure 11.1 – Timber ply L-shaped backer used to assist in allowing the compaction of the dry pack into the void

Figure 11.2 – Ply backer can be seen on the bench (before use): see ***Figure 11.1***

Figure 11.3 – Placement of dry pack achieved using timber former on a test piece following removal of the top plate

12. Repairs and modifications

This chapter considers the issues to take into account when consider repairs and modifications to precast units.

12.1 Concrete repairs can require detailed control measures to ensure that they are successful over the required design life. Accordingly, careful assessment is need to whether to repair damage in-situ, remove the unit and then repair and reinstall or to replace the item altogether. This decision may be required at the time of placement in order to enable an efficient change out with a similar unit.

12.2 Non-cement based repair products should only be undertaken subject to the client's prior approval. This may require a proven track record in order to support acceptance on a project.

12.3 Key points to consider include:

a) The surface colour and texture requirements. Architectural finishes can be very difficult to match.

b) The performance requirements, e.g. protective coatings, water resisting properties, etc.

c) When and how will the repair be performed, as well as the access required for repair and subsequent inspection(s)

d) The minimum repair thickness required and surface preparation, etc.

e) Whether the installation methodology increases the probability of damage (and whether protective coating should be left in place, timber packing used, the use of steel pry bars restricted, etc.).

f) The risk associated with the repair failing over time, e.g. spalling of thin repairs in exposed locations.

g) Considering whether to engage the precast supplier to perform the repair (thus aiming to maintain any warranty).

h) Ensuring the precast supplier issues an approved repair procedure for typical scenario, e.g. edge cracking and impact damage, so allowing pre-planning for repairs. A documented repair strategy should meet the requirements of BS EN 1504 and use only propriety materials. All repairs should be subject to the approval of an authorising body.

i) Assessing carefully how stains/marks should be removed. For example, excessive pressure washing can damage exposed surfaces. Seek advice from the precast supplier on suitable cleaning products that prevent further damage occurring.

j) On exposed surfaces, minimise the risk of rust staining by the use of galvanised or stainless fixings and/or lifting points.

k) Seek engineering advice on repair to pre or post-tensioned items. Excessive concrete removal could result in failures. Thin panel precast units can also be complex to repair.

12.4 Consult technical guidance, e.g.:

- Concrete Society Technical Report 69, Repair of Concrete Structures with Reference to BS EN 1504 (2009) [5]
- BS EN 1504, Products and systems for the protection and repair of concrete structures, Parts 1 to 10 [6]

13. Demolition (including pre-stressed and post-tensioned construction)

This chapter considers some of the issues that arise from the demolition of structures that contain precast concrete (whether in composite construction or standalone).

13.1 Introduction

13.1.1 Occasionally, it may necessary to demolish all or part of some precast concrete. The following is not intended to be a 'demolition guide' but awareness of some of the issues to be considered in demolition that contains precast concrete (whether in composite construction or standalone) [7].

13.2 Considerations

13.2.1 The demolition of precast concrete should be planned particularly carefully. There are a number of potential challenges that precast concrete elements pose, that may make it more hazardous than the demolition of traditional in situ concrete structures:

a) instability - leading to the potential for uncontrolled collapse;

b) unusual reactions - arising from the presence of in built loads from post tensioned and pre stressed components;

c) hidden history - knowledge of the structure's history as built and maintenance;

[5] http://www.concretebookshop.com/tr69-repair-of-concrete-structures-with-reference-to-bs-en-1504-1867-p.asp

[6] https://shop.bsigroup.com/SearchResults/?q=bs%20en%201504

[7] See: BS 6187:2011, Code of practice for full and partial demolition

d) age;

e) competency of the materials - due to age and degradation, to maintain a state of equilibrium;

f) unusual load distributions – and any modifications post design and construction;

g) hazardous materials - either contained within the precast element or contaminating them;

h) the potential for unrestrained of failed restraint within post tensioned elements – which, as a result, are a source of significant quantity of potential energy.

13.2.2 Never assume that the deconstruction is a reverse of the construction process. In particular, where the precast element forms part of a composite structural arrangement this is unlikely to be an appropriate approach.

13.2.3 In all cases, some points to note are:

a) all demolition work, irrespective of size, is covered by the CDM Regulations;

b) refer to the guidance and recommendations in BS 6187:2011, for full or partial demolition;

c) specialist knowledge and expertise should be sought within the both main contractor's and sub-contractor's management teams;

d) validation of competence for those involved in the assessment, planning, checking and execution of the works is important;

e) accurate communication [8] of the approved methods of work to the workforce is required;

f) have an action plan ready on how deviations in predicted reactions should be managed;

g) where a design is prepared this should always be supplemented by an independent Category 3 design check and certificate.

13.2.4 **Figure 13.1** illustrates a simplified process flow chart to assist in determining how to identify and procure the right specialist partner(s) when tasked with undertaking a planned and safe deconstruction of structures that may contain elements of precast concrete.

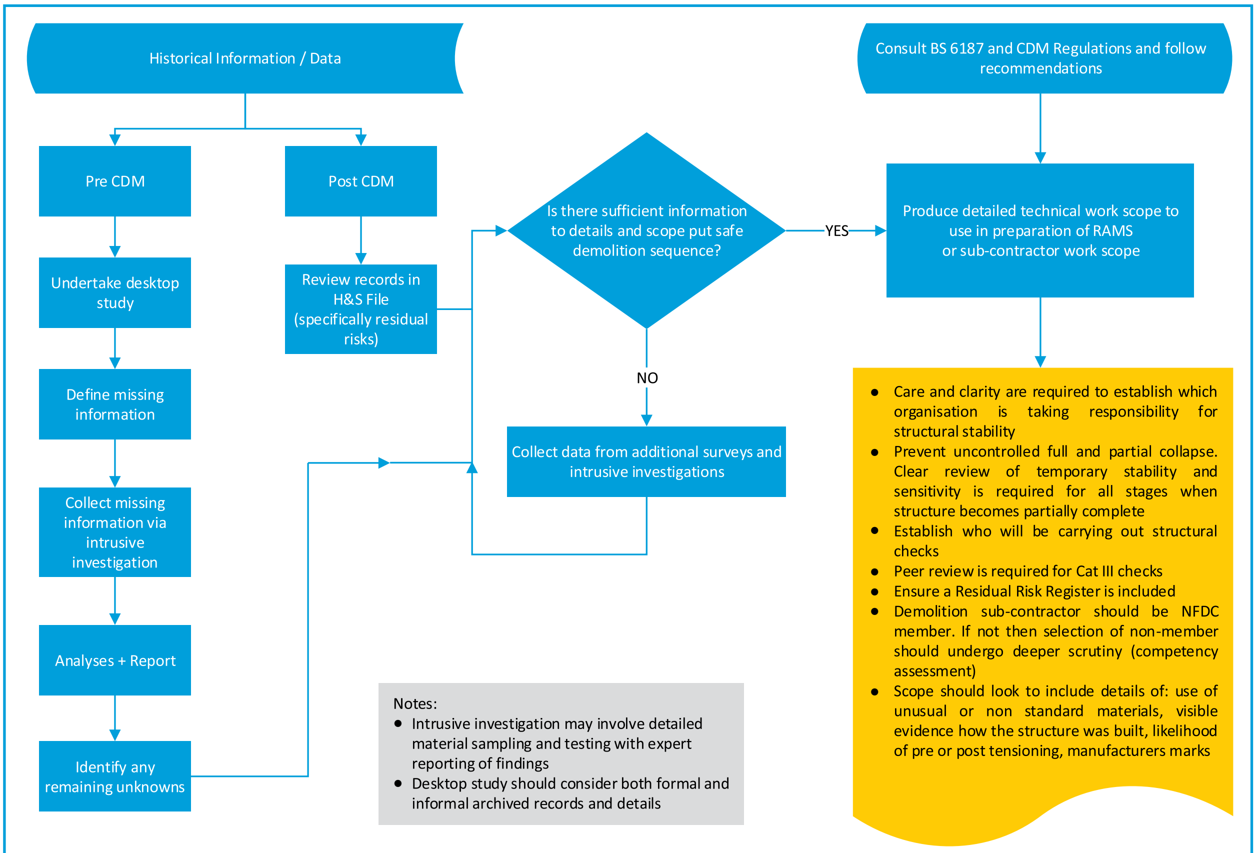


Figure 13.1 – Precast demolition

[8] *Regular and effective communication: See Structural-Safety Report 781, Newsletter No. 52, October 2018 (https://www.structural-safety.org/media/501411/cross-newsletter-no-52-new.pdf)*

