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Concreting for improved speed and efficiency

Introduction

The European Concrete Building Project is a joint initiative aimed at improving the performance of the concrete frame industry.

The principal partners in the world's most ambitious concrete research programme are:

British Cement Association
Building Research Establishment Ltd
Construct - the Concrete Structures Group
Reinforced Concrete Council
Department of the Environment, Transport and the Regions

The programme involves the construction of a series of full-sized concrete structures in the Large Building Test Facility at Cardington, where they are being subjected to comprehensive testing of the building process and of their performance.

With support from the DETR and the Engineering and Physical Sciences Research Council, the first of these buildings, a seven-storey in-situ flat slab concrete frame, was completed in 1998. The results of investigations into all aspects of the concrete frame construction process are summarised in this series of Best Practice Guides.

These Guides are aimed at all those involved in the process of procurement, design and construction of in-situ concrete frames. They should stimulate fundamental change in this process in order to yield significant improvements in the cost, delivery time and the quality of these structures.

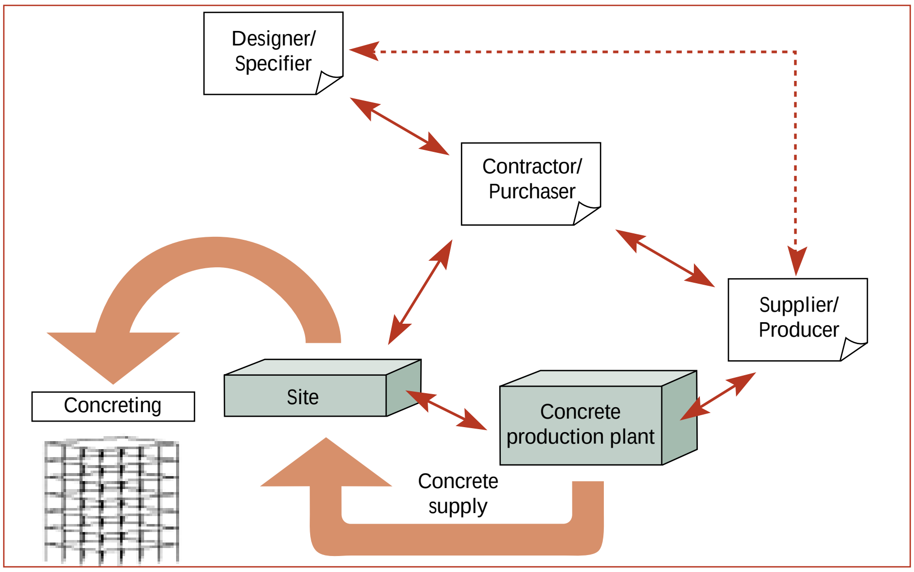

Figure 1: *Organisations and facilities involved in the concrete procurement process*

This Guide provides recommendations for improving the efficiency of the concreting process whilst maintaining quality

Key messages

Achieving optimum efficiency and quality of the concreting process on site requires consideration of:

- The concrete procurement process as a whole (Figure 1).
- Interactions between concreting and inter-related construction processes (Figure 2).
- The use of performance-based concrete specification.

Best practice

When planning the concreting process, the following aspects should be considered:

- Specified properties of hardened and fresh concrete.
- Selection of the concrete supplier.
- The method of handling / transporting the concrete on site.
- Reinforcement densities and congestion of reinforcement.
- Appropriate compaction, curing and finishing methods.
- Pour sizes and construction joints.
- Use of special concretes and innovative methods.
- Implications of interactions with other construction activities that may share resources.
- The overall construction programme.
- Appropriate communication methods.

BCA British Cement Association www.bca.org.uk
BRE www.bre.co.uk
CONSTRUCT concrete structures group www.construct.org.uk
REINFORCED CONCRETE COUNCIL www.rcc-info.org.uk
DETR Environment Transport Regions www.detr.gov.uk

Specification

Concrete specifications should be in accordance with BS 5328: 1997, *Concrete,* Parts 1 and 2 as referenced by the *National Structural Concrete Specification for Building Construction,* (NSCS, Reference 1). The specification documents should be concise and complete as given in NSCS Part 2. This enables the supplier to immediately consider the specification data without having to first interpret a new format.

Specifications should be performance-based. They should state the required properties of the hardened and fresh concrete, but should otherwise be free of unnecessary restrictions. This means that much of the responsibility for ensuring that these qualities are achieved lies with the supplier. This is appropriate, since the concrete supplier is producing concrete on a daily basis and therefore is likely to have much greater expertise relating to concrete production than any other party in the construction process. Under BS 5328, performance specified concretes are categorised as either designed or designated mixes.

