Visual Concrete

Guidance on specification of formed concrete finishes

Contents

Cover image: The Hepworth Gallery in Wakefield used pigmented self-compacting concrete (SCC) for the external walls. © VIEW.
This page: Precast concrete cladding designed to replicate the Elgin Marbles frieze at the Olympic Village, London.

Some benefits of exposed concrete finishes:

- Avoids additional finishing materials and their associated costs, waste and programme
- Optimises thermal mass effect
- Minimal long-term maintenance requirements
- Visually attractive
- Variety of available finishes, textures and colours
- Diverse shapes and forms possible
- Cost-effective
- Durable
- Non-flammable with no spread of flame
- Inert material, so no off-gassing
- Resistant to mould and insects
- Robust
- Flood resilient
- Range of construction solutions available
- Potential canvas for future finishes if desired
- Optimum material efficiency: structure providing the final finish
- Structural material often exceeds minimum fire resistance and acoustic insulation

Introduction

Concrete is once again being appreciated and used expressively. It is increasingly recognised as integral to energy efficient strategies for many building types, through the use of thermal mass together with its other inherent benefits including fire, acoustics and structural performance. The desire to optimise its benefits and express the structure internally and externally requires an understanding of the process of achieving visual concrete. Particular care is required to ensure a high quality finish, where the formwork, workmanship, curing and concrete mix design require detailed consideration. These requirements should be understood by architects, structural engineers and other members of the team to ensure a successful outcome.

THIS GUIDE AIMS TO ENABLE DESIGNERS TO REALISE THEIR ASPIRATIONS IN CONCRETE

This document provides guidance on formed finishes (achieved by casting the concrete against formwork). It will assist with the process of specification through consideration of key issues. It provides useful information on how the formed finish is affected by the concrete mix, formwork and quality of workmanship. Unformed finishes, such as the top of a floor slab, are not considered and further guidance can be found in other publications; for example, *National Structural Concrete Specification for Building Construction Edition 4* [1].

Both precast and in-situ concrete are considered in this guide. The specification routes for these two forms of concrete construction are different. For precast concrete cladding, the originator of the concrete specification is the architect with input from the structural engineer. For in-situ concrete and structural precast concrete, the originator is usually the structural engineer with a focus on the structural rather than aesthetic aspects. However, for visual concrete, there will be input from the architect by necessity and this guide is written to provide all parties with an understanding of how to produce a specification delivering the required result. It will also be useful to others involved in the project, including cost consultants and main contractors.

It should be noted that high quality visual concrete costs more to produce than a basic finish. However, these additional costs are offset by a reduction in the cost and programme for additional finishes, as well as savings in ongoing maintenance costs, and the long term benefits of thermal mass.

In-situ concrete using ggbs at City of Westminster college, shows high quality finish on the columns and formwork panel layout on the soffit.

Visual concrete

Visual concrete is designed to be visible throughout the lifetime of the building. An acceptable appearance for the concrete finish can range from a natural finish with significant variations through to a more consistent quality smooth or textured surface. The more consistent the quality of finish required, the more care is needed.

What appearance is required?

The first task is to determine what appearance is being sought. It can be a plain or textured surface, or moulded to patterns and shapes. Texture is created by working the surface of the concrete after it has been cast or by the concrete being cast against a textured surface. High quality finishes are successfully achieved in concrete, particularly in precast concrete that is worked in the factory, after being cast, to produce a more uniform surface. However, some variation in colour and texture is unavoidable and should be considered as part of the natural appearance of concrete rather than as a defect, particularly for cast in situ or structural precast concrete. Clients, contractors and designers need to understand that there are natural variations in concrete.

The focus of this guide is on how to define and achieve the desired finish and to provide information on the different types of finish available. A selection of textured finishes are illustrated in Table 1, which gives references for further guidance.

Table 1: Some techniques for achieving textured formed finishes.