13.3 Additional guidance notes

a) When dealing with structures records are often - if available - scant, of varying standard, inaccurate or at best unreliable. Therefore, it is particularly important to ensure that the works are physically surveyed to look for evidence and/or indicators that may be helpful in determining a potential methodology. For example:

- construction joints;
- tendon terminations;
- repairs;
- deterioration damage, corrosion, section loss, etc.

b) In the absence of detailed records or physical evidence a range of intrusive investigative work should be considered. This should be done with the appropriate technical assistance to provide advice on what to collect, how it will be analysed and how it should assist in developing a safe methodology. Techniques that should be considered include:

- sampling, e.g. coring;
- in situ tests, e.g. scanning, ultra-sonic, radar;
- microscopic, e.g. petrographic.

c) The National Federation of Demolition Contractors (NFDC) provides details of member companies: https://demolition-nfdc.com/find-members/.

d) In some cases, the extent or nature of the work may require smaller specialist contractors who offer niche services. As part of any procurement process, care should be taken to ensure that there is a suitable, sufficient and appropriate competency check.

e) It can be invaluable to arrange for a peer review of the planned methodology, focussing on the management of risk.

f) Investigation, analysis of investigation works, peer reviews and temporary stability assessments can be time consuming. **Early planning is essential**.

14. Case studies

Case Study 1: Casting, transporting and installation of precast kerbs

Location

Railway: up airport relief ramp between the main and electric lines

Description of works

The construction consisted of a reinforced earth retaining wall using reinforced concrete panels, granular infill and robust kerbs containing the 'permanent way' which led to a new, elevated relief line servicing the airport.

Precast challenges

The project was designed pre-construction and the 'robust kerbs' – concrete parapets which act as a kerb and which resist horizontal impact loads – were designed as single entities running separately along each side of the ramp. The primary challenge was the limited level of access via track possession for cranes to lift and install each individual kerb (of which there were about one hundred in total). The program required a track possession for each kerb installation and was not feasible or acceptable.

The solution was to design and cast a 'u-kerb' using a section of the in-situ cross ramp stitch as part of the pre-cast connecting the original single standalone kerbs (see **Figure 14.1.1**). In other words, there parts were now reduced to one.

The PWDs were responsible for re-designing the u-kerbs. The principal contractor (PC) and the TWC who were tasked with designing the lifting points.

Through the client's engineering assurance process, the lifting points designed by the PC were approved by the client. The TWC then ensured that the u-kerb supplier was formally in receipt of details of the approved lifting point, so that they could be installed during the fabrication process.

The fabrication was undertaken overseas, so an external consultant was contracted to carry out an inspection of each pour. This included the lifting anchors.

Initially, it was envisaged that a 20 Te 'pick and carry' crane would be utilised to carry the kerbs up along the ramp to their final locations. However, with the emergence of a new item of specialised plant (known as the "monster crane"), a more controlled and safer option was deemed to be the installation of a set of rails up along the ramp with a 'road rail vehicle' (RRV) delivering the u-kerbs via these tracks (see **Figure 14.1.2**).

Conclusion

Through combined foresight and engineering thinking - featuring the PC's engineering team, the PWD, the client and the precast supplier – an improved solution was developed that ensured the original design could be constructed safely. The entire process, from the re-design to the physical installation, was co-ordinated successfully by the project's TWC.

Figure 14.1.1 – U-kerb after connecting standalone kerbs with a cross ramp

Figure 14.1.2 – U-kerb being transported by crane

Case Study 2: Design and installation of precast kerbs

Location

Railway station

Description of Works

As part of the scheme to increase the size of a railway station, a retaining wall was to be built to its north. A set of tracks for one platform were to be located on top of this wall. It was necessary to install a concrete kerb unit along the top of the wall, capable of containing a train derailment. Within this kerb there was a need for an access walkway (see **Figure 14.2.1**).

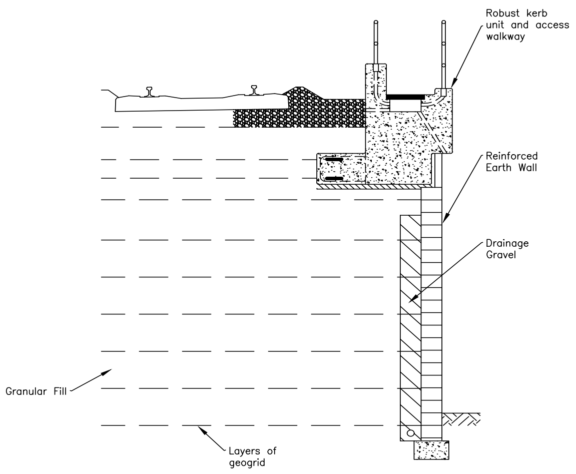


Figure 14.2.1 – Cross section of retaining wall

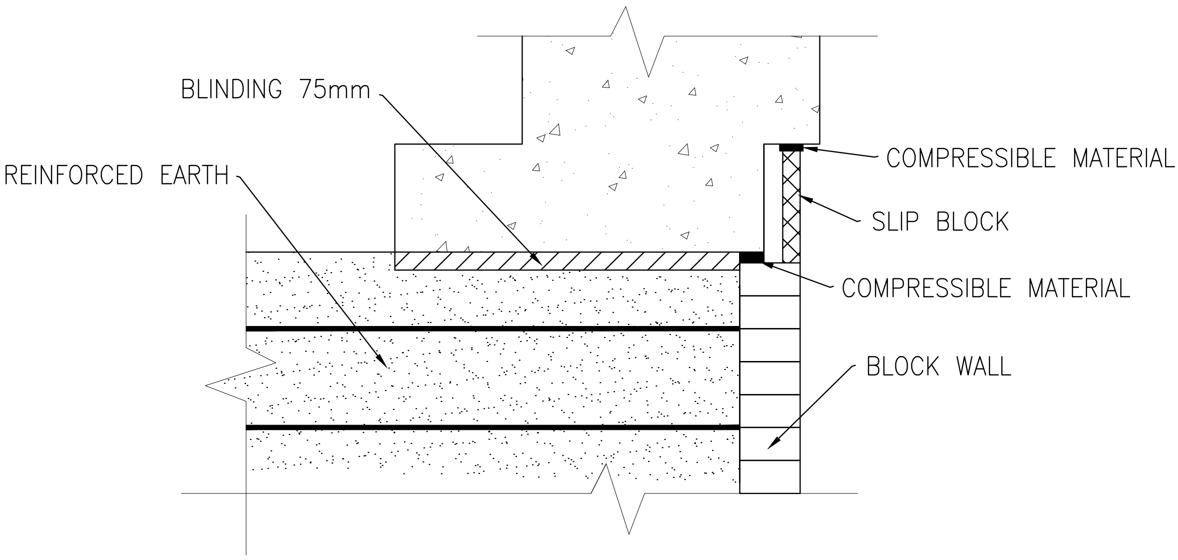


Figure 14.2.2 – Detail of top of reinforced earth wall with precast kerb

Issues with the design

The kerb unit was designed to be cast in situ, in 12 m long bays. The following were key issues with the design:

- Its location on top of the wall required significant temporary falsework and access staging to construct the section which overhung the retaining wall.
- Due to its location it was also on the project's critical path.
- The reinforced earth was a contractor-designed element but the robust kerb was a client-designed element.
- The reinforced earth solution was not suitable for large loadings close to the front edge of the wall. No vertical load was allowed into the reinforced earth facing bricks. Hence, the introduction of a compressible fill layer (see **Figure 14.2.2**).
- The compaction of fill material close to the front of the reinforced earth wall was deemed problematic. The facing bricks are held in place under self-weight, so any meaningful compaction would push them over. This would, more than likely, result in insufficient compaction in an area of high loading.
- The toe of the robust kerb was designed to have lengths of Tensar grid cast into them, in order to provide the horizontal restraint required to resist train derailment loads. This resulted in concrete compaction being very challenging.

