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CONCRETE QUARTERLY

VISUAL CONCRETE FOCUS

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WELCOME



Elaine Toogood
Senior architect,
The Concrete Centre

More beautiful than ever

There are many reasons for the current popularity of concrete, and the choice to leave it exposed, from its thermal mass and durability, to a desire to express the structure, to the inspiration supplied by so many award-winning concrete projects. There is also a growing recognition of the material efficiency benefits of using concrete as both structure and finish, not only in the construction phase but over the whole life of a building, as concrete requires very little maintenance to keep it looking at its best.

Concrete is an inexpensive and widely available building material, but specified carefully and executed correctly, it can create beautiful, luxurious surfaces. Concrete has sculptural potential, and the ability to form both vertical and horizontal planes, and everything in between. One expression of the craft of concrete is architectural precast concrete cladding, where intricate textures and patterns can be realised using elaborate moulds, and easily replicated using advanced factory techniques.

Perhaps it is this potential for individuality and bespoke design that is at the heart of concrete's visual appeal. Not just the potential for creativity and its ability to be moulded into almost any shape, but that each part of the surface is unique. Concrete is, after all, made from natural materials, and its surface expresses these natural variations and the way in which the constituents have come together.

Specifying visual concrete can be a complex but ultimately very rewarding endeavour. It is also an essentially collaborative one, the end product being the result of many different decisions and actions on the part of designers, contractors, specialists and manufacturers. The chosen surface finish must be considered from the very earliest design stages, and during every stage of the process. Achieving fabulous exposed concrete does require care, time and patience – but the result amply repays all the effort invested in its creation.

> PERHAPS IT IS THIS POTENTIAL FOR INDIVIDUALITY AND BESPOKE DESIGN THAT IS AT THE HEART OF CONCRETE'S VISUAL APPEAL ... EACH PART OF THE SURFACE IS UNIQUE

YOUR VISUAL CONCRETE COMPANION

Since Autumn 2015, Concrete Quarterly's Focus section has included a series of articles to aid project teams in the specification and delivery of visual concrete. This compendium brings all of them together in one place. For further guidance on the many possibilities of visual concrete, The Concrete Centre website offers a comprehensive library of publications and webinars on many relevant topics. And for those seeking even more inspiration, the entire Concrete Quarterly archive going back to 1947 is free to access at **www.concretecentre.com/cq**

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The Concrete Centre website offers a regular series of case studies, viewable as a list or on a map. Take a closer look at each building and find out how the visual elements were achieved. Visit **concretecentre.com/casestudies**



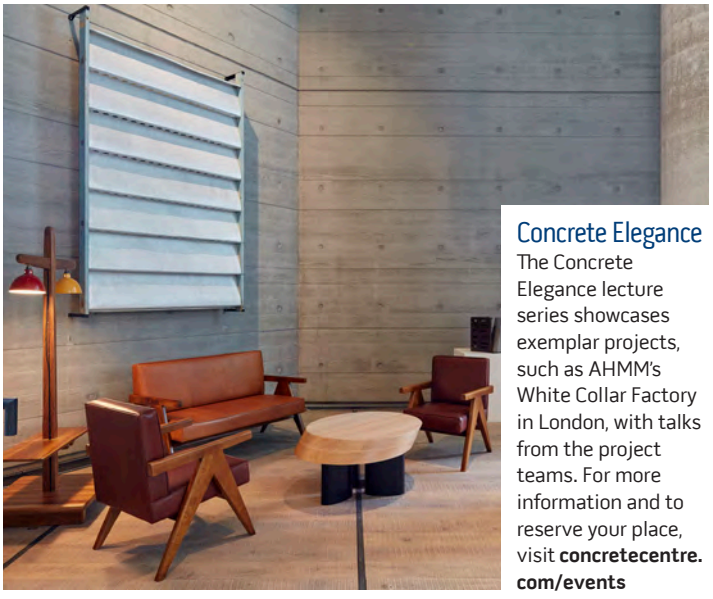
Technical guidance

Visual concrete can serve as both structure and finish, making it a highly efficient material. The Concrete Centre has published a guide, Material Efficiency, which provides information on the material and resource efficiency of concrete and masonry during manufacture, design, construction and demolition. The cover shows Stanton Williams' Simon Sainsbury Centre in Cambridge. Download your free copy at **concretecentre.com/publications**



YouTube videos

Join a virtual tour of projects such as Victoria Gate in Leeds, on The Concrete Centre's YouTube channel, and watch technical webinars on visual concrete. **youtube.com/c/TheConcreteCentrevideos**



Concrete Elegance

The Concrete Elegance lecture series showcases exemplar projects, such as AHMM's White Collar Factory in London, with talks from the project teams. For more information and to reserve your place, visit **concretecentre.com/events**



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THE BOLD AND THE BEAUTIFUL

Concrete can provide stunning visual finishes, but it must be considered from the earliest design stages. Elaine Toogood outlines the golden rules

Beauty, it is said, is in the eye of the beholder – a phrase worth remembering when embarking on the specification of visual concrete. Concrete can perform its principle functions of structural support and fire protection without needing to look particularly attractive, and even the best quality visual concrete is likely to have some marks and tonal variation. This is all part of its material quality, its "natural beauty". Understanding, describing and agreeing the desired standard of finish is essential to a successful outcome.

This article provides an overview of the key considerations for the creation of good-looking "formed" finishes. For more information on "unformed" finishes such as exposed concrete floors, see CQ 250.

The fundamentals: early design decisions

■ **Look at other examples of concrete** Visit some of the many contemporary examples of visual concrete. Take the design team and client in order to manage both your and their expectations of the types of finish achievable. It is very useful to benchmark an existing project, or part of it, as a quality reference. This is a simple way of conveying your expectations to the construction team at tender. Ideally the buildings should be of similar scale and reasonably local, but this is not essential. What is essential is that the type of construction be similar – that is, precast or in situ. References should also relate to equivalent parts of the building, so internal examples are used for proposed internal locations.

■ **Establish if precast or in-situ concrete is required** The desire for a particular colour or texture could determine where and how the concrete is made, and so it is recommended that the choice of manufacturing route is made early. Both ready-mixed concrete cast on site and pre-manufactured (precast) concrete offer visual concrete solutions, but with different aesthetic possibilities.

Visual precast concrete

There are many precast concrete products designed to be on show. This includes off-the-shelf units such as blocks and paving, but also larger precast elements made to order. Architectural precast offers a wide range of colours and textures, often with mixes developed to mimic stone – hence the term "reconstituted stone" or "recon". It is possible to achieve a high degree of quality control and replication through factory-based processes. Specialist manufacturers offer samples for reference, using a wide range of combinations of aggregates, pigments and finishing techniques. Precast concrete is typically the route to choose if white concrete is required, for example. Cladding is a common use for these products but bespoke structural elements are also available.

Most structural precast is not intended to be left exposed, but good aesthetic results are achievable. Structural precast is usually made to order, often with some properties predetermined by the method of manufacture – for example, hollowcore floors of a standard width and depth. Colours are typically limited to shades of grey with either a matt or satin sheen as-struck texture. In this regard, the finish is similar to standard in-situ concrete, except that it is usually cast face-down. The standard of finish should be established pre-tender in discussion with manufacturers as it will inform processes of manufacture, storage and handling.

Visual in-situ concrete

Ready-mixed concrete is mixed or manufactured in a batching plant not far from site, for direct delivery to be cast-in-situ. Often, concrete made in this way is concealed, but good aesthetic results can be achieved through careful specification, manufacture and workmanship. Site-batched concrete is not typically recommended for visual concrete due to the challenges of adequate measurement and mixing.

Most in-situ concrete is supplied in shades of grey, the colour determined principally by the cementitious content. Higher percentages of ground granulated blast furnace slag (GGBS) produce a lighter colour, while fly ash (FA) gives a deeper grey. Colour can vary slightly between suppliers and between different parts of the country as ready-mixed concrete plants mainly use





◀ Burntwood School

Wandsworth, south London
Allford Hall Monaghan Morris, completed 2014

AHMM's Stirling Prize-nominated transformation of Burntwood school merges a 1950s modernist campus with six new buildings. A range of both in-situ and precast visual concrete finishes are on show throughout the project, but its most striking feature is the sculpted facades of the four new curriculum buildings.

The reinforced precast concrete panels are 3m and 4.5m long to align with a typical classroom and structural module of 7.5m, while providing the flexibility for smaller modules. They were cast at Techrete's facility in Lincolnshire.

The base panels are acid-etched black concrete with mica fleck, while the upper panels use an off-white cement with dark aggregate fleck, and are also heavily acid-etched. To address considerations of staining and weathering, final detailing of drip edges and a corduroy base was also developed with Techrete.

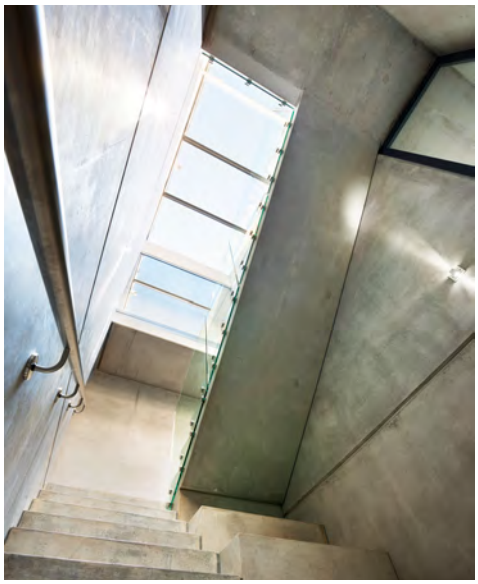
locally available course and fine aggregates. Hence, consistent supply is essential for visual concrete. Coloured concrete can also be obtained by adding pigments to the ready-mixed concrete.