Finish	Description	Further
Sand or grit blasting	Sand or grit blasting is used to remove the surface paste or matrix to expose the aggregates. Depending on the pressure and grit size used, it is possible to achieve a variety of different surface finishes from a light abrasion (sand blasting) removing just the surface laitance down to a deep removal (grit blasting) to reveal the coarse aggregates. Patterns are achievable through the use of stencils, usually carried out by specialist contractors.	Guide to off-form concrete finishes **[2]**. The art of precast concrete **[3]**. Exposed aggregate concrete finishes **[4]**.
Surface retarding	A proprietary liquid retarder is applied. The concrete in contact with the retarder is prevented from hardening in the normal way. The surface laitance can then be washed away to expose the aggregates. Patterns and images are achievable through various specialist techniques, including screen-printing the retardant.	Exposed aggregate concrete finishes **[4]**. The art of precast concrete **[3]**.
Acid etching	Acid is used to remove the surface laitance to reveal differing levels of the concrete beneath. Acid etching can be shallow, normal or deep, depending on the duration of the etching process. This is not generally used on site for health and safety reasons. Shallow acid-etched surfaces can be rubbed during the finishing process to produce a fine smooth surface.	The art of precast concrete **[3]**.
Bush hammering	A bush hammer is a mechanical tool used to shatter the surface of the concrete into small pieces. It gives a rough texture and exposes the course aggregate, which will also be fractured by the action of the tool. Panel edges are vulnerable to spalling with this method and thus plain borders are often used. This finish is possible for cast insitu work depending on the healtwwh and safety situation.	Tooled concrete finishes **[4]**. The art of precast concrete **[3]**.
Point tooling	A pointed tool is used to remove as much as 20mm of the concrete surface to leave a rough textured finish.	Tooled concrete finishes **[4]**.
Needle gun finish	The needle gun contains hardened steel rods used to remove some of the surface laitence and give a light texture to the concrete surface. The coarse aggregate will be abraded with this technique, similar to bush hammering.	Tooled concrete finishes **[4]**.
Rope finishes	Rope can be fixed to the inside of the formwork and concrete cast against it. When the rope is removed, it gives a grooved finish with the rope weave expressed.	Textured and profiled concrete finishes **[4]**. Guide to off-form concrete finishes **[2]**.
Board marking	Sawn timber boards can be used to produce a fine, shallow texture all the way through to a deeply grained timber finish. The exact finish will depend on the type of timber used, the fineness of the saw blade and how the joints between the boards are expressed. It is used for precast or in-situ work. The timber can be the formwork or laid over formwork as a form liner.	Textured and profiled concrete finishes **[4]**. Guide to off-form concrete finishes **[2]**.
Form liners	Formwork can be lined with a variety of materials to create any number of textures or patterns. The most common materials used are polystyrene, rigid plastics, fibreglass, profiled metal sheets and elastomeric materials. A large range of proprietary form liners are available, as well as bespoke designs.	Guide to off-form concrete finishes **[2]**. The art of precast concrete **[3]**.

Precast concrete

Much precast concrete is fabricated as standard components with a standard finish. Specifiers can check the quality of the proposed finish by viewing other examples; either in the factory or on another project. Some precast concrete is bespoke, and the specification of the finish is similar to that applying to precast cladding. Precast concrete cladding, also known as reconstituted stone or architectural concrete cladding, is largely bespoke, with the exception of concrete and masonry block work (which is not covered in this guide).

Specification and prelims

The specification for precast elements should be in the form of a performance specification, allowing manufacturers to provide a practical solution. Specialist precast concrete manufacturers should be consulted before the specification is completed, as precasters have a wide knowledge of possible finishes and colours and will be able to provide samples of each.

The performance specification should include manufacturing tolerances, and indicate where movement joints are acceptable. It should also allow for 'making good' the panels to an agreed quality.

Sample panels are important and should be requested in the specification. Typically these will be of sufficient size to show the proposed finish at a reasonable scale, as well as any rebates and sealants used for the joints between elements.

Design process

Specialist subcontractors will enter into a detailed design process with architects and structural engineers. This will include consideration of:

- Joint positions
- Structure type
- Loadings
- Tolerances and movements
- Interfaces with other materials and elements
- Selection of samples
- Weathering details (if required)
- Thermal insulation (if required)
- Windows (in cladding).

The location of joint positions will be determined by balancing the requirements of aesthetics, cranage and haulage. The joint positions should be considered as part of the design process and the facade composition. Each precast element needs to be able to be brought to site, normally by road, and then lifted into position by crane. The crane can either be a tower crane provided by a main contractor or a mobile crane supplied by a specialist subcontractor. The size of the element and its location on site is dependent on the capacity of the crane.

All types of concrete finishing shown in Table 1 are available in precast concrete. The most widely-used type of finish for concrete cladding is acid etching.

Precast concrete cladding used at Shoreditch Station, London.

Programme

The programme for precast concrete cladding will depend on specialist subcontractors' workload when the order is placed, but normally is a minimum of 12–20 weeks from letter of intent to start on site, including the design and manufacture periods. The site programme will depend on the number of panels; typically one team can erect 30 panels per week with dedicated use of a crane.

The programme for structural precast elements depends on whether the elements are standard or bespoke. Bespoke elements will have a similar lead-in period as cladding; standard elements will have a shorter lead-in period.

The precast company will enter into a subcontract based on, and including, design, manufacture, supply, delivery and erection.

In-situ concrete

Specification and prelims

Two standard specifications are used for concrete frames in the UK: the *National Structural Concrete Specification Edition 4* (NSCS4) **[1]** and *National Building Specification* (NBS) **[5]**. While some guidance is given here, it is not possible to provide full details of specifications for both documents as this would require project-specific context and decisions. Other specifications are used for civil engineering works such as bridges, and are not covered by this publication. However, the same care and thought is required for visual concrete in any structure.

Formed finish standards

The European Standard BS EN 13670 *Execution of Concrete Structures* **[8]** defines the standards for formed finishes. The two finishes appropriate for exposed visual concrete are 'Plain' or 'Special', depending upon the quality required. 'Ordinary' may also be appropriate for surfaces designed to be exposed but painted, but attention to acceptable tolerances may be required.

Definition of standards in NSCS4

Plain finish [1]

A 'Plain finish' should be used when the visual quality is of some importance or where it is to be painted. The formwork to produce any one surface should have the same number of previous uses. Joints between the panels can step by up to 3mm. For this finish, a trial panel is not recommended but a project example should be made from one of the first areas of concrete poured on the project.