Contractor proposed changes

The reinforced concrete sub-contractor proposed pre-casting the main part of the robust kerbs in 4m long sections and then stitching them together in-situ to form 12m long bays (and, at the same time, casting the toe of the units in-situ). This removed their casting from the critical path and removed the need to cast in- situ at height). In principle, this was a good solution to a number of issues but it introduced the temporary case of the units needing to be shimmed in place and temporarily supported).

Kerb unit temporary support

The precast units were typically 11 Te in weight. As the front of the wall could not take any vertical load, the shims used to support the kerb units during installation had to be positioned 613 mm back from the front of the kerb unit. This meant that the shims were only 87mm forward of the unit's centre of gravity (see **Figure 14.2.3**).

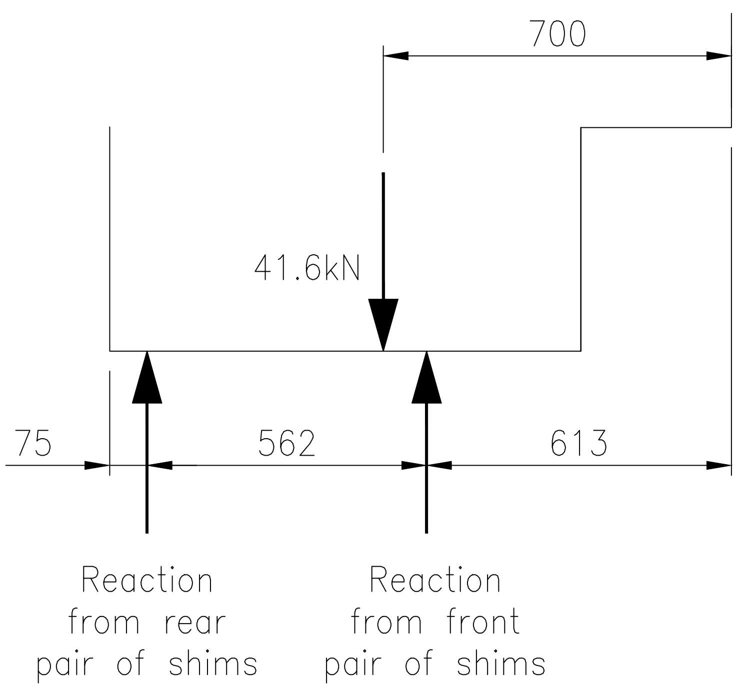


Figure 14.2.3 – Location of shims under robust kerb unit

Figure 14.2.4 – Precast unit tie back

Figure 14.2.5 – Location of precast units

Figure 14.2.6 - Spalling

The initial solution was to install straps around the top of the unit, back to kentledge. This was adopted for the first run of kerb units (see **Figures 14.2.4 and 14.2.5**).

This solution resulted in a number of issues:

- The straps meant that the work space required to undertake the cast in-situ elements was restricted (see **Figure 14.2.4**).
- Although the units were stabilised there were still very high loads in the blinding under the front shims. This led to the need for blinding to be 200mm thick, with a layer of mesh.

Approximately one-third of the way through the kerb installation there was an issue when installing a kerb unit, when the front shims punched through the blinding concrete and the kerb unit leant forward (see **Figure 14.2.6**).

Therefore, the support solution was changed from straps to raking props at the front of the units (see **Figure 14.2.7**).

Figure 14.2.7 – Additional propping

Case Study 3: Propping of precast twin wall

Location

Railway station

Description of works

As part of improvement work, a number of escalator structures were to be built at a railway station. The client was responsible for the permanent works design and had designed the escalators as cast in-situ. The reinforced concrete (RC) sub-contractor proposed changing the escalators to a twin wall precast solution. This had many benefits for the project, but also introduced safety risks and installation issues.

The incident

During the erection of the second lift of twin wall panels on one of the escalators a 3.5 Te panel fell over (see **Figure 14.3.1**). This occurred during panel alignment using the push-pull props provided to hold the panel vertical and provide lateral restraint.