The workability specified for the concrete must be appropriate for the intended placing method. The addition of water on site should be avoided wherever possible and must not be seen as a substitute for specifying the correct workability in the first place.

Where there are many separate concretes specified within a project, it may be more efficient to rationalise these by merging those with similar performance requirements. This will result in reduced risk of confusion and possibly economies of scale in batching.

Concrete specification can be made more efficient by using software tools, e.g. ConSpec (for more information see the Ready-mixed Concrete Bureau's website at www.rcb.org.uk).

Concrete supply

To achieve the most efficient concreting, potential concrete suppliers must be supplied with the concrete specification as well as additional information such as the proposed volumes, pour rates and placing method. They may request further information or may make suggestions for improvement (e.g. further rationalisation) before providing a quotation and mix design information.

When selecting a concrete supplier, the primary issue other than cost is the ability to supply at the required rate, particularly for large pours. The provision of a back-up supply should be considered by the purchaser in case the primary plant fails.

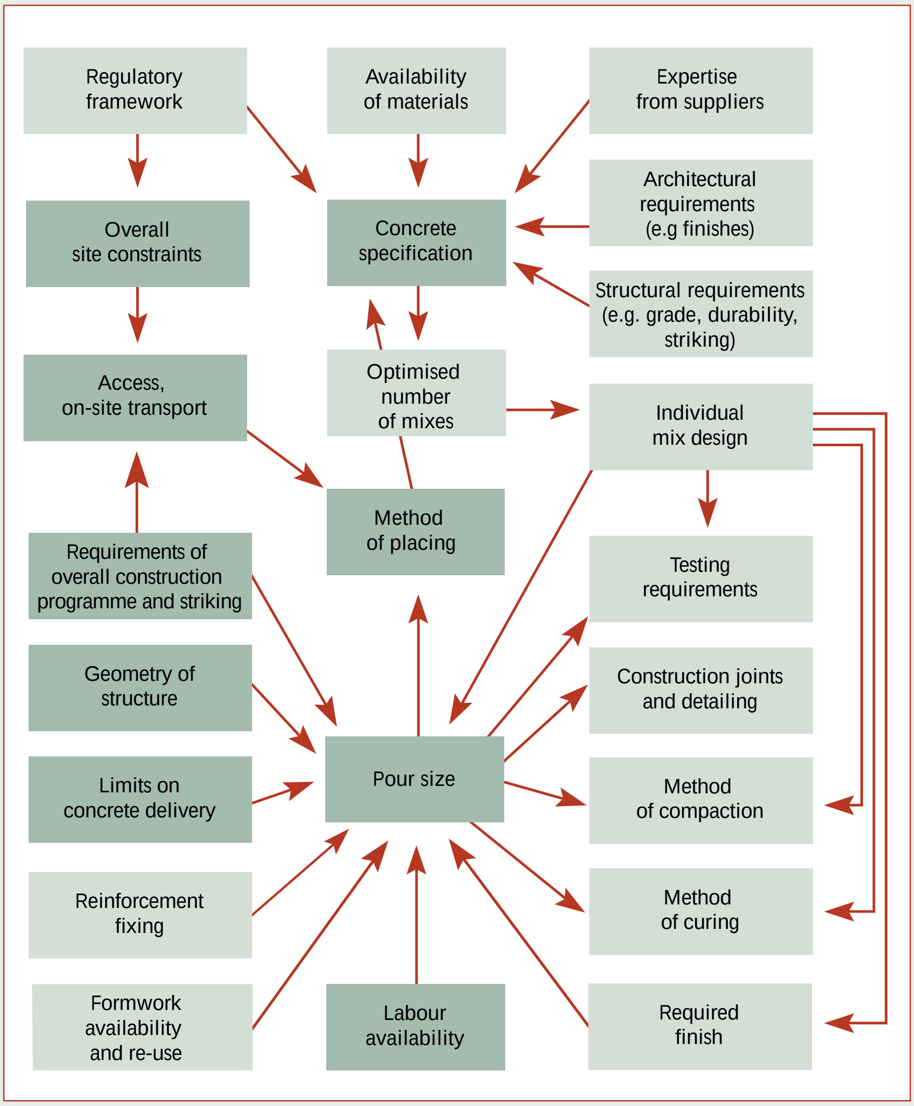

Figure 2: *Issues and interactions affecting optimisation of concreting process for in-situ concrete frames. Key influences are highlighted*

Table 1: *Influence of pour size on aspects of slab construction for the ECBP in-situ frame*