Special finish [1]

A 'Special finish' requires careful selection of the concrete and release agent, and the use of good quality formwork. The concrete must be thoroughly compacted and all surfaces should be true with clean arrises. Only very minor inherent surface blemishes should occur, with no discolouration from the release agent or grout runs from adjacent pours. The struck surface should be of a consistent colour. Steps at formwork joints should not exceed 3mm.

Trial panel

A project specific control (trial panel) is recommended for visual concrete, but for a 'plain' finish it does not necessarily have to be a separately constructed panel. Trial panels must be full size and representative of the proposed building. It should be cast under similar conditions to the actual construction. It is best to cast a trial panel as early in the construction process as possible using the project workforce, in a location where it will be accessible for comparison with the finished works. It is important to recognise that the initial colour of the concrete when the formwork is removed is not the final colour of the hardened concrete when it has matured; therefore the trial panel should not be used to judge the concrete colour. A density of reinforcement should be used that is similar to an element in the project.

A trial panel will enable the following items to be tested:

- Concrete mix
- Quality of the formwork
- Adequacy of the falsework
- Suitability of the release agents
- Workmanship
- Concrete repair mortar.

The requirements for the trial panel should be included in the specification; for example, requesting the workforce for the project to construct the trial panel.

Viewing distance

Consideration of the viewing distance is important and needs to be specified. When the concrete can only be viewed from afar, there is little reason to strive to reach the highest quality finish; the acceptance criteria for these elements should be reduced accordingly. Unless otherwise required, the viewing distance is normally 3m.

The quality and finish of visual in-situ concrete is largely dependent on the formwork, concrete and workmanship on site. These are detailed over the following pages.

Trial panels, such as seen here, for the Angel building, London, allow for many items of specification and workmanship to be tested prior to construction.

Formwork

A wide variety of formwork is suitable for concrete construction. Experienced concrete contractors know what type of formwork to use to achieve standard concrete specifications. Where specifiers are seeking a visual concrete finish, the formwork face required should be described in the specification. Guidance should be sought from specialist formwork and falsework suppliers to understand the appropriate formwork and falsework product for the desired finish. Table 2 (page 8) outlines a variety of available formwork finishes.

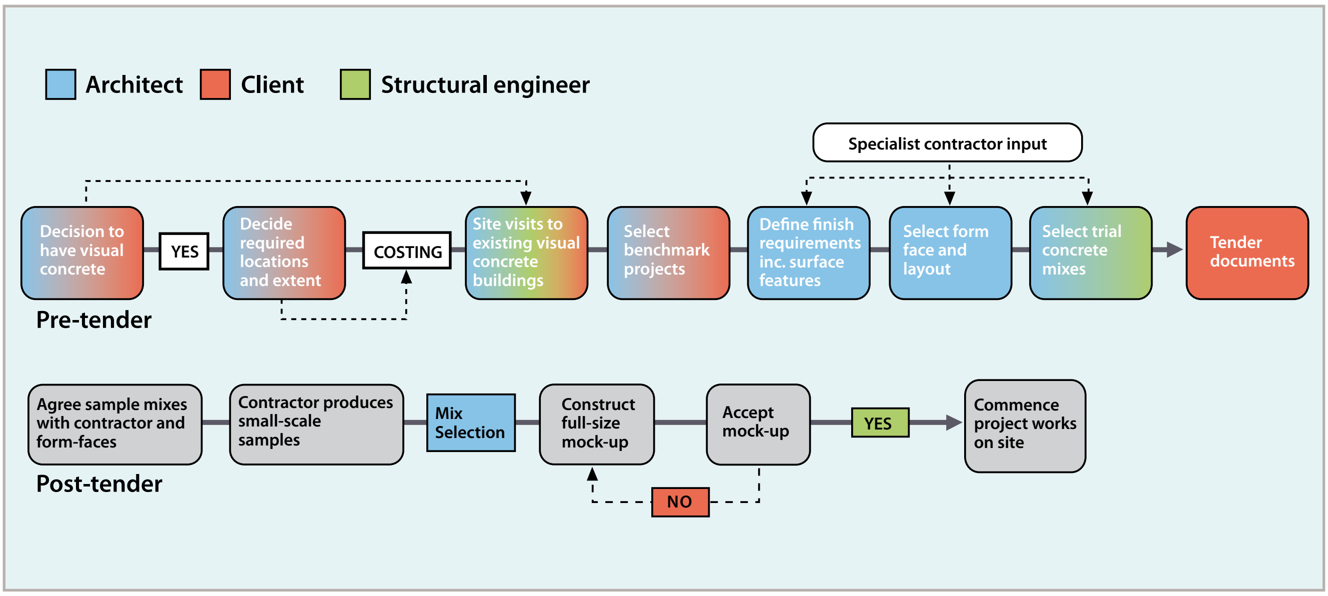
The choice of formwork will be primarily determined by the final finish requirements but other construction criteria should be taken into account; the relative importance will depend upon project particulars. These include: re-use of formwork, available repetition, shape of concrete (curved or otherwise), weight and size of panels (which will be affected by crane capacity) and access arrangements.