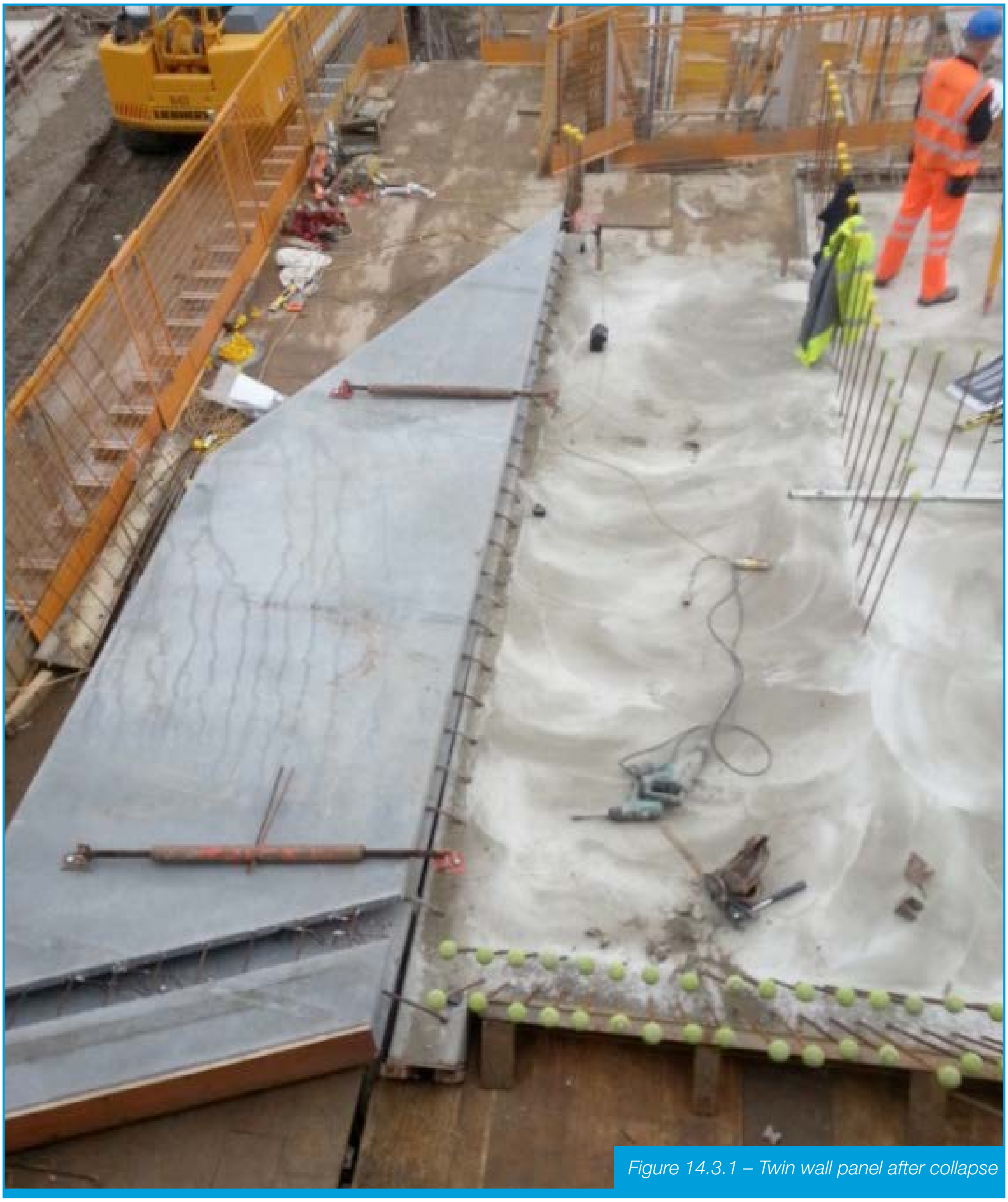


Figure 14.3.1 – Twin wall panel after collapse

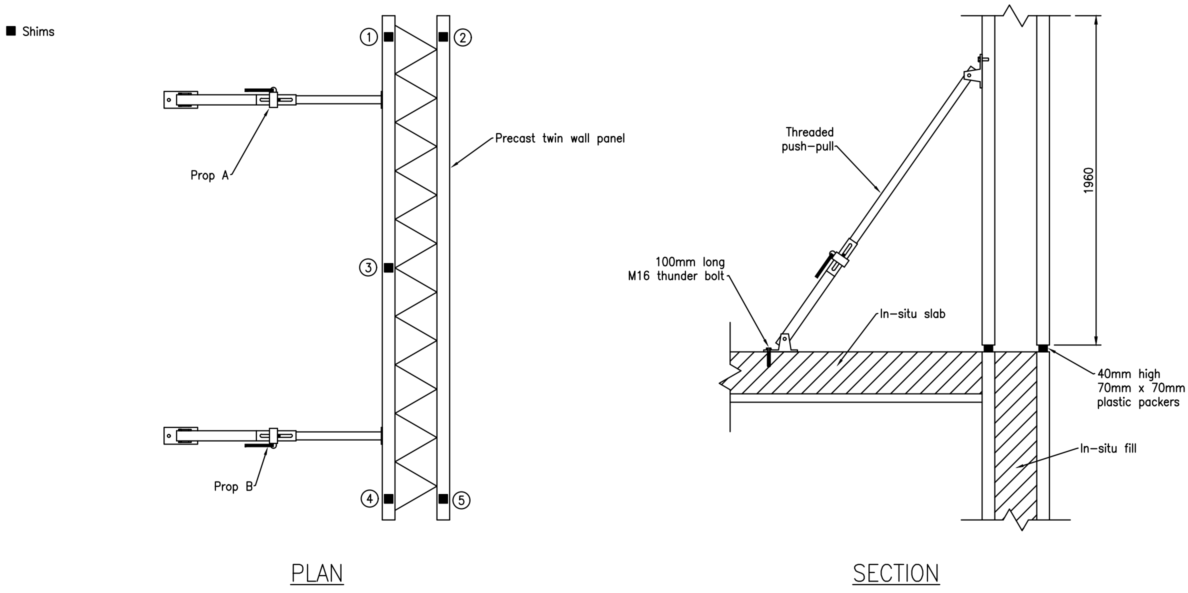


Figure 14.3.2 – Shim and prop arrangement before the collapse

What went wrong?

The root cause of the incident was that the panel propping arrangement did not taken into account the accidental load case when a panel comes off a shim (see **Figure 14.3.2**). The wall panel bases were not laterally restrained and the shims relied on friction only (that, between the smooth surface of the precast panels, was not great).

The props had been designed for wind loading only (and not as a 'plumbing device'). It is thought that whilst the push-pull props were being adjusted the panel twisted and slipped off one of the shims. This resulted in the props resisting the load from one side of the wall panel being unsupported, causing the prop anchorage to fail.

NOTE: A contributory factor was the concrete to which the base of the push-pull was only 24 hrs old. Also, the anchor bolt was 80 mm long and not the designed 120 mm; pointing to inadequate site control.

The solution

Further panels were erected using a series of props introduced to restrain the base of the wall panels to stop the panel kicking out (see **Figure 14.3.3**).

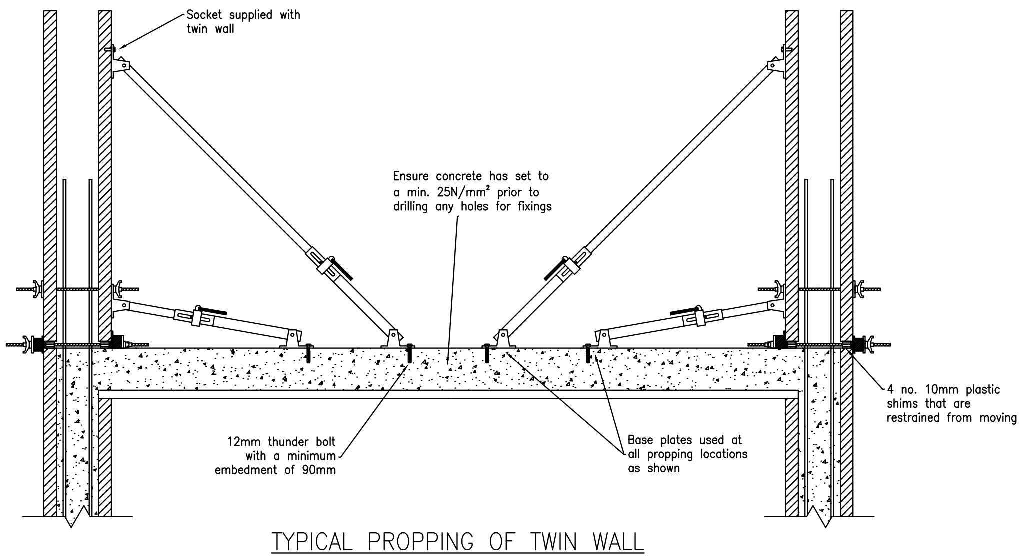


Figure 14.3.3 - General arrangement showing propping of twin wall (Example)

Case Study 4: Tank precast wall

Location

Wastewater treatment works (WwTW)

Description of works

During the erection of precast units for a lamella clarifier tank, the stabilising foot of one wall unit failed. This case study examines the failure with the aim of providing advice on how to avoid similar problems in the erection of other precast units.

What happened?

- At the time of the incident the weather was fine. Wind speeds were within the working limits of the crane being used to place the units. Visibility was good.
- Prior to the incident, eight precast wall units had been placed without incident (except, in places, for some minor spalling of the feet).
- The unit that failed subsequently, with an attached launder channel, was lifted into place.
- With the load still on the crane the unit was stabilised and plumbed by placing shims under reinforced concrete stabilising feet, provided as part of the precast unit. A steel bar was used as a 'pry' to help in placing the shims.
- As the load from the crane was released the stabilising foot under the launder channel failed (see **Figures 14.4.1** and **14.4.4**) rendering the unit unstable.
- The crane lifted the broken unit to a safe location and laid it on its back in a stable position.
- There were no injuries, damage to construction plant or any of the permanent works (except the precast unit concerned).

Figure 14.4.1 – View of failed support foot

Figure 14.4.2 – Typical unit showing raised foot

Figure 14.4.3 – Shape of failed unit

Supplementary information

- The precast units were placed on a concrete slab.
- The precast units were designed and installed by the precast supplier, under a sub-contract.
- The precast supplier designed and manufactured the units and appointed a sub-contractor to install them.
- The precast supplier had submitted their proposals for temporary support of the units, where required, prior to their incorporation into the permanent works.
- The units had been checked for stability against overturning under wind and construction loads.

Observations

- **Design:** Some of the units, as a result of their shape (those with a launder channel attached), put a high load on the stabilising foot on the side of the launder channel.
- **Construction practice:** When stabilising and plumbing the units, prior to releasing the crane, shims are placed under the end of the feet. Mortar is then placed in the remaining gap between the foot and support slab. The RAMS indicated the use of shims. The placing of shims was facilitated using a steel bar to 'pry' open the gap. Thereafter, the crane released the unit. It appears that the steel bar had been left in the gap, leading to cracking of the foot adjacent to the bar.

Figure 14.4.4 – Previously installed units (NOTE: Repairs to feet.)