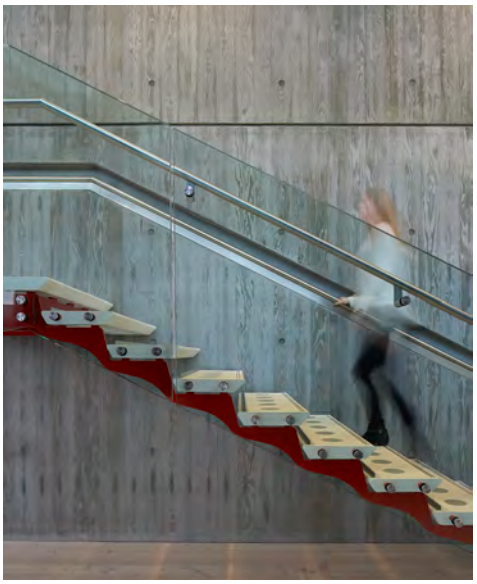
Pattern and texture

The texture of in-situ concrete is typically dictated by the formwork facing material. The selection and construction of appropriate, good-quality formwork is fundamental to achieving an attractive finish. Impermeable linings such as steel, polypropylene, glass reinforced plastic (GRP) and high-density overlay (HDO) board produce a smooth, shiny surface, whereas timber, unsealed plywood, paper-faced or medium-density overlay (MDO) boards give a matt finish. Pattern or texture can also be created by lining the formwork – proprietary form liners are available with either established or bespoke textures or patterns. Timber is often used as a form liner to create a board-marked finish.

Post-finishing can also be used to change the concrete's surface texture, and techniques such as acid etching and polishing are commonly used for architectural precast. Concrete can be shot or grit-blasted, the degree of texture dependant on the depth of mechanical abrasion. Water jet-blasting is also possible on freshly struck concrete, to expose the aggregates, but a more controlled

CONCRETE CAN BE SHOT OR GRIT-BLASTED, THE DEGREE OF TEXTURE DEPENDANT ON THE DEPTH OF MECHANICAL ABRASION





FAR LEFT Hilltop House in Oxford by Adrian James Architects uses precast concrete specified for an exposed finish
LEFT Hugh Broughton Architects specified self-compacting concrete for a feature wall at the Institution of Structural Engineers headquarters in London. It was cast in situ in formwork made from Douglas fir to leave a beautiful board-marked surface

and recommended method is to apply a surface retardant to the inside of the formwork, where the depth of reveal is determined by the type of retardant. Point tooling is possible but requires time to implement safely.

Specification

The National Structural Concrete Specification (NSCS v4) is a sound basis for the specification for concrete, especially when including visual concrete. It incorporates both standards and guidance in one document and usefully includes a detailed description for each of the finishes stipulated by BS EN 13670 for visual in-situ concrete (that is, plain and special).

Whether the NSCS or NBS specification is used, it is a good idea to include a short section on the specific requirements for the visual concrete elements. This ensures they are all in one place, so better communicated, and makes it easier to price and control. It is best to clearly define the extent of the visual concrete and indicate the areas where the greatest care should be taken. Design intent drawings should include formwork setting-out, 3D sketches of details, extent of cast-in services, corner and edge profiles and tie-bolt positions.

Typically +/– 1.5mm is the tolerance stipulated for good-quality visual concrete, but this can be tightened up with double-boarded formwork. The tender documents need not be specific about the type of release agents used, only that they "suit the concrete mix and facing material" and are "correctly applied to manufacturers guidance", the final selection being determined through trials on sample panels. Chose spacers appropriate for visual concrete, especially in slabs, and stipulate that day-work joints should not be visible. This can be difficult where large expanses of concrete are on show, such as in atriums or staircase shafts. Here it is worth considering introducing a shadow gap at the day-work joint position.

Concrete mix

BS 8500 stipulates five methods of specifying concrete. While good results are possible using high-strength concrete by "designation" (performance) only, for in-situ concrete it is advisable to use a "designed" concrete, limiting the allowable components and proportions of the mix to those suitable for visual concrete, while still allowing the contractors and suppliers some input into the design. The following recipe is recognised as suitable for achieving visual concrete and forms the basis of a designed mix specification.

TYPICAL VISUAL CONCRETE MIX	
Cement content	Minimum 350kg/m^3
Sand content	Not more than twice the cement content
Total aggregate	Not more than six times the cement content
Coarse aggregate	20mm max. Size not more than 20% to pass through a 10mm sieve
Consistence	125 to 150 slump S3
Water-cement ratio	0.5 or less

Alternatively there are proprietary concretes, including self-compacting concrete products, specifically designed to be used for visual concrete. These have been used successfully on a number of recent high-profile projects.

The specification included at tender can be regarded as a trial mix to be tweaked as necessary prior to construction through the process of supply and approval of sample panels and mock-ups. The exact proportions are likely to vary between projects depending in part on the properties of local materials. A full-size mock-up is to be recommended and is an invaluable way to agree workmanship, final detailing and release agent. As a minimum, a review of the first pour of visual concrete should be included in the programme to provide an opportunity to adapt the specification or processes if necessary.

Workmanship

The importance of good workmanship cannot be overemphasised in the process of achieving visual concrete. It is a good idea to begin a pre-tender collaboration with specialist contractors and suppliers. Appropriate site procedures should be established and rigorously enforced to maintain consistent quality. This includes the preparation, storing and construction of formwork and ancillary elements; the delivery, placing and compacting of concrete; and its subsequent striking, curing and protection. Cleanliness on site, and in particular of the formwork, is of paramount importance, as is good communication between all trades before and after the concrete is cast.

These efforts in preparation and installation should significantly reduce the risk of unwanted blemishes and colour variation on the surface of the concrete. However, there may still be areas that would benefit from post-finishing. Although much can be done to improve the surface of concrete, it must be implemented by a skilled operative, or the finish may end up looking worse than if it had been left alone. Most specifications include a clause to avoid making good or any remediation without prior agreement with the architect. This doesn't mean that it won't be required, just that the extent and means need to be established beforehand.

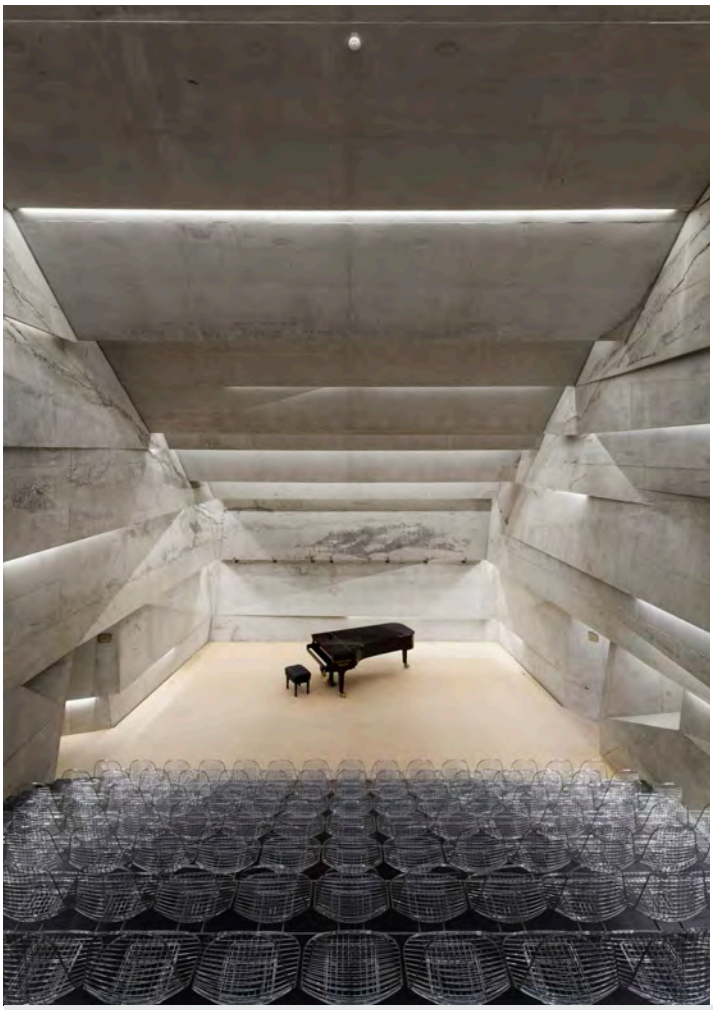
So with some preparation, collaboration and understanding, beautiful concrete is very achievable. Fortunately, unlike in many other areas of life, concrete requires little further attention to maintain its good looks over time, thus providing enduringly rewarding results.

Key references

How to Achieve Visual Concrete, MPA – The Concrete Centre, www.concretecentre.com

National Structural Concrete Specification, fourth edition, MPA – The Concrete Centre, on behalf of CONSTRUCT, www.construct.org.uk

Technical Report 52, Plain Formed Concrete Finishes, second edition, The Concrete Society, www.concretebookshop.com







▲ Blaibach Konzerthaus

Bavaria, Germany
Peter Haimerl Architektur, completed 2015

Konzerthaus, a new 200-seat concert hall designed by Peter Haimerl in the Bavarian village of Blaibach, is full of surprises. Externally, its partially buried form tilts up to create a dramatic granite protuberance in the town square. But there's even more of a shock inside, where the all-concrete subterranean concert hall utterly defies expectations.