Panel layouts

Tie bolts and joints between individual panels will always be visible in the finished concrete. Therefore, architects should take account of this at an early design stage and produce design intent drawings of the preferred panel layout and tie bolt positions for tender. The design intent drawings will require coordination with formwork specialists to ensure buildability. Formwork sheet sizes are usually 1220mm by 2440mm (although other sizes are sometimes available, depending on the source) and the layout of the sheets should be discussed with the formwork specialist to reduce wastage and ensure cost effectiveness.

Formwork panels at One Paradise Street, Liverpool. Courtesy of DOKA.

Figure 1: Process for decision-making in the use of in-situ visual concrete.



Falsework design

Formwork is supported by falsework, the design of which is usually carried out by specialists. For visual concrete, falsework design should include an additional requirement to specifically consider deflections of both the formwork and falsework under working loads. Small movements of the formwork during casting can be noticeable in the face of the finished concrete; particularly if it results in grout loss or a ripple effect due to deflection between the falsework elements. Deflection of the formwork between supports should be minimised. The more rigid the panels and their supports, the smaller the deflection will be. Specialists will design the falsework to achieve the stated allowable tolerances in the specification.

Movements of the falsework system can lead to grout loss between the joints if not constructed correctly. The falsework should not deflect more than 1mm between tie-bolt positions or panel supports. The falsework should also have sufficient stiffness to prevent it twisting or warping when lifted by crane. Individual panels should not bow or move out of alignment.

The system should be designed so that striking can be undertaken easily and with no risk of damaging the finished face of the concrete. Particular attention should be paid to ensuring arrises and returns are not damaged when striking the formwork.

Board-marked in-situ concrete at The Collection, Lincoln.

Table 2: Selection of formwork finishes.

Finish	Description
Softwood plywood	Plywood consists of a number of plies of timber laid orthogonally to the adjacent plies and glued together. WBP grade should be used for concrete work. Softwoods are not ideal because tannins can be released, staining the concrete and they have a limited number of uses before the surface becomes unsuitable.
Natural birch plywood	Birch is a hardwood and ideal for forming visual concrete surfaces. Birch can be used throughout the plywood or as veneer to a softwood plywood. A high quality face finish should be chosen for visual concrete. Waterproofing is required and an acrylic lacquer is recommended.
Phenolic film faced (PFF) plywood	Plywood can be faced with a phenolic film to maximise the number of re-uses, hide the wood grain and defects and prevent timber staining the concrete. Phenolin is a fully cured and impervious resin hot pressed onto the face of the plywood to give a dark brown, waterproof finish to the plywood. A shiny smooth concrete finish is obtained.
Medium density over-lay (MDO)	An overlay of paper saturated in resin is used with plywood to minimise tannins released from the timber. MDO is less prone to temporary surface ripple than PFF. MDOs generally give a satin finish to the concrete, although products are available offering a matt finish.
High density overlay (HDO)	A higher resin content is used than for MDO and thus it gives a better surface finish, at a cost. Tannin migration is prevented, which makes it more suitable for situations in which the ply is in contact with the concrete for longer periods, for example slabs rather than walls. HDOs give a shiny finish to the concrete.
PFF orientated strand board (OSB)	As an alternative to PFF plywood, PFF OSB is available. OSB is an engineered timber product made from strips or strands of timber. It is orientated orthogonally and bonded with a resin.
Steel	Steel can be used to give a high quality finish and is most cost effective through multiple reuses. It is currently used for column shutters and 'tunnel-form' construction. The face of the steel must be treated with care, as any marks and imperfections will be imprinted on the concrete surface. Sand-blasting must not be used to clean the surface of the shutter, as it will pit the surface of the formwork.
Cardboard (EPS and plastic lined)	Impermeable cardboard is often used for circular column formwork. It can be used for visual concrete but tends to be difficult to strike and is disposed of after each use. However the cardboard former can be used as temporary protection to the column.
Polypropylene, plastic composite	Alternative materials are being developed, avoiding the problems of swelling, staining and water damage associated with timber-based systems. Manufacturers claim long life and a high quality finish can be achieved with the right workmanship. The provision of 'seamless' formwork may be possible in some instances.
Note: This table is for guidance only. Further information can be sought from formwork suppliers.	

Care of the formwork

The finished concrete surface will take on any imperfections in the face of the formwork and it is therefore important that care is taken of the formwork face. The following require particular attention:

- Whenever possible, formwork sheets should be used uncut. The sheets should not be drilled and, where cutting is necessary, it should be carried out in the dry using machinery that will not cause rough edges or damage the face. Cut edges should be properly sealed before assembling into the formwork.
- The formwork should be grout-tight and all joints between panels sealed appropriately to eliminate any grout loss.
- The exposed formwork face should not have any fixings through the form face (unless agreed with the architect) or come into direct contact with metal objects. When this is not possible, alternatives should be agreed with the architect and any fixings filled or coated.
- Site operatives should take care not to damage the surface by scuffing with sharp tools or implements.
- After casting, the face of the concrete formwork should be cleaned using plastic tools, wiped down with a cloth and recoated with release agent to the manufacturer's instructions.
- All formwork should be protected from rainwater damage and standing water. Prefabricated panels should not be left flat on the ground after use but stored upright and covered to prevent the top surfaces absorbing moisture and swelling.
- When handling formwork, measures should be taken to ensure no metal chains, metal carriers or abrasive tools scrape or come into contact with the formwork face or finished concrete face.