- **Construction detailing:** The precast supplier's drawings show the bottom of the levelling foot flush with the bottom of the unit. However, the levelling feet on the units delivered to site were approximately 15mm above the bottom of the unit. This was a deviation from the drawings.
- **Checking:** The check certificate for unit stability prohibited the use of shims under the stabilising feet. This was based on the assumption that the bottom of the feet would be flush with the bottom of the unit, whereupon the use of shims may result in the whole weight of the unit being carried on three or four shims (with the risk of failure unless designed for this).
- **Communication:** The checking engineer was not notified about the difference in levels of the foot (from that shown on the permanent works drawings).
- **Unit's shape and constructability:** The base width-to-height ratio was very high. Furthermore, they were heavy. Were the bottoms of the units flat? In practice, the requirement to produce a slab flat enough to evenly distribute load - and plumb the units without shimming - would require a very flat slab (necessitating power floating or similar).
- **RAMS:** The precast supplier's RAMS contained limited detail about the final placing of the units and how to plumb and position the units (and the appropriate tools and techniques to achieve this).

Recommendations

- The precast supplier decided that it would no longer provide units with the launder channel attached. The channel would be attached in-situ once the unit was incorporated into the parent structure. In addition, all placed units were linked together with purpose-designed steel wailings.
- The site was required to inspect/check that precast units were provided are in accordance with the design drawings.
- In addition to a temporary stability check, all precast units in their temporary condition should be checked for their 'robustness' to withstand loads that may reasonably be expected during installation (which may be different from those applied in the permanent condition).

Other issues:

- Adoption of a recessed base between shim locations may have solved the necessity for power floating, etc.
- It should be clear who is responsible for checking the overall design and structural integrity of precast units. An effective check on the proposals should, as a matter of course, consider these elements.
- There should be early and continuing interaction between all participants, especially any external temporary works designers.

15. Useful publications

NOTE: The reader should ensure that refer to the latest edition of these references.

British Standards Institution (https://shop.bsigroup.com)

1) BS EN 13369:2013, Common rules for precast concrete products
2) BS EN 13670:2009, Execution of concrete structures
3) BS 5975, Code of practice for temporary works procedures and the permissible stress design of falsework
4) BS 8297:2017, Design, manufacture and installation of architectural precast concrete cladding. Code of practice

The Concrete Centre (https://www.concretecentre.com)

5) Precast concrete in civil engineering

   www.concretecentre.com/Publications-Software/Publications/Precast-Concrete-in-Civil-Engineering.aspx

6) Precast concrete in buildings

   www.concretecentre.com/Publications-Software/Publications/Precast-Concrete-in-Buildings.aspx

5) Design of hybrid concrete buildings

   https://www.concretecentre.com/Publications-Software/Publications/Design-of-Hybrid-Concrete-Buildings.aspx

The Concrete Society (http://www.concrete.org.uk/)

6) Precast concrete arch structures – State of the art report

   www.concretebookshop.com/precast-concrete-arch-structures---state-of-the-art-report-1533-p.asp

7) Seminar Technical Report 69, Repair of concrete structures with reference to BS EN 1504

www.concrete.org.uk/events.asp?cmd=moreinfo&ID=2250

Steel Construction Institute (https://steel-sci.com/)

8) Precast concrete decks for composite highway bridges (P316)

https://portal.steel-sci.com/shop.html

9) Precast concrete floors in steel framed buildings (P351)

Precast Flooring Federation (https://www.precastfloors.info/)

10) Code of practice for the safe installation of precast concrete flooring and associated components

www.precastfloors.info/pff/Publications/Code-of-Practice-Safe-Installation.aspx

11) British Precast Architectural and Structural Code of Practice for 'The safe installation of architectural and structural precast concrete'

Publication pending

Prestressed Concrete Association

12) Technical Advice Note: Handling of bridge beams on site

Available at: Temporary Works Forum: www.twforum.org.uk

Structural-Safety (https://www.structural-safety.org/)

13) Structural-Safety incorporating CROSS and SCOSS

Publications: https://www.structural-safety.org/publications/

Fédération Internationale du Béton (fib) https://www.fib-international.org/

14) Planning and design handbook on precast building structures

Bulletin No. 74, Planning and design handbook on precast building structures

Manual/Textbook (313 pages, ISBN 978-2-88394-114-4, September 2014)

Wiley-Blackwell

15) Multi-storey precast concrete framed structures

Kim Elliott and Colin Jolly, 2nd Edition, January 2014, Wiley-Blackwell, 760pp

Chapter 10, Site practice and temporary stability

16. Management tools: RACI matrix (Theory and examples)

16.1 Understanding a 'responsibility assignment matrix' (RACI matrix)

16.1.1 A 'responsibility assignment matrix' - also known as RACI matrix - describes the participation by various roles in completing tasks or deliverables for a project or business process. 'RACI' is an acronym derived from the four key responsibilities most typically used: **Responsible**, **Accountable**, **Consulted** and **Informed**.

Figure 16.1

	Construction Stage									
Topic	Concept	Tender	Design (Permanent works)	Design (Temporary works)	Planning / Programme	Manufacturing	Transport	Storage	Lifting in place	Construction
Procurement	•	•			•	•				
Precast vs in-situ	•	•	•							
Project requirements	•	•	•	•	•	•	•	•	•	•
Design intent	•	•	•	•						
Design coordination	•	•	•	•					•	•
Responsibilities	•	•	•	•	•	•	•	•	•	•
Roles	•	•	•	•	•	•	•	•	•	•
Quality	•	•			•	•	•	•	•	•
ITP						•	•	•	•	•
Lifting points			•	•		•	•	•	•	•
Cranes		•	•	•		•	•	•	•	•
Transport	•	•			•		•			
Storage		•			•			•		
Turning	•	•	•	•	•	•	•		•	
Erection	•	•	•	•	•	•			•	•
Temporary stability	•	•	•	•	•	•	•	•	•	•
Propping	•	•	•	•	•	•		•	•	•
Founding / shimming	•	•	•	•						•
Grouting	•	•	•	•						•
Stitching	•	•	•	•	•					•
Pre-stress	•	•	•	•	•	•	•	•	•	•

16.1.2 The matrix (see **Figure 16.1**) shows the interdependence of the topics that need to be addressed when managing precast activities against the construction stages. The matrix is not intended to be exhaustive, but illustrates how a single topic may be important across several construction stages. The matrix should be adopted to reflect those issues important to each specific project. Serious consideration should be given to engaging an external temporary works design specialist.

16.1.3 The matrix is useful but does not define the roles that individual organizations or individuals should perform. It is now common for a number of sub-contractors to be used. This introduces many interfaces that need to be coordinated. Often, a small omission or misunderstanding can have large repercussions; with subsequent delays and/or increased cost to complete the works. Accordingly, there is benefit in using a RACI analysis at each of the construction stages.

16.1.4 Delegation is an essential part of a project manager's role, so identifying roles and responsibilities early in a project is important. Applying the RACI model can help. From the outset, it is important that a project manager sets out the expectations of those involved in their project.

16.1.5 Projects require the involvement of many, but should avoid situations where those involved struggle against one another to complete a task. Equally difficult is dealing with a situation where no one will take ownership and make a decision.

16.1.6 The RACI model is a straightforward tool used for identifying roles and responsibilities during a project and avoiding confusion over these. Levels of responsibility are set out. It should be clear when to involve the project manager, or when personal judgment can be exercised.

16.1.7 The acronym 'RACI' stands for:

- **Responsible:**

  Define the person(s) who undertake the work to achieve a task. They are responsible for getting the work done or, for example, making a decision. As a rule, this is one person (Examples include: a business analyst, an application developer or a technical architect).

- **Accountable:**

  This is the person who is accountable for the correct and thorough completion of the task. This must be one person and is often the project executive or project sponsor. This is the person that those responsible are accountable to (and who approve their work).

- **Consulted:**

  These are the people who provide information for the project and with whom there is two-way communication. There are usually several people, often subject matter experts.

- **Informed:**

  These are the people to keep informed of progress and with whom there is one-way communication. They are affected by the outcome of the tasks, so need to be kept up-to-date.

16.1.8 Without clearly defined roles and responsibilities, it is easy for projects to run into trouble. When staff know what their management expects of them it is easier for them to complete their work on time, within budget and to the right quality.