Rather than a gloomy cave, this is an uplifting space, created with pleats of highly textured, in-situ concrete with the grainy appearance of marble. Concealed lighting within the walls and beneath the seats illuminates the concrete interior – where only the wooden stage breaks the material's expanse.

Haimerl was inspired by the delicate strength of Gothic churches. "You feel the lightness – it isn't oppressive," says Haimerl, who was inspired by the delicate strength of Gothic churches. "I wanted a modern Gothic aesthetic."

He chose concrete primarily for its aesthetic and acoustic qualities, specifying a stiff yet lightweight foam glass mix. This was made using cellular glass from recycled bottles to give the desired, roughly textured, grainy effect. "The surface looks more like a natural stone and feels much warmer to the touch," he says.

This hard surface is also ideal for performance acoustics, as are the concrete strata, which are faceted to create the optimum acoustic environment for classical music. Horizontal "cuts" allow the architect to incorporate more than 50, 6m-wide insulated boxes behind the concrete walls and beneath the seats to absorb bass tones, and conceal LED light fittings so that the audience sees only slits of light between the strata. The untreated, "grizzled" surface of the concrete absorbs middle tones while reflecting rather than absorbing the high ones.

An in-situ approach was essential to create the complex interior form of the 560m^2 concrete hall. The installation was highly challenging, especially as this particular concrete mix is not very common.

TOP LEFT Concealed LEDs within the in-situ concrete walls illuminate the wooden stage
TOP RIGHT A tilted granite block is all that marks the concert hall's entrance in the town square
ABOVE RIGHT The untreated "grizzled" surface of the concrete helps the acoustics by reflecting high tones and absorbing middle tones

The architect brought in a car-building company to configure the formwork, which was created using 3,000 different timber elements. "We needed a preciseness which you couldn't get with other formwork," he explains.

The intricate pouring, which took place over a six-week period, was complicated by the need to integrate the insulation and lighting boxes and tubing for radiant heating into the formwork. The resulting concrete ranges in thickness from 50mm to 600mm.

The outcome, both visually and acoustically, exceeded even the architect's expectations for his first concert hall: "It's fantastic," says Haimerl. "Much better even than we hoped."

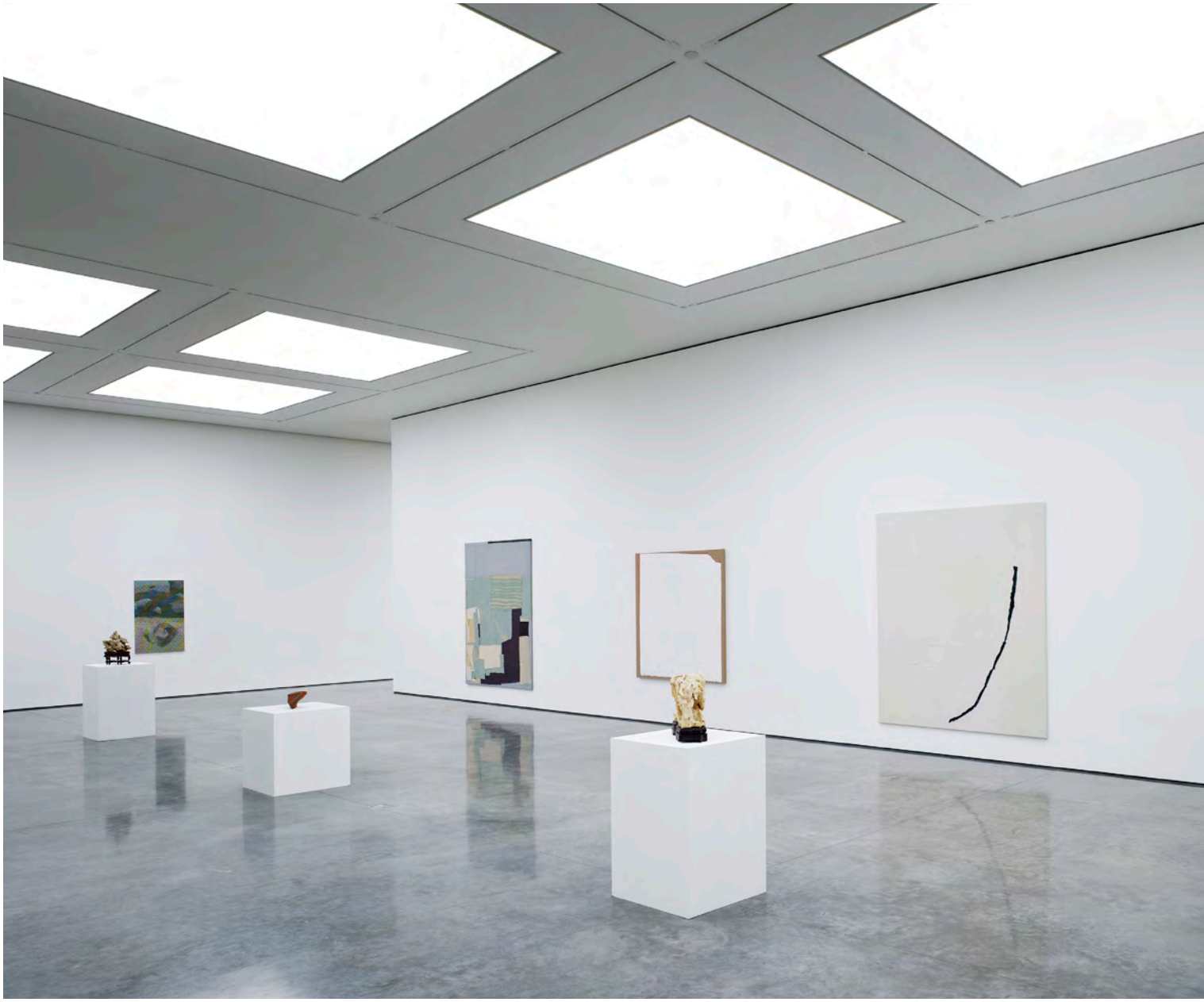


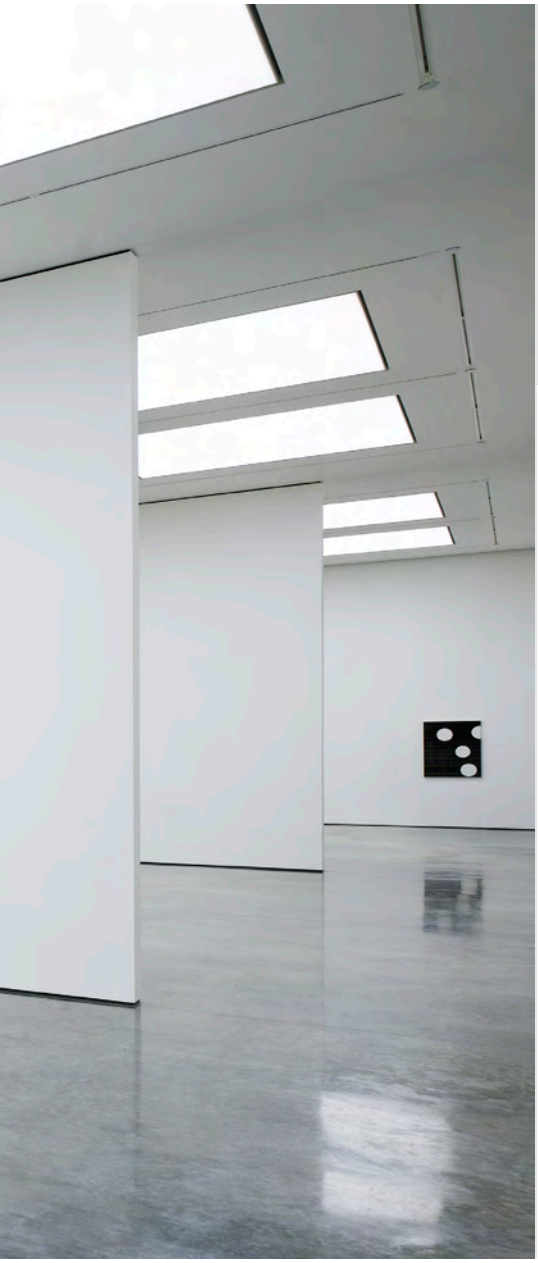
Photo: Paul Riddle

SURFACES, IN DEPTH

Concrete can be polished, textured, coloured, washed, brushed or blasted to give a huge range of aesthetic and hardwearing floor finishes. Elaine Toogood explores the options

Exposed concrete floors are durable, hardwearing and useful for all sorts of applications, from warehouses to art galleries, and from garages to living rooms. They are particularly useful for heavy loads or traffic or, when combined with underfloor heating, for continuous and efficient space heating. As a finish they can appear utilitarian or luxurious depending very much upon the chosen materials and installation techniques. This article considers some of the different textures, colours and even patterns available for concrete floors and the techniques used to achieve them.