Further formwork details

The following details may also be specified:

- Surface regularity
- Maximum deflection of the formwork
- Maximum deflection of the falsework
- Maximum step between panels

Extent of acceptable blow holes. The highest quality visual concrete should have no more than 10no. 3mm diameter blow holes per m^2.

Guidance can be found in NSCS4 **[1]**.

Release agents

Release agents help prevent the concrete from binding to the formwork. The release agent must be neutral pH, non-staining and not wash off for a period of 10 days or break down over the concrete curing period. They should give a uniform finish to the surface, with no dusting or discoloration. The release agents should be used strictly in accordance with the manufacturer's instructions, correctly applied and must be compatible with admixtures in the concrete, the formwork used and any subsequent finishes (to be applied). It is recommended that this is checked with both the release agent manufacturer and the concrete producer.

PANELS SHOULD NOT BE LEFT FLAT ON THE GROUND BUT STORED UPRIGHT AND COVERED

Visual in-situ concrete, incorporating cementious binder with 34% fly ash, at the Angel Building in London.

Concrete

The concrete has a critical role to play in achieving the right finish, and should not be ignored. Specifiers should appreciate that concrete contractors have an input into the specification of concrete. *How to design concrete structures using Eurocode 2: BS 8500 for building structures* [7] states that the concrete specification passed to concrete producers will contain requirements from both designers and concrete contractors.

To achieve finishes for visual concrete, there should be a reasonably high content of cementitious binder. It is generally considered that the minimum content of cementitious binder for visual concrete is 325 to 350 kg/m^3 but some advocate an even higher cement content. Even when the structural design does not require it, specifiers may consider specifying a minimum content of cementitous binder to ensure the cost is included in any tender submissions.

Since the content of cementitious binder is higher than would be used for a typical concrete, this will result in a higher strength concrete, and the structural engineer can exploit this to minimise either the section size or reinforcement. As a guide, BS 8500 advises that a minimum content of cementitious binder of 340kg/m^3 will produce a concrete strength of about C40/50. Thus the section can be designed using 40MPa cylinder strength (or 50MPa cube strength).

The finished colour of concrete is normally the colour of the smallest particle. Pigments are very fine in order to provide the finished colour. If pigments are not present, the smallest particles – apart from water – are the cementious materials and sand and therefore these dictate the long-term colour of the concrete. When the shade of the concrete is important, specifiers should state the cement or combination providing the appropriate shade. This can only be an approximate shade as concrete is a natural material and some variation should be expected. To achieve a consistent finish, the aggregates and cements should come from a consistent source, and this requirement should be included in the specification.

It should be noted that combinations with high percentages of additions can slow down the strength gain of the concrete, and this may affect the programme. Further guidance can be found in *Specifying Sustainable Concrete* [8].

Of the methods for specifying concrete using BS 8500, three are appropriate for visual concrete. The most common is **designed concrete**, for which specifiers set out required parameters such as strength and minimum cement content, and concrete producers design the concrete to meet the specification.

Prescribed concrete may also be used, for which specifiers prescribe the exact composition and constituent materials of the concrete. Specifiers should note they will also be responsible for ensuring the concrete is suitable for its application. This method is more appropriate when special finishes are required such as exposed coloured aggregates or white concrete. Trial mixes are essential. The strength of prescribed concretes cannot be specified so this option has limited applicability.

Some concrete producers have their own **proprietary concretes**; a number of which are suitable for visual concrete (for example, self-compacting concrete or coloured concrete). In this case, the specification should state the name of the proprietary concrete and the options required if offered by producers.

Further guidance on specifying concrete to BS 8500 can be found in *How to design concrete structures to Eurocode 2: BS 8500 for building structures* [7].

Concrete constituents

Typically, the five main constituents of concrete are (with very approximate proportions):

- Fine aggregate (sand) – 25%
- Coarse aggregate – 50%
- Cementitious material (binder) – 15%
- Water – 8%
- Air – 2%

Each has a varying impact on the colour, consistence and strength.

Other constituents may include:

- Admixtures
- Pigments

Fine aggregates (sand)

Fine aggregate (sand) is granular material which passes a 4mm sieve. For visual concrete, well-graded fine aggregate with a consistent colour supplied from a single source is essential.

If the fine aggregate meeting these requirements is not already available at batching plants, specifiers will have to work with concrete producers to develop an appropriate concrete giving consistent, acceptable results.

Coarse aggregates

Coarse aggregates are those which do not pass a 4mm sieve and come in many shapes and sizes. Aggregate can be obtained by crushing rock, which gives very angular aggregates or as natural uncrushed gravels. Crushed rock has better cement/aggregate interface properties and potentially gives a higher strength concrete than more rounded aggregates. It can also be more variable. Natural uncrushed gravels are more rounded and therefore have a more consistent surface area. Their water demand varies less and therefore offers a more consistent result in the finished concrete. Natural gravels should be used when possible but this will depend on availability from local producers.