16.1.9 A RACI matrix can be used to discuss, agree and communicate roles and responsibilities.

16.2 Creating a RACI matrix

16.2.1 The following step-by-step process can be used to create a RACI matrix (see **Figure 16.2**):

1. Identify all the **tasks** involved in delivering the project (and list them down the left-hand side in order of completion).
2. Identify all the **project roles** (and list them along the top of the chart).
3. Complete the cells of the chart identifying who has the responsibility, the accountability and who will be consulted and informed for each task.
4. Ensure that every task has a 'responsible' role and an 'accountable' role.
5. No tasks should have more than one role accountable. Resolve any conflicts where there is more than one for a particular task.
6. Share, discuss and agree on the RACI matrix with stakeholders before a project starts.

Figure 16.2

Step	**Tasks**	**Project roles**				
		Project executive	Project manager	Business analyst	Technical architect	Application developers
1	Task 1	C	A/R	C	I	I
2	Task 2	A	I	R	C	I
3	Task 3	A	I	R	C	I
4	Task 4	C	A	I	R	I

Key:

R: Responsibility

A: Accountability

C: Consulted

I: Informed

16.3 Example

16.3.1 The following example shows how to create a RACI matrix for one of the construction stages, assuming the following:

- A contract has been awarded and a Principal Contractor (PC) appointed;
- The PC undertakes an engineering study to identify the pros and cons of replacing in-situ items with precast concrete elements;
- The PC has contacted a potential precast manufacturer for technical, cost and schedule advice;
- The PC has already let a contract to a sub-contractor for the construction of the main concrete works;
- The precast elements will be designed by the PC and its subcontractors;
- The design responsibility for the precast elements during manufacture and installation remains with the PC and its sub-contractors,
- The client will have the Principal Designer (PD) and Permanent Works Designer (PWD) review the PCs design and adopt the design responsibility and professional indemnity for the precast elements once incorporated in the permanent works.

16.3.2 Develop a RACI matrix for the precast concept (structural design). Lifting should be considered in so far as rigging will dictate the magnitude and direction of applied loads to the precast element.

16.3.3 From **Figure 16.1**, identify the topics associated with the ‘concept’ stage. These headings act as an aide-memoire of what needs to be considered. Identify the major materials and design issues:

- Precast vs in-situ study;
- Materials specification;
- Finish specification;
- Build tolerance;
- Structural strength and stiffness design;
- Lifting design;
- Lifting points;
- Permanent fixings.

16.3.4 Some of these items need to be broken down into finer detail to reveal the appropriate level of responsibility needed through the lifetime of the construction phases, e.g.:

- Structural and stiffness design:
- Demoulding;
- Curing and storage;
- Loading on and off road transport;
- Site handling and storage;
- Handing and delivery into position;
- Temporary works support condition;
- Permanent support condition.

16.3.5 Thus, the RACI matrix starts to develop (see **Figure 16.3**):

Figure 16.3

Topics to be considered	Concept	
	Heading	**Sub-heading**
Procurement	Precast versus insitu study	
Precast vs in-situ	Materials specification	
Project requirements	Finish specification	
Design intent	Build tolerance	
Design coordination	Structural and stiffness design	Demoulding
Responsibilities		Curing and storage
Roles		Loading on/off road transport
Quality		Site handling and storage
Transport		Handling and lift into position
Turning		Temporary works support conditions
Erection		Permanent support condition
Temporary stability	Lifting design	Demoulding
Propping		Curing and storage
Founding / shimming		Loading on/off road transport
Grouting		Site handling and storage
Stitching		Handling and lift into position
Pre-stress		Temporary works support conditions
	Lifting points	
	Permanent fixings	

16.3.6 Additional columns can be added to represent the various companies or parties that may be involved in the completion of the concept study. For example:

- Clients Technical Team;
- PC Engineering Manager;
- PWD (either the Client's, PC's or Sub-contractor);
- TWD (either the Client's, PC's or Sub-contractor);
- TWC;
- Precast Fabricator;
- Transport sub-contractor;
- Crane sub-contractor;
- Installation sub-contractor;
- Concrete sub-contractor.

16.3.7 Thus, the RACI matrix continues to develop (see **Figure 16.4**):

Figure 16.4

Topics to be considered	**Concept**		**Client's techncial team**	**PC Engineering Manager**	**PWD (Either Client's, PC or Sub-contartor Organisation)**	**TWD (Either Client's, PC or Sub-contartor Organisation)**	**TWC**	**Precast Fabricator**	**Transport Sub-ciontrac tor**	**Crane Sub-ciontractor**	**Installation Sub-contractor**
	Heading	**Sub-heading**									
Procurement	Precast versus insitu study										
Precast vs in-situ	Materials specification										
Project requirements	Finish specification										
Design intent	Build tolerance										
Design coordination	Structural and stiffness design	Demoulding									
Responsibilities		Curing and storage									
Roles		Loading on/off road transport									
Quality		Site handling and storage									
Transport		Handling and lift into position									
Turning		Temporary works support conditions									
Erection		Permanent support condition									
Temporary stability	Lifting design	Demoulding									
Propping		Curing and storage									
Founding / shimming		Loading on/off road transport									
Grouting		Site handling and storage									
Stitching		Handling and lift into position									
Pre-stress		Temporary works support conditions									
	Lifting points										
	Permanent fixings										

Precast vs in-situ

16.3.8 The precast study is 'owned' by the PC and their technical team so they are *accountable* (and represented by '**A**').

NOTE: There should only ever be one accountable person. If two or more different people are accountable, then break down the task onto smaller elements where only one accountable person remains.

16.3.9 The PC engages a design consultant to perform the engineering and produce a design. This party is *responsible* for the design (and represented by '**R**'). Specifically, the responsible person for the study is the PC's TWD (which is an in-house engineering service).

NOTE: Not illustrated in this example, the responsible person may also the accountable person - so 'A/R' would be used.

16.3.10 The client's technical team will need to know what is being proposed and have their input. Therefore, they should be classified as people who need to be *consulted* (and are represented by '**C**').

16.3.11 As the major structural works sub-contractor is on board they will also be consulted - as will the precast fabricator. The TWD is highly likely to be involved and so is the TWC.

16.3.12 Others who may be informed might include the transport sub-contractor, the crane sub-contractor.

NOTE: The size of the precast elements and their weight are well within both the known transport capacity and cranage lifting capacity already on site. This may not always be the case.

16.3.13 The RACI matrix continues to develop (see **Figure 16.5**):

Figure 16.5

Topics to be considered	Concept		Client's techncial team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
Procurement	Precast versus insitu study		I	A	C	R	C	C	I	I		C

Material and finish specification

16.3.14 In this example, the client has been clear that the material and finish specification may not change from the original in-situ solution, so the PC's team is informed and not consulted (See **Figure 16.6**).

Figure 16.6

Topics to be considered	Concept		Client's techncial team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
Precast vs in-situ	Materials specification		A	I	R	I	I	I				I
Project requirements	Finish specification		A	I	R	I	I	I				I

Build tolerance

16.3.15 The PC wishes to demonstrate that they will meet the original specification so the RACI designation is with their team and keeping the client's team informed. The coding reflects how the PC delivers this message to the client (see **Figure 16.7**).

Figure 16.7

Topics to be considered	Concept		Client's techncial team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
Design intent	Build tolerance		C	A	R	C	I	I				C

Structural and stiffness design

16.3.16 The designers need to consider all the load cases that the precast element is subjected to; from demoulding to working as part of the whole structure in service.

16.3.17 The precast fabricator has been given the contractual responsibility to undertake sufficient design that the precast element will be sufficiently strong to withstand all the load conditions that it is subjected to up to delivery at the site gate. Road transport was included in their package.

16.3.18 Once on site, the PC takes responsibility, using its in-house temporary works design team, to design the element to resist the loadings from road transport unloading, moving the units into and out of storage, lifting them into position with a assistance of temporary works and fixing them to the structural substructure.

16.3.19 The precast elements' final design condition is to be adopted by the client's PWD. Thus, the hence RACI matrix develops (see **Figure 16.8**).