	Single pour	**Two pours on separate days**	**Four pours on separate days**
Each pour achievable within a working day	Just	Yes, easily	Yes, easily
Supporting columns required to be complete before slab pour	All	Over half	Over a quarter
Can proceed with next level of columns before slab completed	No	Yes	Yes
Columns (above) poured at same time as slab (if same specification)	No	Possible	Possible
Formwork required	Full slab area	Two-thirds of slab area	One-third of slab area
Construction joints	None	One	Three
Efficient use of pump hire	Yes	Less	Much less
Need for additional safety provisions (e.g. edge protection)	None	Some	Considerable
More even use made of site resources (plant, operatives, materials etc.)	No	Yes	Yes (closer to a continuous manufacturing process)

Handling, transporting and placing concrete on site

Access for the ready-mixed concrete truck should be provided as close as possible to the required location in the structure. It may be possible to discharge concrete directly from the truck into foundations and column bases, but for other components a means of transporting the concrete from the truck discharge point to its required location in the frame will be required.

The two methods of transporting concrete that are most applicable to multi-storey frame construction are:

1. **Pumping.** A truck-mounted (or occasionally static) concrete pump is sited at ground level with its delivery boom and/or hoses deployed so that concrete can be pumped directly to where it is required in the frame. The input hopper of the pump is topped-up from truck-mixers.
2. **By skip.** A site crane hoists a skip from ground level (where it is filled with concrete from a truck-mixer) to the required location in the frame.

A typical in-situ reinforced concrete flat-slab frame has two primary structural components: columns and slabs (with or without downstands). The volume of these components is significantly different and they are best considered separately. For example, the European Concrete Building Project frame at Cardington consists of seven flat slabs each with 20 columns. Each floor has a volume of about 165 m³, whereas the columns for each floor have an overall volume of only 9 m³.

Slab concreting

The volume of concrete required is a major factor affecting the planning of slab concreting operations. Daily pouring rates and hence slab concreting times can be determined from considering the limits on the supply, handling on site, and placing and finishing requirements. It may be possible to pour an entire slab in one day, but it could be more cost-effective to split the pour across two or more days.

Pumping is an attractive method for placing concrete in slabs, since a relatively high rate of almost continuous placing is possible. The pump can be located where two truck mixers can discharge simultaneously into its hopper, resulting in a zero changeover time. Little or no use is made of site cranes, which are therefore available to work elsewhere on the site. Breaks in placing are required only to connect or disconnect pipework as the placing front moves across the slab.

However, using a skip for slab pours should still be considered. This will make continuous use of a site crane, but if the crane would otherwise be idle during the concreting operation it would be an efficient use of this resource. The rate of placing is likely to be significantly less than that possible by pumping since the placing is not continuous. This can be alleviated by using the largest capacity skip that can be hoisted by the crane or by using additional skips. As the frame rises, the time taken to hoist the skip to the slab will increase.

Both pump and skip placing will benefit from a planned progression across the slab. In general, pumping should be started in the corner most distant from the pump and worked backwards toward it in a swathe of a convenient width, reducing the length of the pipeline as required. For skip placing, the swathes should be aligned in such a way that the most frequent movements of the crane are rotational.

Column concreting

In contrast to slab concreting, that for columns may involve small volumes of concrete. For example, at each level of the in-situ frame at Cardington, the total volume of concrete for the columns was 9 m³. There were 20 columns and seven sets of formwork available, so the concrete was supplied and placed on three separate days, each delivery being 3 m³ (i.e. half a truckload).

Overall speed of construction should be balanced against other costs. For example, these columns could have been poured on two separate days if ten sets of formwork had been available; in which case each concrete delivery would have been 4.5 m³. One or two days would possibly have been cut from the construction programme, but formwork costs would have increased. On the other hand, concrete costs might have decreased due to fewer part-load surcharges.

Pour sizes and construction joints

Ideally, each structural component of a building would be cast monolithically, but this is often not practicable. The NSCS, Part 1, Table 1 (Reference 1) suggests limits on pour sizes for walls and slabs, although these can be exceeded by agreement. In general, a pour should be achievable within a working day. Above ground level, a pour for the floor slabs of a typical frame can be over 500 m² in area and up to 30 m in any dimension (the ECBP in-situ frame was 30 m by 22.5 m or 675 m²). Construction joints are acceptable provided they do not compromise the performance of the structure. Even when the use of a construction joint is not intended, the possibility of an unexpected cessation of a pour should be planned for.