Technically, the upper face of a concrete floor is called an "unformed" face, in contrast to "formed" concrete faces which obtain their shape and texture from the moulds or formwork in which they



1 Polished natural concrete

White Cube Bermondsey, London (2011)

Architect Casper Mueller Kneer decided to let concrete's natural beauty shine through in this south London gallery. It is made of reinforced readymix concrete with no additional pigments or additives, and no finish applied. The 150-200mm structural floor slab was simply power-floated and burnished, though it has subsequently been cleaned and polished with an oil-based product. The contractor was Steyson Floors.

are cast. Unformed faces are typically flat and need post-finishing techniques to achieve the required texture. The most prevalent texture or finish for internal exposed concrete floors is polished – either power-floated for a smooth solid appearance or diamond-ground to expose the aggregates. A requirement for greater slip resistance is often a driver to explore other options, such as the inclusion of retardants or shot-blasting. Some of the techniques more commonly used for external surfaces, such as imprinting or brushing, can also be used to good aesthetic effect inside.

This article focuses on finishes for internal concrete floors, but the same techniques are commonly used for exposed screeded floors too. Wearing screeds (formerly known as high-strength concrete toppings) are usually installed once the space is enclosed, unlike a structural floor slab. They are specifically designed to serve as a floor finish, often incorporating pipes for underfloor heating, and require care and expertise to execute correctly. Designers are advised to seek guidance from specialist installers at early stages of design development when specifying screeded floors.

Polished concrete

There are two ways to create a smooth, polished patina to concrete floors, but each achieves quite a different visual appearance.

■ **Diamond-polished, or ground and polished** This technique creates a smooth finish, with varying degrees of shine and exposed cross-sections of aggregate. The top millimetres of the concrete are mechanically ground away to expose the aggregate, often using diamond grinders. The surface is then polished with increasingly fine-grade buffers to achieve the desired finish.

Diamond-polished concrete can take on the appearance of terrazzo depending upon the colour of cement, pigments and type of aggregates used – specialist suppliers and installers offer a huge range of colours and aggregate combinations. The depth of grind will determine the degree of aggregate exposure – that is, larger aggregate sections will be revealed with a deeper grind.

More commonplace mixes of in-situ concrete can also be finished in this way. This is often a technique used to level and finish existing floors, although the final result is unlikely to be as consistent as a floor designed and placed to be polished in the first place.

■ **Pan-floated or trowelled** Unlike the mechanically abraded system, this technique takes place before newly placed concrete is fully cured, and timing is critical to achieve a successful finish. The surface is floated, using a pan floater, and then trowelled progressively to produce a polished sheen. This is most commonly achieved using power tools but it is also feasible to trowel small spaces by hand. Further degrees of polish can then be obtained by using different surface sealants if required.

The resulting floor has a more solid colour, sometimes described as mottled, or a natural patina but with minimal visible aggregate. The colour of the floor is determined primarily by the fine content of the concrete mix – that is, the cement, sand fines and any pigments in the mix.

Alternatively, this technique can be used to install a pigmented dry-shake finish, creating the desired colour on the top surface of the concrete.

Texture and pattern

Exposing the aggregate in concrete can also create grain, texture and pattern in floor surfaces, which is particularly useful for areas requiring greater slip resistance. The uppermost layer of concrete, or surface mortar, can be removed in a number of ways, each with subtly different results.

A key consideration is the practicality of application and the degree of control required for the specific project. Appropriate specification of the concrete mix is essential for a high-quality exposed aggregate finish, since "normal" concrete is unlikely to contain sufficient aggregate at the surface once compacted. A range of proprietary mixes are available with different combinations of coloured aggregates and binder.

Common techniques include the following:

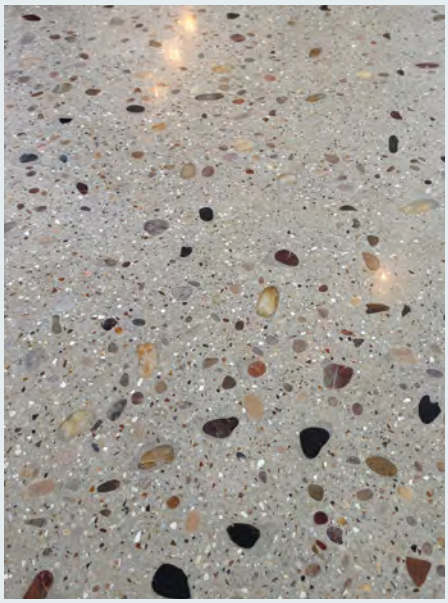
■ **Exposure by washing or brushing** Washing or brushing away the surface mortar of the concrete is in principle the simplest method of exposing aggregate in newly poured concrete. However, skilled execution and timing are critical to ensuring that the concrete is sufficiently stiff to hold the coarse aggregate in place while the surface is sprayed or brushed, but not so hard that it is difficult to remove the surface layer.

■ **Use of surface retardants** Surface retardants offer a more controlled method of exposing the aggregate. Liquid surface retardant is sprayed onto the surface of the wet concrete, preventing the uppermost layer, or mortar, from setting and allowing it to be washed or brushed away. The depth of mortar removed, and therefore amount of aggregate revealed, is determined by the choice of retardant.

Texture patterns can be created in the floor surface by using stencils to mask areas of the concrete before the retardant is applied. The protected areas remain smooth alongside the more grainy texture where the aggregate is exposed. The effect is intensified when the pigment and/or cement colour contrasts with the sands and aggregates. As with all techniques, timing and skill is important for effective execution.

■ **Shot, grit or sand blasting** This is a simple technique for mechanically removing the top layer of hard concrete to create a stippled surface, often used to improve adhesion for supplementary

EXPOSING AGGREGATE CAN ALSO CREATE GRAIN, TEXTURE AND PATTERN – PARTICULARLY USEFUL FOR AREAS REQUIRING GREATER SLIP RESISTANCE



2 Diamond polished

Residential project (2014)

Steysons created this floor using natural concrete into which additional 20mm Scottish pebbles and a blend of 40mm coloured stones were added. It was then diamond polished to expose the aggregate.



3 Patterned

Lazenby office, London

The smooth dry-shake surface has been removed using a stencil to expose the textured aggregate below. In this instance, an acid wash was applied in layers before being washed off. A deeper reveal can be achieved with shot blasting.



4 Sandblasted

Sample, Cornish Concrete Products

This is greystone natural concrete which has been sandblasted. If this mix was to be polished, it would take on a dark blue colour, but sandblasting tends to dull colours and reveal trapped air holes, which will be more prominent in darker mixes.



5 Brushed

Beach walkway, Whitstable

This concrete has been brushed while wet to add texture and slip resistance. A wide, stiff-bristled broom was dragged in one direction, with care taken to apply even downward pressure. Different effects can be achieved depending on the implement used.

finishing layers. If intended to be a final finish, careful control is required to ensure consistency. A test patch is recommended so that the degree of shot blast can be agreed. As with depth of polish, the heavier the abrasion, the larger the pieces of aggregate that will appear. There are many fine examples of patterns created using stencils with this technique.

Imprinting wet concrete is a common technique for creating texture in external areas and can be a cost-effective way of improving slip resistance. A tamping beam is progressively lowered and raised along the face of the floor to imprint freshly placed and levelled concrete. This creates a surface with ridges, the frequency and width of which depend on the size of the beam. It can be specified as light, medium or heavy tamp, but these descriptions are not clearly defined and a benchmark or test panel is advised.

Brushed or dragged concrete is a similarly cost-effective finish for adding slip resistance and is best suited to utilitarian areas where aesthetics are less important, due to the difficulty of obtaining a uniform finish. It does offer opportunities for pattern and variety depending on the direction of drag and the material used. Stiff bristled brooms give a coarser texture than those with soft bristles, for example. While actual sweeping brooms can be used, a purpose-made brush with steel bristles or tines is more appropriate for commercial applications. Other dragged finishes include "turf drag", "hessian drag" or "tine finish", which use different materials to create textured effects.

An alternative method for adding texture to wet concrete is stamped or pattern imprinting using mats or rollers. Usually used externally, standard systems are most likely to be in the form of patterns with stone, cobbles or herringbone for paths and patios, but the technique offers opportunities for unique textures and patterns through the creation of bespoke mats.

The use of tamped, brushed and imprinted concrete on internal spaces may be restricted by the ability to gain access to create the finish in the wet concrete. This therefore requires consideration of sequencing early on.

Colour

The colour of a concrete floor will be determined by the through colour of the mix, which will itself vary in appearance depending on the surface texture employed and how much aggregate is exposed. It is also possible to add permanent colour, but only to the upper surface of the concrete.

■ **Dry-shake toppings** These toppings are powder or granules broadcast onto the surface of the concrete before trowelling and floating. Once pan-floated into the floor, this results in a hard, durable surface. There is a wide range of coloured pigments available, including grey, and toppings can be selected to suit the specific performance requirements of the floor. Many include a surface hardener to improve the durability of the finish, but they can also provide abrasion resistance and are often used to improve the surface finish



Photo: Jeremy Philips

of large pours when steel fibres are included.

■ **Colour stains** These can be applied to either power-floated or diamond-ground polished floors and offer the advantage of colour variety and a controlled application to create pattern, allowing the natural tonal variation of the concrete surface to show through.

Precast

Robust floors can also be created using prefabricated concrete elements. Inherently strong concrete sets and paviors are typically used outside but can also be specified internally and are particularly suitable in heavily trafficked areas such as foyers. A huge range of proprietary products are available in all manner of sizes, shapes, textures and colours, including very large format concrete "tiles" specifically designed for internal use.