Figure 16.8

Topics to be considered	Concept		Client's technical team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
Design coordination	Structural and stiffness design	Demoulding	I	I	I	R	I	A				
Responsibilities		Curing and storage	I	I	I	R	I	A				
Roles		Loading on/off road transport	I	I	I	R	I	A	C	C		
Quality		Site handling and storage	I	A	I	R	C	I		C	C	C
Transport		Handling and lift into position	I	A	I	R	C	I		R	C	C
Turning		Temporary works support conditions	I	A	I	R	C	I			C	C
Erection		Permanent support condition	A	I	R	I	I	I			C	C

Lift design

16.3.20 In this example, lift design is limited to the lift geometry at each of the stages in the precast element's life time. The required output is the location of the forces applied to the element and the vector of that force (which can be defined by tension, shear in specified directions at the anchor point). This data is part of the input for the structural design in Figure 16.8 and is shown to illustrate how inter-dependant tasks can be (see **Figure 16.9**).

Figure 16.9

Topics to be considered	**Concept**		**Client's techncial team**	**PC Engineering Manager**	**PWD (Either Client's, PC or Sub-contartor Organisation)**	**TWD (Either Client's, PC or Sub-contartor Organisation)**	**TWC**	**Precast Fabricator**	**Transport Sub-ciontrac tor**	**Crane Sub-ciontractor**	**Installation Sub-contractor**	**Concrete Sub-contractor**
	Heading	**Sub-heading**										
Temporary stability	Lifting design	Demoulding	I	I	I	R	I	A				
Propping		Curing and storage	I	I	I	R	I	A				
Founding / shimming		Loading on/off road transport	I	I	I	R	I	A	I			
Grouting		Site handling and storage	I	A	I	R	C	C		C		C
Stitching		Handling and lift into position	I	A		R	C	C		C	C	C
Pre-stress		Temporary works support conditions	I	A		R	C	C			C	C
		Permanent support condition	A	I	R	I	I	I				I

Lifting points

16.3.21 The lifting point design concerns the cast in elements used by the fabricator at all stages up to the units arriving at the site gate.

16.3.22 The way that units are off-loaded, moved, stored, lifted into position (with the possible use of temporary works) and the final fixing to the substructure may require the installation of additional cast-in fixings when the units are cast.

16.3.23 The PC has audited that the precast fabricator and found that they have the technical skill to design all types of cast-in fixing and has therefore sub-contracted all lifting point design to them.

16.3.24 Consultation takes place with the PWD, TWC and the PC's Engineering Manager. The client, the transport sub-contractor, installation sub-contractor and the concrete sub-contractor are all informed of what has been provided (see **Figure 16.10**).

Figure 16.10

Topics to be considered	Concept		Client's techncial team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
	Lifting points		I	C	C	R	C	A	I	I	I	I

Permanent fixings

16.3.25 In this example, the final step is to consider the permanent fixings attaching the precast units to the concrete substructure. Responsibility for the fixings may have been the PC's but the client's PWD adopts the design and the client is therefore accountable in-so-far as they should use competent people and organisations in the procurement of their a building (which is fit for purpose and complies with the CDM Regulations). See **Figure 16.11**.

Conclusion

16.3.26 There is much variety in the application of precast in the construction industry. It is strongly recommended that readers prepare their own bespoke RACI analysis, using the principles set out above.

Figure 16.11

Topics to be considered	Concept		Client's techncial team	PC Engineering Manager	PWD (Either Client's, PC or Sub-contartor Organisation)	TWD (Either Client's, PC or Sub-contartor Organisation)	TWC	Precast Fabricator	Transport Sub-ciontrac tor	Crane Sub-ciontractor	Installation Sub-contractor	Concrete Sub-contractor
	Heading	**Sub-heading**										
	Permanent fixings		A	C	R	I	C				I	I

17. Management tools: Other

17.1 Procurement of precast concrete

This is a list of considerations which should be used in the procurement process. The list should not be considered exhaustive and does not cover all possible considerations. It should be used as a guide only and should be amended to suit any particular project.

Figure 17.1 – Procurement requirements

PROCUREMENT REQUIREMENTS	
NOTE: Temporary works and permanent works both require the same level of consideration.	
Bespoke elements	Could self-delivery be an option? (Possible if the number of elements is small and if there are not too many variables.)
	Is there multiple choice for potential suppliers or do the installation requirements limit the options?
Programme requirements	Is the programme constrained by precast concrete installation?
	Is the production a single linear output or periodic batches?
	Is the supply a critical path activity?
	Can supplier output match the programme requirements?
Production quality	Does the supplier hold ISO9001 accreditation? Consider an audit or surveillance of current quality process.
	If there other QMS in place? Consider desktop audit.
	Consider pre-order placement production facility visit.
Performance form and finish	Are there any unusual finish requirements?
	Are all units standard or multiple variants?
	Are they any special requirements like cast-in elements or openings, etc.?
	It is a water retaining structure?
	Is it a single or multi-stage casting?
	Are samples or test pieces required?
	Are there any project-specific standards or performance requirements?
	Are there any pre-stress or post tensioning requirements?
	Are there any special architectural requirements, e.g. consistency, colour, blemishes, etc.?
	Consider initial production approval.
	Establish supplier technical capability.
	Review suppliers' previous works
Materials	
Concrete	Is concrete supplier QSRMC registered? (If not, are higher levels of surveillance required?)
	Consider any additional level(s) of management production control required to meet contract assurance requirements.
	Can the supplier's facility meet the requirements of BS EN 206 and BS 8500? (If not consider audit records and production continuous surveillance.)
	Are there any requirements for long lead time?
Rebar	Is rebar supplied under CARES Quality Management System mark?
Formwork	Is the formwork production to be supplied/made by the supplier (in-house) or is this sub-contracted?
Production	Is any production plant able to meet the demand?
	Is there an option for multiple production facilities?
	Is there sufficient technical competence?
	Is there a requirement for any unusual sampling, testing, records or control measures?
	Is the workforce sufficiently skilled in depth?

17.2 Design requirements

This is a list of issues which should be used when considering any design requirements.
The list should not be considered exhaustive and does not cover all possible considerations.
It should be used as a guide only and should be amended to suit any particular project.

Figure 17.2 – Design requirements

DESIGN REQUIREMENTS		
Precast unit foundation - concrete	Plan, levels, cross falls	Survey after foundation construction
	Depth, reinforcement details	
	Shims	Shims: Technical specification (compressive strength, coefficient of friction, etc.)
	Grouting	Grout technical specification (compressive strength, minimum thickness, etc.)
		Required strength prior to unit's installation
		Cube crushing tests
		Access for grouting, grout flow
		Removal of grout formwork
	Propping	Allowance for installation tolerance
		Detailed sequence for installation and removal
		Robustness / redundancy (especially in cases with public interface)
		Fixings to precast unit – precast or post-drilled?
		Fixings to foundation – precast or post-drilled?
		Load test for fixings (pull out)
		Approval of fixings to permanent structures (permanent works designer)
		Accidental load - impact load (by site vehicle, by public vehicle, by lifted another precast unit, etc.)
	Concrete strength required for precast unit's installation	Cube crushing tests, etc.
		Assessment based on temporary support arrangement (shims, grout, props, etc.)
	Assessment and approval for any load/support arrangement and concrete strength different from shown on design drawings	Permanent structure: PWD
		Temporary structure: TWD
Precast unit foundation - steel beams	Levels, cross falls	
	Detailed sections, elevations, etc.	
	Minimum required bearing lengths	Temporary restraints to ensure bearing length
	Assessment of stability of steel beams (bridge beams, etc.)	Current loading
		Current restraints (braces, etc.)
		Fixings
		Detailed installation sequence - load paths through a partially completed structure usually differ from those in a completed structure