Single size, 4/10mm and single size 10/20mm aggregate should be used whenever possible, enabling a degree of control over the quantity of smaller aggregate sizes. A larger quantity can lead to a phenomenon known as aggregate bridging. If a single size aggregate is not available, a well graded 4/20mm coarse aggregate with not more than 20% passing a 10mm sieve would be acceptable, provided the grading is kept constant from one batch to the next.

Normally coarse aggregates do not significantly affect the appearance of finished concrete. However, if aggregate will be exposed using one of the methods in Table 1, careful selection of the coarse aggregate is paramount and it may have to be obtained especially for the project.

The Yellow Building, London, utilises an exposed concrete structure within the building.

Cementitious binder

The cementitious binder may be Portland cement (CEM I); or a combination of CEM I and an addition or a factory-made equivalent. The addition can be ggbs, fly ash, limestone fines or silica fume. These cements are listed in BS 8500 and some are described below.

Portland cement (CEM I)

CEM I (formerly known as Ordinary Portland Cement) is the nomenclature used in BS 8500 for pure Portland cement. All cement contains CEM I; whereas other cementitious materials are often considered to be replacements for CEM I and are known as additions. As cement plants throughout the UK use locally available raw materials, each batch has slightly different compositions and thus potential for small colour variations. To ensure consistent colour of concrete throughout the project, cement from a single source should be specified.

Ground granulated blastfurnace slag (ggbs)

Ground granulated blastfurnace slag is a by-product of the steel-making process. It is off-white in colour which, when used to replace a portion of the CEM I as cementitious material, results in a pale grey concrete. When concrete containing ggbs is first struck, it may have a blue-green tint to the surface, which fades as a result of exposure to oxygen and usually disappears.

Fly ash (fa)

Fly ash is a by-product from coal burning power plants. It is dark grey in colour, and the shade will vary according to the source of coal being burned and combustion conditions in the furnace. Variations between batches should be minimised to ensure a consistent colour.

White cement

White cement is produced by carefully selecting the raw materials, burning fuels that will not contaminate the cement in the production process and operating a higher temperature in the kiln. The colour may vary from supplier to supplier; thus sourcing from one producer is advisable.

Water

Water is an essential constituent in concrete, as it is required for the hydraulic reaction with cement to form the hardened mass that is concrete. The amount of water used, as indicated by the water/cement ratio, influences the strength and durability including weathering of concrete. It also has an effect on the final colour achieved. It is advisable to keep the water/cement ratio at or below 0.5 and use admixtures to increase workability. Consistency of the water/cement ratio between batches is essential to provide continuity of colour.

Superplasticisers

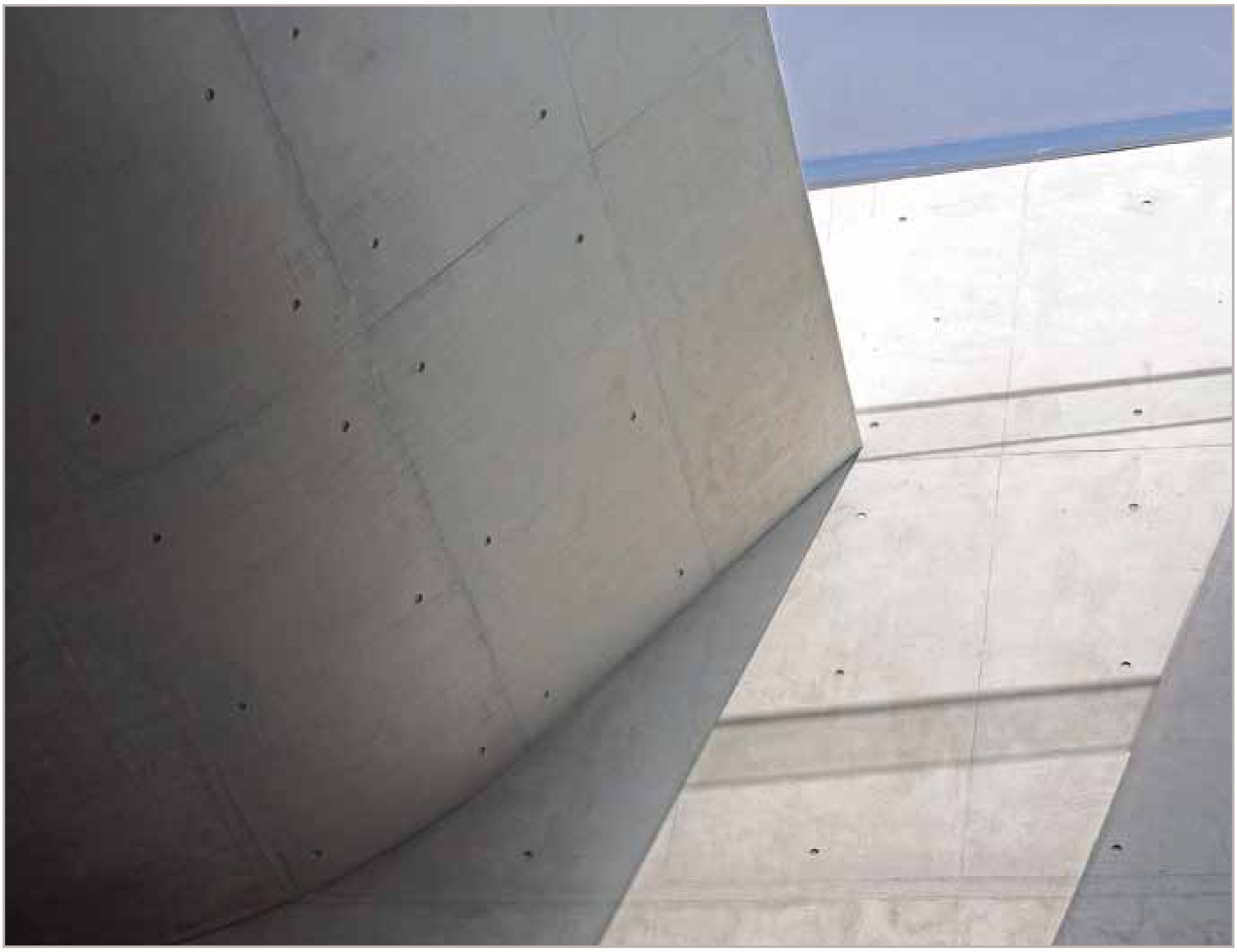
To achieve an appropriate consistence (workability) of concrete for the chosen method of placement, water-reducing admixtures or superplasticisers may be used. An S3 slump class is normally selected but a higher slump class may be required when placing by pump. This will make it easier to place and compact the concrete and therefore contribute to improving the quality of the finish.