Key references

"Indoor Decorative Concrete Floors", Concrete Advice Sheet 45, Concrete Society

"Visual Concrete: Finishes", CS170, Concrete Society

"Assessing the Slip Resistance of Flooring", Health and Safety Executive

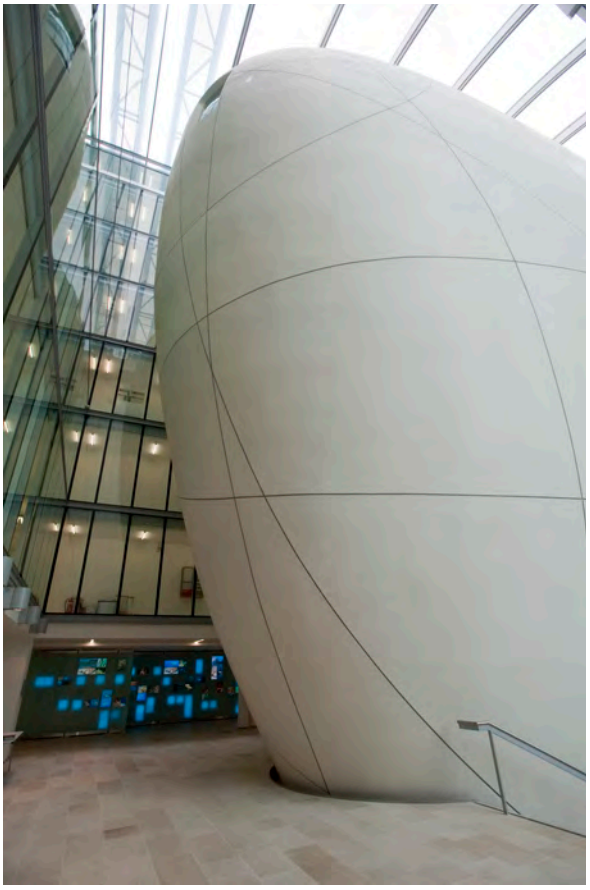
BS 8204-1:2003+A1:2009 "Screeds, bases and in situ floorings. Concrete bases and cementitious levelling screeds to receive floorings. Code of practice", British Standards Institution (BSI)

BS 8204-2:2003+A2:2011 "Screeds, bases and in situ floorings. Concrete wearing surfaces. Code of practice", BSI

For further guidance on screeds, go to the Technical Information section at www.concretecentre.com, and click on "Building solutions"

ABOVE Lazenby installed this floor in an apartment at the Talisman building in London. A dry-shake topping in Mayfair grey was applied and the concrete polished to achieve a satin finish





Photos: Flanagan Lawrence Architects; the Trustees of the Natural History Museum, London

GO WITH THE FLOW

ABOVE Flanagan Lawrence's Acoustic Shells in Littlehampton

RIGHT The Darwin Centre at the Natural History Museum in London by CF Møller

Complex curves are becoming an increasingly common feature of concrete structures. Elaine Toogood explains how it's done

One of the delights of concrete is that it can take any shape, including regular and free-form curves. Here, the challenge lies not with the concrete, but rather in making the mould, or formwork, to the desired shape, and for it to be sufficiently rigid to contain the concrete until it is strong enough to hold its own shape.

Regular two-way curves are relatively simple to form. Circular concrete columns are commonplace, and there is a range of proprietary formwork systems made from steel or cardboard-like tubes. Plywood and steel are common materials for formwork facing and can be bent, and there are proprietary systems for creating curved walls with a radius of up to 1m. Tighter curves require profiles made from metal, GRP or thinner ply, braced to provide the necessary support. For very tight curves or more complete shapes, the formwork needs to be flexible enough to be removed, or dismountable to release the concrete. Shaped polyurethane form liners offer an established technique for this, and can be made to order. Polystyrene or GRP can be used to create regular lengths of trough moulds for a curved, profiled, ribbed deck.

Three-way or free-form curved structures require different solutions. The formwork typically needs to be a material that can either be carved out or moulded itself into the desired shape. Free forms, such as the diving boards at the London Aquatics Centre by Zaha Hadid Architects, can be achieved by carving polystyrene forms with a digitally controlled five-axis router, and then using these to create more rigid GRC moulds. An alternative technique involves strengthening the polystyrene forms themselves, as used to create the 54 unique elements that make up the 20m-high Dream sculpture by Jaume Plensa outside Saint Helens, Merseyside. Each one was first strengthened using a polyurethane foam and then, after further accurate routing, sealed with epoxy resin ready for the concrete to be cast in the factory.

There are many examples of curved thin-shell structures from the last century, and the current focus on resource efficiency has led to renewed interest in these elegant forms. Felix Candela's hyperbolic paraboloid geometric shapes were created using strips of straight timber, a technique employed more recently on the Casar de Cáceres Bus Station in eastern Spain by Justo García Rubio. Flat sheets of MDF were used by Tonkin Lui to create the sinuous retaining walls of the Dover Esplanade, but here the boards were cut into curved strips and stacked on top of each other.

Sprayed concrete is an alternative solution that does not use formwork. Concrete is projected onto curved reinforcement bars or mesh, usually resulting in a slender structure. This method requires considerable skill and an appropriate mix, and is widely used in tunnel construction. The Darwin Centre at the Natural History Museum in London by CF Møller is an elegant example of the technique, an eight-storey concrete cocoon with a smooth outer coating of render. More recently, Flanagan Lawrence's beautiful Acoustic Shells on the seafront at Littlehampton, West Sussex used hand-trowelled sprayed concrete to create smooth-flowing surfaces.

Using fabric as a mould inevitably creates curved forms, with results dependant largely upon the type of fabric used and its configuration. This form of construction has not yet reached the mainstream, but a good deal of research and experimentation is underway to refine it and overcome the unusual challenges it poses. One delightful aspect is that the pattern of the fabric is left on the concrete surface. Bomnong L'or School in Cambodia (see page 3) is a rare example where fabric formwork has been used to cast a structural frame on site.

Other innovative solutions using flexible moulds include inflated pneumatic structures, wax and lattice grids. But perhaps the most revolutionary process for shaped concrete is 3D printing – the rising popularity of which suggests that the future of concrete construction may be very curvy indeed.

MARKS OF DISTINCTION

The use of exposed concrete stands or falls on the quality of the finish – which is why it's essential to understand the effects created by different formwork facing materials



Photos: Timothy Soar

ABOVE AND BELOW LEFT
Richard Dudzicki Associates' Eco Lodge in Chiswick, west London features both smooth and board-marked exposed concrete

The selection of a formwork facing material is arguably the most significant decision when specifying exposed in-situ concrete. It is this inner surface that dictates the texture, surface and sometimes the tone of the as-struck concrete.

Formwork, or shuttering, has typically been constructed using load-bearing sections of timber, which led to a proliferation of board-marked concrete. Today it is more common to see smooth concrete in which the joint lines between plywood panels are expressed. Engineered timber boards manufactured especially for use as formwork come in a range of factory-applied surface treatments to extend their reuse capability and to smooth over the grain. Each type gives a different finish to the concrete. This may be the determining factor for selection, but other criteria should also be taken into account, such as reuse and cost. Guidance should be sought from specialist formwork and falsework suppliers.

As a general rule, materials that breathe or are permeable, such as timber, fabric or paper-faced ply, will produce a matt finish and are less prone to blow holes. Impermeable materials such as phenolic film-faced boards (PFF), steel, plastic and glass-fibre-reinforced plastic (GRP) produce concrete with a shiny surface and a greater likelihood of blow holes.



In theory, you can cast concrete against almost any material, so long as you can remove it afterwards. Form liners can be fixed to the formwork boards to impart their pattern and shape onto the face of the concrete. For example, elastomeric sheets or "rubber mats" such as polyurethane are flexible and can be peeled off the surface of the concrete, enabling deep profiles and patterns to be formed. An extensive range of different patterns and textures are available or can be made to order. Board-marked concrete can be created in this way or with real timber fixed to the inside of the formwork sheets.

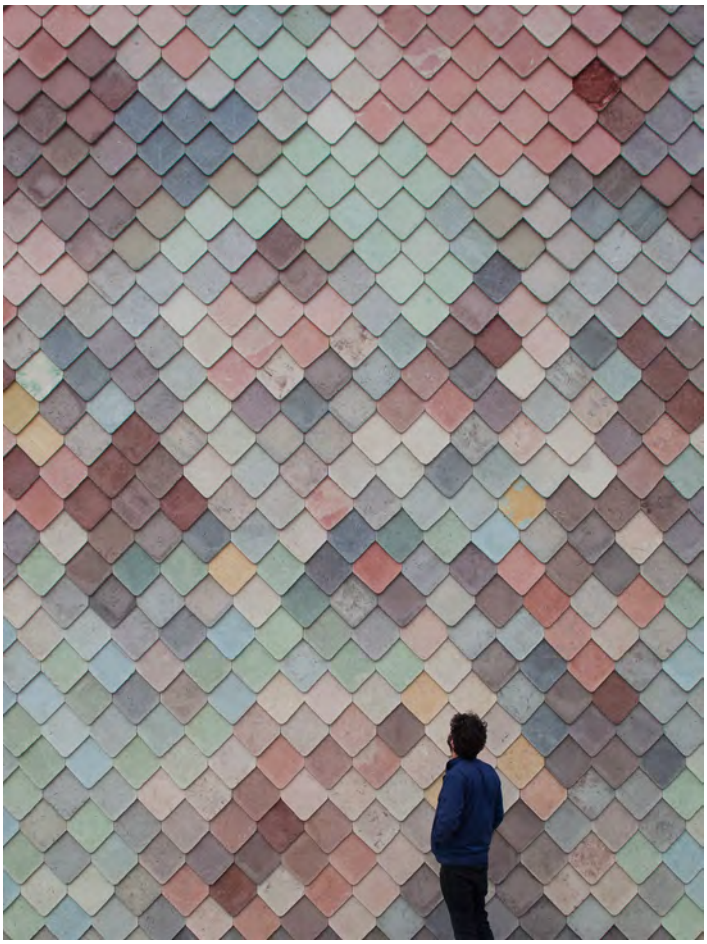
The longer the concrete is in contact with the formwork facing, the more impact this will have on the tone or colour. For example, tannin from medium-density overlay (MDO) boards may impart a brown colour to a soffit if left for a long time. This highlights the importance of taking a holistic approach to design to create high-quality visual concrete. Considerations include strength-gain requirements and the concrete mix.