The size and number of pours for each floor slab of a multi-storey frame affects the overall progression of construction, particularly the processes related to formwork and reinforcement. For example, each slab of the ECBP in-situ frame was cast in a single day, but this major pour could have been split into two or four pours, each carried out on separate days. To determine which approach is most efficient it is necessary to consider the cost implications of the points of comparison listed in Table 1.

Compaction

Adequate compaction is essential to ensure that the concrete performs satisfactorily in the completed structure. Under-compacted concrete will have reduced strength and/or durability, and may be of unacceptable appearance. Appropriate compaction equipment must therefore be available when it is required and concrete-placing personnel should be trained to use it correctly

The poker vibrator is likely to be most appropriate compaction device for in-situ reinforced concrete frames. Beam vibrators or hand tamping can be used to compact and finish the top surfaces of slabs, but a poker vibrator will still be required to ensure that adequate compaction is achieved through the full thickness and at the edges.

Finishing

The finish required for a frame will be specified within the overall specification for the structure. It will be at least Type A for formed finishes and U1 for unformed finishes (References 1 and 2). These will generally be adequate where the concrete surfaces are to be covered by cladding or raised floors etc, as is often the case for office buildings. If the concrete surface is to be visually exposed, or is to be directly fitted with a floor covering, then a higher quality finish may be required. This should be specified in the NSCS, Part 2, *Project specification*.

Curing

Curing involves preventing the loss of moisture from the concrete after casting. This can best be achieved by protecting exposed surfaces.

It may also be desirable, or even essential, to control the temperature of the concrete to ensure that cement hydration proceeds at an acceptable rate. In winter, the ambient temperatures may be so low that it is necessary to take measures to ensure that the concrete temperature is maintained at a suitable level during the initial stages of curing. The cast concrete can be insulated against loss of heat generated by the hydration process; in addition the concrete can be supplied at an elevated temperature.

Special concretes

Ready-mixed concrete suppliers have extensive databases that will allow them to rapidly produce a mix design to meet the requirements of most in-situ frames. In some cases, however, some mix design development will be necessary. Examples include high strength and self-compacting concretes.

High strength concrete

High strength concrete is being increasingly used, particularly in highly stressed compression elements. The columns on the lower three levels of the ECBP frame were of grade C85 concrete, which permitted the same column size to be used economically over the full height of the structure. Polypropylene fibres were added to the high strength concrete columns at Cardington to reduce the potential for spalling in the event of fire.

Self-compacting concretes

Self-compacting concretes are now becoming available. They can be placed much more rapidly with savings in labour and plant costs, which will offset the higher material cost. Their use results in reduced noise on site and permits placing of concrete in circumstances which would otherwise be difficult or impossible with conventional concrete (e.g. highly congested reinforcement, pumping from below, and greater lift heights up to 10 m).

Use of such special concretes, which is not currently routine, can affect the construction process. The supplier may need to develop and test an appropriate mix design. An extended lead-time will be required for this and it will need to be built into the overall construction programme. Special arrangements may also be necessary if some of the mix constituents are not routinely stored in hoppers at the ready-mixed plant.

If the use of such special concretes is proposed, discussions with the supplier should be held as early as possible.

Early striking of formwork

To increase the speed of the construction process and reduce formwork costs, it may be desirable to strike formwork as rapidly as possible to make it available for early re-use. The NSCS states that it is the contractor's responsibility to ensure that the concrete has adequate strength to support its own weight and any construction loads without suffering short- or long-term distress. This is covered by a separate Guide in this series, *Early striking for efficient flat slab construction*. Concrete **not** required to carry its own weight should still have a compressive strength of at least 5 N/mm^2, to ensure that damage does not occur during formwork stripping.

Planning for interactions with other site operations

Concreting is but one component of a complex construction process. Many parameters affect its efficiency and these will vary between projects. Major planning decisions concerning concreting operations cannot therefore be taken without considering interactions with other processes on site. This needs to be done within the context of the specific project and with reference to the erection drawings, which may preclude some economically attractive options. Consideration must also be given to the effect of the various options on construction loadings and required concrete maturity.

Figure 2 identifies the main issues and interactions in relation to the concreting of an in-situ frame.

Communications

Communications are an important aspect of concreting, and indeed the whole construction process. Everyone should be aware of the need for information flow to be concise, complete and timely. Clear specification is the key in this process (Reference 3). All parties must have the information they require in order to play their part in placing the specified concrete in the correct location in the frame, in an appropriate manner. Information technology and document layouts that are standardised across the industry should be used more widely.

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- Improving concrete frame construction
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- Improving rebar information and supply
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