Figure 17.2 – Design requirements – *continued*

Jacking	Locations of jacks	
	Assessment of structures for jacking loads	
	Detailed sequence of jacking/de-jacking	
	Redundancy in jack capacity/stroke	
In-situ stitch	Stitch links/starter bars – size, dimensions, centres	Survey to avoid clashes with precast unit starter bars
	Required concrete strength for removal of temporary props, etc.	Confirmed by PW Designer
Loads	Wind	Level of foundation
		Details of terrain
	Permanent elements attached to precast units	Traffic barriers, etc.
	Temporary elements attached to precast units	Handrails
		Banners, debris netting
		Formwork for stiches
	Concrete pressure (stitch, diaphragms, etc.)	Sequence of pours
		Details of pours (rate of raise, temperature, concrete group)
		Formwork details (any fixings to precast units?)
	Accidental loads	Impact load (by site vehicle, by public vehicle, by lifted another precast unit, etc.)
	Construction loads	Wheel loads, storage, access, etc.
	Soil pressure	Soil profile and properties (BH logs, trial pits, etc.)
		Ground water level
		Expected surcharge at top of soil
	Hydrostatic loads	Water level, flow
Lifting / turning	Lifting anchor loads arrangements	Vertical lift
		Diagonal lift (slings at angle), sling angle
		Transverse pull (turning)
	Assessment of precast unit for stresses due to lifting	By precast unit designer
		Required concrete strength for lifting
	Recess for lifting anchor if cannot be left exposed	Effect on lifting eyes/bolts – do they fit?
		Risk of damaging units during diagonal lift
	Additional reinforcement for diagonal lifting (slings at angle) or transverse pull (turning)	

17.3 Checklist for installing precast concrete units

This is a list of considerations for the Temporary Works Coordinator (TWC) to consider for the installation process. The list should not be considered exhaustive and does not cover all possible considerations. It should be used as a guide only and should be amended to suit any particular project.

Figure 17.3 – Installation checklist

INSTALLATION CHECKLIST		
1	Review the permanent works design and confirm all aspects of the installation within can be fully catered for on site	
2	Ensure that an experienced temporary works designer(s) has been assessed formally and deemed competent to carry out the required design works and/or checks	
3	Confirm the appropriate shimming, propping and grouting systems have been designed and checked by a competent designer(s)	
4	Confirm that the lift plans are up to date and in place	
5	Confirm all cranage platforms have been designed (and the required permits issued)	
6	Confirm any lift point being utilised on site has been independently checked by the temporary works designer (TWD)	
7	Confirm any bearing platform (whether permanent or temporary) has been designed and assessed prior to landing the respective units	
8	Review all task briefings, risk assessment and method statements (RAMS) and Inspection and Test Plan (ITPs) relevant to the operation	
9	Ensure all the necessary equipment on site being used to land and secure the precast units has is certified as fit for use	
10	Ensure the TWC is present on site when the specific operations take place or when landing and securing the precast units	
11	Observe activities on site to ensure that they are in accordance with RAMS and design drawings	
12	Conduct a temporary works debrief and provide feedback	
13	Feedback lessons learnt to peers	
14	Check and ensure safe removal of any temporary works	

18. Examples of precast concrete documentation

18.1 Inspection casting (Precast concrete supplier)

This is an example inspection casting checklist for a precast concrete supplier. The list should be used as a guide only and should be amended to suit any particular manufacturer, contract and/or project.

Figure 18.1.1 - Inspection casting (Precast concrete supplier)

Kijlstra Precast

QC1 Sheet Rev04 Page | **1**

INSPECTION CASTING

Mould Inspection Date: -...

Mould No/Name... Inspected by: -.......................................

Drawing No: -.. Mould Suits Drg YES ☐ NO ☐

Project No: - .... Damage to Mould YES ☐ NO ☐

Unit Reference: - ....

Description of Damage: -

....

....

Person that the damage was reported to: - Sign: -...

Date: -..

Casting Prep Date: -...

Correctly cleaned/oiled YES ☐ NO ☐ Inspected by: - ....

Sizes Correct YES ☐ NO ☐ Mould Level YES ☐ NO ☐

Cage Correct: -

- Bar sizes YES ☐ NO ☐
- Spacing YES ☐ NO ☐
- Stainless Tying Wire YES ☐ NO ☐
- Correct Fixings & Position YES ☐ NO ☐
- Cage installed correctly YES ☐ NO ☐
- Rebar cover correct YES ☐ NO ☐
- Correct Lifters YES ☐ NO ☐

If No, Comment: -

....

Concrete Delivery Inspection Date: -..

Inspected by: -.......................................

IF ANY OF THE FOLLOWING STATEMENTS ARE ‘NO’ THEN REPORT IMMEDIATLEY

Delivery Note Correct Mix YES ☐ NO ☐

Batched within 2hours YES ☐ NO ☐

Slump Test Acceptable YES ☐ NO ☐

Figure 18.1.2 - Inspection casting (Precast concrete supplier)

Kijlstra Precast — QC1 Sheet Rev04 Page | 2

Casting Time: -……….. Date: -……………………………………………

Conc. Delivery Ticket No: -…………… Inspected by: -……………………………………

Mould Fully Filled YES ☐ NO ☐

Self-Compacting Concrete

NOTE: - Do not over agitate, no external vibrator

Non Self-Compacting Concrete

NOTE: - Fully agitate using either a poker or external vibrator

If lifters are required in surface are they there YES ☐ NO ☐

Finish Required YES ☐ NO ☐

IF YES, SPECIFICATIONS REQUIREMENTS: -……………………………………

Mould Covered YES ☐ NO ☐

De-moulding & Final Inspection Date: -……………………………………………

De-Moulded by: -………………………………………… Inspected by: -……………………………………

Demould Time: - ………………………………………… Curing Time: - ……………………………………

STRENGTH MUST BE REACHED Rebound Hammer Reading ☐ NM

AS PER THE RELEVANT DRAWING Carried out by: -…………………………………

Damage to Casting YES ☐ NO ☐ If yes Report

Dimensioning Correct YES ☐ NO ☐ If No NCR: - ………………………

Finishing Required YES ☐ NO ☐ If yes detail below: -

………

………

Cast in items openings, additional parts as per drawing all present & correct

YES ☐ NO ☐ If no Report

Identification Attached YES ☐ NO ☐

Unit fit for delivery YES ☐ NO ☐ If No move to Quarantine & NCR

Final Loading Check Carried out YES ☐ NO ☐

Date Loaded: - ………………………………………………

REMEMBER TO TAKE A PHOTO OF **ALL** UNITS WHEN LOADED

18.2 Inspection and Test Plan (ITP)

This is an example inspection and test plan. It should be used as a guide only and should be amended to suit any particular manufacturer, contract and/or project.

Figure 18.2 - Inspection casting (Precast concrete supplier)

Inspection and Test Plan (ITP)	**Ref:**		**Issue No.**	
Project:	**Prepared by:**		**Date:**	
	Checked by:		**Date:**	

Item No.	**Operation**	**Controlling document**	**Acceptance criteria**	**Verifying document**	**Action**	
					Type	**By**
Insert Ref. No.	For examples, see **Legend 1**	For examples, see **Legend 2**	For examples, see **Legend 3**	For examples, see **Legend 4**	For examples, see **Legend 5**	Insert party

Notes:

Legend 1
Operation (Examples)
Contract receipt
Purchased product and goods inward
Production control
Mould preparation
Reinforcement cage
Preparation for casting
Concrete
Casting operations
Initial curing
Demoulding
Finishing operations
Curing and storage
Delivery

Legend 2	
Controlling document (Examples)	
BS EN	British standard
CARES	UK Certification Authority for Reinforcing Steels
D	Drawing(s)
FPC	Factory production control
P	Procedure
PO	Purchase order
QMS	Quality management system
S	Specification
SHW	Specification for highway works
TQ	Technical query
	etc.

Legend 3	
Acceptance criteria (Examples)	
A	Approval by client
BS EN	British standard
C	Calculations
M	Material certificate
	etc.

Legend 4	
Verifying document (Examples)	
IR	Inspection record
ITR	Inspection and test report
QC	Quality inspection
RFI	Request for information
TQ	Technical query
	etc.

Legend 5	
Action type (Examples)	
A1	100% actual inspection/test
A2	Random actual inspection/test
D	Submit documents
H	Hold point
N	Notification point
R1	100% review
R2	Random review
S	Surveillance
W1	100% witness
W2	Random witness
	etc.

Temporary Works forum

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Secretary: David Thomas, CEng FICE CFIOSH

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