Great care and attention is required in the assembly and fixing of formwork facing for visual concrete, so that the desired tolerances and grout-tight joints are achieved. There must be rigorous selection of undamaged boards, which should be protected, as well as the correct selection of release agent. For a high-quality finish, the specification and workmanship of the formwork facing should be considered as carefully as if it were the final finish of the structure – because in effect it is.

Facing facts

Phenolic film facing (PFF) is impervious due to its high resin content. The more resin, the more the plywood is protected and the greater the potential reuse. These film coatings create a very smooth, shiny surface to the concrete, and sometimes a slightly marbled pattern. They are often used for stair cores and slip form.
Medium-density overlay (MDO) boards have a film of paper impregnated with resin but with far lower saturation levels, allowing the formwork to breathe, giving a matt or satin sheen.
High-density overlay (HDO) leaves a shinier finish and can be reused more often than MDO.
Unsealed plywood leads to greater levels of water absorption producing a slightly darker toned, matt concrete surface, often with a timber grain pattern. It has a limited number of reuses and is prone to tannin release so not recommended for fine finishes. High-quality birch-faced ply can produce a good finish but should be sealed before use.
Controlled permeability formwork (CPF) is a polypropylene fabric system that produces a darker concrete. The surface has the fine texture of the fabric and potentially very few blow holes.
Steel is commonly used for prefabricated forms such as columns, and can be used multiple times. When new, it produces a shiny, mottled appearance similar to PFF.
Plastic lined circular cardboard forms are often used to create a good, smooth and shiny finish on circular columns.





Photos: Iñigo Bujedo Aguirre/View Pictures; Assemble

TRUE COLOURS

Concrete doesn't have to be grey. Elaine Toogood considers ways to achieve concrete of a different hue

ABOVE City of Justice, Barcelona by David Chipperfield Architects

RIGHT Yardhouse workspace in London by Assemble

The colour of concrete is predominantly dictated by the finest particles in the mix, because these migrate to the surface. Cement typically contributes most of the fine content and since most cement is grey, most concrete is also grey. By the same logic, replacements such as ground granulated blast-furnace slag (GGBS) and fly ash can be used to create different tones. Ready-mixed concrete makes use of locally available materials, so there are also regional variations, depending largely upon the strength of colour of the local sand and how fine it is. With paler cements, the colour of the sand will have more impact.

The technique of colouring concrete using natural sands is established practice when making many precast concrete products, such as "architectural precast" or "recon", which is often designed to resemble the colour and texture of natural stone. White cement provides a neutral base, receptive to both coloured sands and pigments, and offers a high degree of control and replication. Pigmented ready-mixed concrete is becoming more available in a range of colours. While pure white concrete is not typically available ready-mixed, a pale cement base using GGBS will provide a brighter colour. Pigments are commonly supplied in granulated form for easy dispersal, pre-measured to suit each load and placed in the back of the concrete truck. They are typically inorganic compounds, which are not affected by UV light, available in earthy tones such as reds and yellows though to browns and blacks, though blues and greens are also possible. White pigment is also used to lighten the tone.

Colour can also be created through the treatment of the concrete surface. Aggregates, normally hidden, can be revealed using surface retarder, mechanical abrasion such as grit and shot blasting, polishing or acid etching. In these circumstances, the colour of the concrete will be a combination of the colour of the aggregate, how much of it is exposed and the base cement or mortar colour. Architectural precast concrete can be created from a large range of coloured aggregates sourced especially to be exposed.

Of course, concrete can also be coloured using an applied coating such as masonry paint or semi-transparent tints, many designed specifically for use on concrete. Stains are also available, although currently less common in the UK. They work by migrating through the upper surface of the concrete and chemically reacting with the lime content to create more permanent colour in the outer surface. Dry shake toppings are a more frequently used application for colouring concrete floors, where pigmented surface hardeners are power-trowelled into the surface of a freshly laid concrete. This achieves a dense, durable, embedded hue, which can be specified to match RAL colours.

The choice of formwork will have an impact upon the colour of as-struck concrete. Linings that absorb water tend to create a darker tone, while timber-based products, if left in contact with the concrete long enough, can impart their tannins into the surface in the form of brown patches.

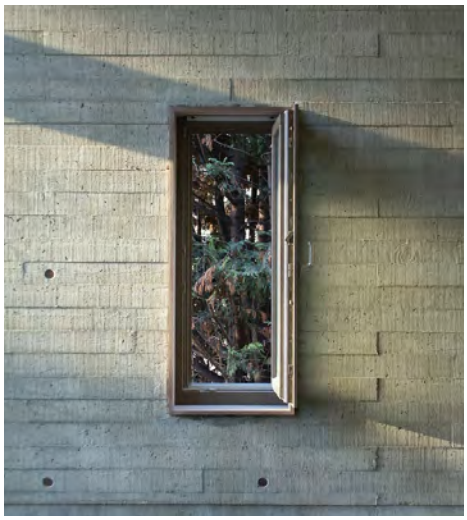
Other colour variations can be created by localised water or grout loss, and the release agent used. An interesting, but not permanent, phenomenon is the appearance of a blue hue when concrete containing a high percentage of GGBS is cast against an impervious formwork.

Freshly cast concrete will become a few tones lighter during the first few months of exposure, so the colour of new concrete should never be judged just after striking the formwork. This highlights the importance of building sample panels to trial different combinations of mix and formwork construction where colour control is required.

To summarise, colour in concrete can be created through the choice of cement colour and sands, by adding colour to the concrete mix, and by exposing the aggregates – or indeed a combination of all three. And colour can be applied, or incorporated into the surface of concrete. Your choice is likely to be influenced by the intended use of the concrete, its required durability and the method of manufacture. But however you do it, rest assured that it certainly doesn't have to be grey.







Photos: Edgley Design; Hélène Binet; Alex de Rijke

CLOCKWISE FROM TOP
Pear Tree House in south London by Edgley Design; One Centaur Street in south London by dRMM; The Collection museum in Lincoln by Panter Hudspith Architects

GRAIN MAKER

Done well, timber formwork can leave beautiful textures and patterns. Elaine Toogood explains how to get it right

Before plywood was widely available, the entire structure of formwork or shuttering was typically made from sections of timber. This is one reason for a proliferation of board-marked concrete from the last century.

Contemporary board-marked concrete is more likely to be created using a timber-textured lining, be it slender sections of actual timber (normally 25mm thick) fixed to the inside face of ply sheets, or a proprietary formliner system, in polyurethane for example, with a wide range of existing or bespoke patterns available. Because the timber is no longer providing structural support, this offers greater scope for creativity in texture and pattern and more freedom in size and orientation. Proprietary formliner systems also offer opportunity for multiple reuses, whereas a real timber facing can typically be used just once or twice before its grain becomes filled up or "flattened". The amount of reuse will depend to some extent upon the species of timber and sealant used, the length of time in contact with the concrete, and the required expression of the fine timber grain.

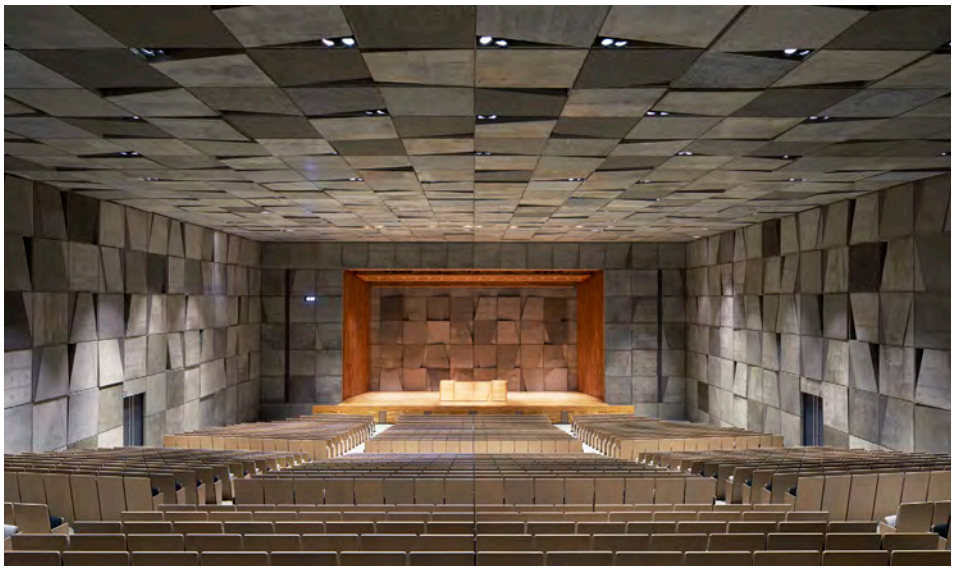
Grain can be accentuated by abrading, using shot or grit, or brushing the timber surface. This technique was used for the feature wall in the reception area at the Institution of Structural Engineers headquarters in Islington, north London (CQ 252). Alternatively, the grain expression can be suppressed by planing the surface, as at The Collection museum, Lincoln. The surface can also be left as a rough-sawn finish with the cuts expressed as at One Centaur Street in south London.