Coloured concrete

Coloured concrete is achieved by adding pigments at batching plants. Trial mixes should be produced to assess and refine the mix until the required properties are achieved. Ranges of proprietary coloured concretes are also available to specifiers and offer consistent colours.

Self-compacting concrete (SCC)

Self-compacting concrete offers the advantage of removing the compaction operation. However, SCC is not a panacea for the perfect finish and requires a special combination of materials sensitive to small variations. Just as much care is needed in specifying, preparing for and using SCC as with normal concrete. When all aspects are correct, the finish is very good. However, not all ready-mixed concrete plants are suitable for producing self-compacting concrete. Trials must be carried out to produce the desired appearance.



East Ham Civic Centre used a concrete mix of C40 and C60 with 50% ground granulated blast furnace slag, limestone fines and omya filler was specified to give light tonal finishes. © VIEW.

Concrete production

Production of concrete with a consistent colour requires suitably equipped concrete plants and care from concrete producers. There are two types of concrete plant: wet batch or dry/semi-dry batch. In a wet batch plant, concrete is mixed before being discharged to the concrete delivery truck. In a dry/semi-dry batch plant, all the dry constituent materials are discharged into concrete trucks in a set order along with the mixing water/admixtures. Final mixing takes place in the trucks. For visual concrete, it is preferable to use a wet batch plant because the concrete produced is more consistent. If there is no option but to use concrete from a dry/semi-dry batch plant, extra measures should be put into place to ensure concrete is thoroughly mixed before being discharged.

Good practice requires aggregates to be stored in separate bins which should be covered to limit variation of the water content of aggregates; it is then easier to control the water/cement ratio during concrete mixing.

Cleanliness is essential in the production and delivery of visual concrete. Batching plants and concrete delivery trucks should be clean to avoid cross-contamination from other concretes. It is therefore advisable for visual concrete to be produced as the first batches of the day, as the concrete plant is cleaned each evening.

Cost

Cost is a key driver on every project. The use of local materials will result in a cheaper concrete than one using imported material, as will one that uses materials already at the batching plant. When the specification requires concrete producers to make special provisions for concrete, costs are likely to rise. Any constituent material not already in stock will have to be brought in and stored separately. When specifiers have very specific requirements (for example, white concrete), dialogue is recommended with concrete producers before finalising the specification as other options (for example, very pale concrete) may be acceptable at a considerably lower cost.

Third-party accreditation

Third-party accreditation for quality and performance is recommended for all concrete. The concrete should be obtained from QSRMC or BSI approved plants.

FOR VISUAL CONCRETE, IT IS PREFERABLE TO USE A WET BATCH PLANT BECAUSE THE CONCRETE PRODUCED IS MORE CONSISTENT

Workmanship

Reinforcement

Structural engineers should ensure elements are sized so as not to rely on heavy reinforcement. Reinforcement congestion makes it more difficult to place and compact concrete and will, therefore, increase the risk of surface blemishes and defects.

Care should be taken to avoid rust staining from the reinforcement. This can happen when the exposed reinforcement has become rusty and rain washes over the reinforcement and onto the finished concrete surface and formwork and hence onto the finished concrete surface. It may also occur when the exposed reinforcement within the concrete pour has become rusty and contamination is carried to the face of the concrete in placing the concrete. The best way to avoid this problem is to order the reinforcement on a 'just-in-time' basis so it remains relatively rust free. Alternatively, epoxy coating of bars or using galvanised or stainless steel bars could be considered.

Spacers

To ensure there is sufficient cover to the reinforcement, 'spacers' are used to hold the reinforcement away from the formwork.