Douglas fir is commonly specified for timber board marking but it is possible to use other timbers. Since all timber absorbs water, and swells in the process, a common issue is the need to control absorption into the formwork face and joints, both to prevent it from swelling and warping, and to enable it to be removed easily from the concrete. Equally, formwork may shrink and crack if left to dry out before use. Traditionally this meant pre-soaking the timber before pouring the concrete, but today an appropriate release agent or sealant may also be used.

Concrete becomes darker with greater water loss, demonstrated by the dark lines often present at the joints between boards. This can be reduced using careful carpentry to plane and butt-joint or interlock boards, or the natural variation at the plank edges can be adsorbed using sealant strip or fillets. To achieve a level concrete surface, the rear of the boards must be planed to create equal depth. This is particularly necessary when using boards of different widths, with correspondingly different depths. Fixings from the front will always be seen, but can be made less visible if pins are level rather than driven deep – look closely at the walls in the National Theatre to see the flat nail heads cast into the concrete at regular intervals.

Board-marked concrete is characterised by the tonal and surface variations created by the natural differences in timber surface, density and water absorption. This offers a significant advantage over smoother surfaces in that other variations in the concrete's surface, such as blowholes, are less conspicuous and therefore more likely to be deemed acceptable. But like any visual concrete surface, it is important to look at benchmarks and pour samples in order to align expectations with process and design.

And finally, do find a use for the timber afterwards. One of its faces will remain clean, so can be made into fencing, cladding or doors. Great examples are to be found in the bar at the Everyman Theatre in Liverpool, or at architect Jake Edgley's home in Dulwich, south London, where a timber garden fence is beautifully juxtaposed with the concrete walls it was used to cast.



Photos: Daici Ano

SCRATCHING THE SURFACE

Post-finishing techniques can create a variety of textures in exposed concrete. Elaine Toogood outlines the main approaches

The as-struck surface texture of concrete is an exact impression of the formwork facing material or lining that it is cast against. Form liners are available or can be created to order with an almost infinite range of patterns and surface reliefs. Further opportunities for pattern or texture are offered by the removal of all or part of the concrete's surface – the result depending on how much of the concrete is removed, and the method.

Acid etching is a common post-finishing technique employed for architectural precast elements, applied a few days after striking in the factory. By removing the smooth outer surface, or laitance, the fine grain and colour of the aggregate in the mix starts to be revealed. With a deeper etch, a different tone and more defined texture emerges, showing more of the aggregate, which means that consistency is important if a more uniform appearance is required. Precast manufacturers are able to provide samples with a range of different finishing techniques and variants.

Abrasive blasting can be used to create a similar effect to etching, depending on the size of grit or shot used and the duration of application. This may also be applied to in-situ concrete. Advance testing is essential for agreeing the blasting technique to be used, and to define the appearance required.

Light abrasive blasting uses grit sized 0.2-1.5mm, removing just a little of the surface mortar, and is best carried out 3-7 days after the concrete is poured. A heavy abrasive blast, on the other hand, will remove all of the surface laitance, back to about one-third of the depth of the coarse aggregate and should be carried out when the surface of the concrete is still relatively weak, say 1-2 days after pouring, depending upon the strength gain of the concrete. The use of stencils or templates with abrasive blasting allows the creation of a permanent pattern in the surface.

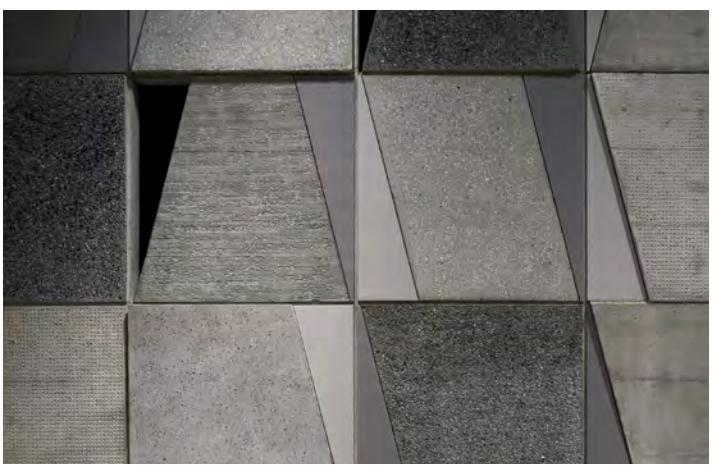
Surface retardants offer an alternative, controlled means of revealing the aggregate. These can be applied to the face of the formwork or to freshly struck concrete, although the latter is more common for unformed faces. In both situations, the retardant prevents the surface laitance from hardening, so it can simply be washed or brushed away once the concrete is struck. The depth of laitance, or cement matrix, removed, can be controlled by product selection. One patented technique prints digital images or patterns in retardant onto a paper form liner. This allows very precise, repeatable articulation of the surface texture by contrasting aggregates exposed by the retardant, with smooth untreated surfaces adjacent. Even large photographic images can be recreated in the surface of concrete.

Tooling, or breaking the hardened surface of the concrete with tools, can be used to create a rougher surface texture, either with or without broken aggregate. This can be carried out by either hand or machine. In practice, such techniques take time and labour to execute safely, and are therefore far less common in contemporary construction.

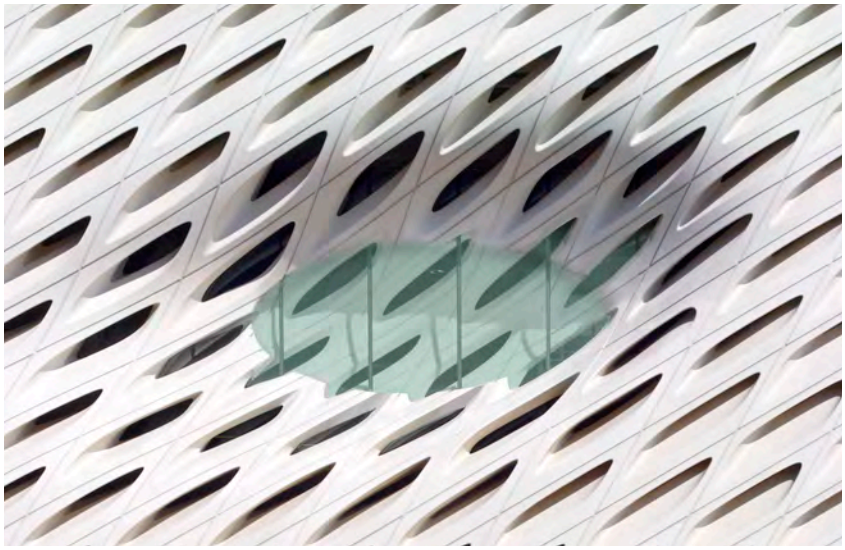
Polishing the formed face of concrete is also a mechanical process, but can be safely and cost-effectively carried out over large horizontal surfaces. Manufacturers of architectural precast elements use an automated bridge polisher for large flat areas, progressively grinding and polishing to achieve an ever smoother, shinier surface. The more concrete that is removed, the wider the cross-section of aggregate on show. Smaller, less accessible areas, such as window reveals, can be polished using hand-held machines.

Selection of aggregate is clearly critical to the final appearance of any concrete, where texture is to be created by exposing the aggregate. Designers should consult precast and ready-mix suppliers to establish what aggregates might be available. Since exposed concrete is at the core of architectural precast products, these manufacturers offer the widest range of concrete mixes and textures – but with an understanding of the techniques, creative possibilities open up for creating textures in all forms of concrete.

For further information on post-finishing see Visual Concrete: Finishes, from The Concrete Society



ABOVE AND LEFT At the Waseda University Senior High School auditorium in Tokyo, Nikken Sekkei designed concrete panels with 15 different finishes, including fair-faced, smooth and coarse polished, medium and fine bush-hammered, shot-blasted and scratched. The panels are tilted at various angles to maximise acoustic performance





Photos: Benny Chan; Milène Servelle; Keith Hunter

DRESSED TO IMPRESS

CLOCKWISE FROM TOP LEFT
GRC is used to sculptural effect on The Broad in Los Angeles; Graphic Concrete at Les Docks Libre apartments in Marseille; Níall Mclaughlin's friezes at East Village Stratford

Elaine Toogood explores the many colours, textures and decorative effects of precast-concrete cladding

Think of a precast concrete facade in the UK and you very likely to conjure up an image of exposed grey walls, with little or no adornment, typical of "brutal" British postwar architecture. Concrete was after all the material of choice during this time of structural expression: inexpensive, quick to build, robust enough to be exposed and without the contemporary insulation requirements to avoid cold bridging.

But concrete facades can be, and are, created in many ways, often so different that they may not be perceived as concrete at all. The concrete panel may be hidden behind a thin facing of brick or stone cast into its surface, offering a cost-effective and efficient use of these materials. Or the concrete itself may be designed to resemble the colour and texture of stone, using sands and aggregates for natural colour. Much of the UK's architectural precast concrete is produced in this way and commonly referred to as reconstituted stone, or "recon". The range of colours and textures is further expanded through the use of pigments in the mix, form liners and finishing techniques such as polishing.