A wide variety are available and, generally, contractors will determine which spacers to use to suit their preferences. Some spacers are inappropriate for visual concrete and the selection of spacers should consider the colour, positioning and type. Specifiers may want to state the type of spacer or require concrete contractors to submit proposals for spacers before incorporating them into the works.

All spacers should be placed in accordance with BS 7973-2 [9] to ensure they are sufficiently robust to maintain the specified cover; particularly when heavy, large diameter bars are used. The specification may require arrangement in an irregular fashion, in case they are visible. The spacers should not cause segregation of the concrete.

Institution of Structural Engineers HQ, London. Board marked wall, cast insitu in self compacting concrete with fly ash. Precast white concrete treads.

Concreting

Good workmanship is essential to achieve a quality concrete finish. The workforce should understand what is required and its importance. The techniques described below should be used for all structural concrete but are particularly important when placing visual concrete.

Prepare equipment

All tools should be clean before use. All concrete handling equipment such as concrete skips, chutes and pumps should be prepared before use.

Placing and compaction

As concrete is placed, air is entrapped in the mix. Unless using SCC, this air should be removed through compacting the concrete. This is usually carried out with a vibrating poker. A high frequency, constant amplitude electronic internal vibrating poker should be used for visual concrete. The poker should be the appropriate size for the element and fitted with a rubber cone to prevent damage to the formwork.

For **vertical elements**, the concrete should be placed into position in layers not more than 500mm deep along the full length of the section. If the layers are any deeper, it restricts air from escaping during compaction. The concrete should be placed where it is required and not moved by means of the vibrating poker. The poker should be immersed in the concrete sufficiently long to ensure full compaction and withdrawn slowly to avoid trapping air against the formwork. Placing of concrete should not be less than 2-3m/hour. The formwork should therefore be designed to take the full height hydrostatic load. The top 600mm of vertical elements should be re-vibrated 1-2 hours after placement.

For **horizontal elements** the concrete should be placed by pump or skip in a systematic way. A continuous and uninterrupted supply of concrete will ensure cold joints do not occur. For thin horizontal layers of concrete such as floor slabs, the internal poker vibrator should be inserted at a slight angle and drawn horizontally through the concrete. The position of day work joints and construction joints should be agreed.

Curing

During curing, a spray applied curing compound or plastic sheets may be necessary. Curing compounds should be specified as non-staining. Plastic sheets, if used should be held 15 to 20mm away from the face of concrete to ensure that they do not touch the concrete as this can cause different curing conditions locally and hence a variation in colour.

Concrete repairs and 'making good'

Ideally, there should be no need to repair defects or 'make good' blemishes and imperfections. There is a danger that attempting repairs may make the appearance worse. Often it is best to leave any minor blemishes and imperfections untouched. They should be considered as normal, even for visual concrete, rather than attempting to fill and cover them.

As part of the trial panel, a section of making good should be carried out and agreed.

Further considerations

Recess detail at construction joint between wall and floor at Old Road Campus Research Building, Oxford.

Protection

It is essential for finished surfaces to be protected from damage and this should be included in the specification. It is important for all site operatives to be aware which concrete is designed to be exposed, in order to avoid damage such as site setting out markings or fixings.

Weathering

Weathering of external elements is an important consideration for all buildings, and those with visual concrete finishes are no exception. Particular attention should be given to the design of copings, parapets, cills and other projections. For further guidance, refer to the visual concrete guide from The Concrete Society. [10].

Sealers

A range of sealers is available for concrete and many have a useful role in reducing the dark patterning caused by rain. When a surface sealer is to be used, the following should be considered in discussion with the sealer manufacturers.

- What will be the maintenance requirements?
- Should it be clear or provide tinting to the concrete?
- Does the sealer have to perform a specific function, for example anti-graffiti coating?
- Should the sealer provide a matt or shiny surface?
- How will the sealer affect the reflectivity of the surface?
- Should the sealer be water-resistant?
- Should the sealer be UV-stable?
- Is the sealer compatible with any surface finishes to be applied?
- Is the sealer compatible with any sealants for windows/joints?
- Will the sealant accentuate any repairs to the concrete?

With all sealers, manufacturers' recommendations should be strictly followed.

Teamwork

Aesthetically pleasing and durable in-situ concrete finishes are achieved through teamwork (collaboration, co-operation and understanding), with each member of the team committed to making their contribution and understanding how their role has an influence in achieving the required finish. On the construction side, the key players are ready-mixed concrete producers, formwork suppliers and specialist concrete contractors.

At tender stage it is important to appreciate that an acceptable appearance for visual concrete cannot be achieved through written specification alone. It should be established as early as possible that the required finishes are achievable within cost constraints, and then a written specification can be discussed and adapted if necessary to be achievable and affordable. Clear communication is required between members of the team so the results do not fall short of expectations.

Designers should consider the buildability of their design. Complicated details can make compaction and striking of formwork more difficult and affect the quality of the finish.

Visual concrete is achievable through collaboration, cooperation and understanding between all the parties involved in the design, construction and supply.

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Exposed concrete at Oundle School, Northampton. Courtesy of Tim Soar and Feilden Clegg Bradley.

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