In terms of ornamentation too, precast-concrete cladding offers a far wider scope expression than simply the reductive aesthetic of modernism. It is not generally realised that a substantial proportion of the ornate bay columns and other decorative features of late Victorian and Edwardian speculative housing are of precast concrete used as a cost-effective, labour-efficient means of reproducing decorative elements. Towards the end of the 19th century, R. Norman Shaw was designing ornate patterns for precast concrete panels, including the earliest examples of non-structural precast concrete cladding used for William Lascelle's patented domestic housing system. A contemporary incarnation of this might be Aecom's prototype Rational House in Hammersmith, a good illustration of how relief, texture and even different textures can be incorporated into a single precast concrete panel.

Any article about decorative concrete in the UK would not be complete without a mention of Bill Mitchell and his extraordinary body of work, including casting concrete panels from sculpted polystyrene. In the UK, architectural precast cladding is a product that offers bespoke design and great scope for creativity and expression. But this does not preclude the repetition of decorative features, in fact the casting process of concrete facilitates it. East Village Stratford (formerly the Olympic athletes' village) offers many fine examples of sculptural decoration using precast concrete. These include Níall Mclaughlin's dramatic friezes of white concrete, cast in moulds created from a digital scan of the Elgin marbles, and cut using an automatic 5-axis router. Here five different-sized panels were cast from each mould.

Digital technology has also provided a simple means of creating permanent pattern and images through the patented processes of Graphic Concrete and Graphic Relief. While manufacturing processes are evolving, developments in concrete technology also offer opportunities for new forms of expression. Panels using fibres as reinforcement are more slender and lightweight but retain much of the material quality of regular precast concrete. Glass-fibre reinforced concrete (GFRC or GRC) for example, as used on The Broad in Los Angeles by Diller Scofidio + Renfro (see CQ 254), can be just 15-20mm thick, enabling the creation of hollow and therefore lighter 3D forms. Ultra-high performance concrete (UHPC) provides similar slenderness but with loadbearing capacity, dramatically widening the scope of opportunities for design using precast cladding, and potentially incorporating cantilevers and even multiple openings.

So precast concrete manufacturing offers myriad ways to achieve high-quality, expressive and beautiful facades – it's time more of us began to realise its potential.



END GAME

Jonathan Reid explains how a well-planned post-finishing programme can enhance the look of new concrete once cast on site

We live and work in an ever increasing number and variety of spaces where concrete is used as the finished medium and visual surface; hardly surprising given the material's sculptural versatility and thermal mass qualities. This places an onus on the project team to produce clearly defined specifications, set expectations and present procurement practices that achieve the original aesthetic design intent. Post-finishing programmes can offer valuable support that's missing from specifications with scant "making good" clauses.

What is post-finishing?

Post-finishing is any controlled intervention or mechanism that improves concrete's aesthetic quality after the concreting process is complete, allowing for future maintenance provision and planning for the end user. Unlike other post-finishing techniques that alter the surface texture of concrete, such as shot blasting, this article will focus on the planning and delivery associated with remediation, or improving the overall appearance of newly formed concrete.

Communication, discussion and planning is key to controlling subjectivity when making aesthetic judgments. Concrete is a natural material, and will always have some tonal and surface variation. Some so-called blemishes are inevitable and often acceptable, depending upon the finish specified.

The objective of integrated post-finishing is to keep the scope of remediation work to a minimum, celebrating concrete itself while improving the aesthetic. Fundamentally, any work undertaken to the as-struck finish must maintain the inherent character and nature of the concrete, unless an applied finish is required.

Planned or integrated post-finishing reduces risk and improves quality under a clear protocol set out at the start of a project. A strategy is established

ANY WORK UNDERTAKEN TO THE AS-STRUCK FINISH MUST MAINTAIN THE INHERENT CHARACTER AND NATURE OF THE CONCRETE





for the following processes:

- Curing and protection
- Cleaning
- Remedial works
- Sealing
- Handover and content for operation and maintenance (O&M) manuals

The flowchart in figure 1 shows the ideal order, process and roles involved in successful post-finishing procurement.

Curing and protection

Curing provides adequate moisture, temperature and time to allow the concrete to achieve the desired properties for its intended use. Maintaining similar levels of moisture in the concrete while keeping an air flow around the surface will prevent permanent discolouration. It is useful to combine protection and curing as one operation by covering or boxing in surfaces with an air gap until the concrete is ready for handover.

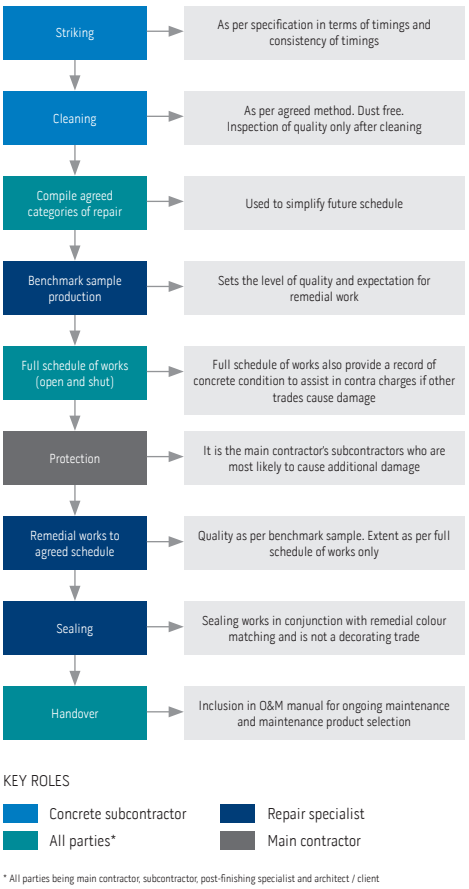
Water ingress, from rain for example, can also create instances of blemishes that cleaning will not resolve. Any protection should be designed to prevent this. Although this is not always practical, it should be noted that such protection can greatly reduce the impact of these blemishes.

Cleaning

The benefits of a consistent cleaning regime cannot be underestimated when it comes to improving aesthetic value. Judging concrete quality is only viable after cleaning, but it can also permanently change the surface quality of concrete.

Methods should be trialled early on depending on the type of surface finish and whether the cleaning is likely to abrade the surface. Soffits often benefit from a different approach to walls on the same project but, whichever method is used, cleaning should start with the least invasive approach. Dry abrasive cleaning will temporarily lighten the tone and wet cleaning will temporarily darken the tone. Only when dust free and dry will the true underlying tone and variation be exposed. Chemical cleaning is

FIGURE 1: ROLES IN SUCCESSFUL POST-FINISHING PROCUREMENT



* All parties being main contractor, subcontractor, post-finishing specialist and architect / client

LEFT Oriel Mostyn Gallery in Llandudno, Wales by Ellis Williams Architects. The high quality of the finished concrete was aided by an integrated post-finishing protocol

BELOW The before and after photographs show what can be done with a clearly defined post-finishing programme. Surface discolouration can be repaired to reveal the true quality of the concrete





Main photo: Hélène Binet; Other images: GreyMatter Concrete





Photos: GreyMatter Concrete

ABOVE The high-quality finish of the self-compacting concrete at London Bridge station's new concourse required some post-finishing





ABOVE An example of construction joint repair

not usually practical for in-situ concrete.

"Active" cleaning regimes should also be maintained during pours. This is key for reducing or removing the risk of grout-loss striations at construction joints on walls and columns. Because grout-tight joints are essential to producing visual concrete finishes, continual inspection during upper pour and compaction is vital. Gentle sponging and buffing of fresh grout loss reduces staining and the need for future cleaning. This is especially true of board-marked concrete where the biggest issue can be unchecked grout stains running from the pour above.

Remedial works

Even with the greatest care and professionalism, some degree of remediation works to visual concrete is inevitable and should be planned for. The biggest potential stumbling block is the failure to to put in place a procedure for how and when to undertake these works and what quality to expect.

Remedial works are intrinsically linked to curing, protection, cleaning and sealing activities, which should be documented and woven into the manual for the O&M programme.

Remedial works should take the following steps, in this order:

- Identifying "categories of repair" as soon as the concrete is clean
- Trialling methods and quality-testing on the mock-up in combination with sealing
- Producing a benchmark sample in situ, treating each category of repair
- Creating a full schedule of works as agreed on site after cleaning is complete
- Undertaking the aforementioned schedule once the protection is removed, the building is weathertight, with glazing, heating and, if possible, lighting installed
- Sealing (if specified) should be implemented as part of the post-finishing package alongside the remedial works programme.

It is very useful to compile a list of repair types early in the contract. This assists in identification and also probable cause, allowing for adjustments in working practices to reduce future issues. Below is a list of common categories of repair:

- Honeycombing
- Blowholes
- Construction joint deflection
- Grout-loss-hydration staining
- Construction damage
- Sand run segregation
- Construction oversights
- Surface discolouration
- Unplanned repairs

Benchmark samples for approval

Producing benchmark samples of remedial processes is key to allowing projects to progress in the knowledge that a full system is in place to deliver the required quality. It is important to produce a full set of samples on the actual concrete for each repair type and for this work to be undertaken as soon as the concrete is clean. Although trials can be undertaken on the mock-up, it is more useful for benchmark samples to be carried out in situ and for these repairs to be inspected from an agreed viewing distance.

It is not particularly useful to present a specific area for approval as natural variations in the material may make this sample non-representative elsewhere. It is more beneficial for each sample to treat each category of repair independently so as to demonstrate that individual repairs will not "interrupt the enjoyment of the design" and will "support the original design intent". Benchmark samples should also be sealed as per the specification so as to make the sample process as comprehensive and informative as possible.

Schedule of works

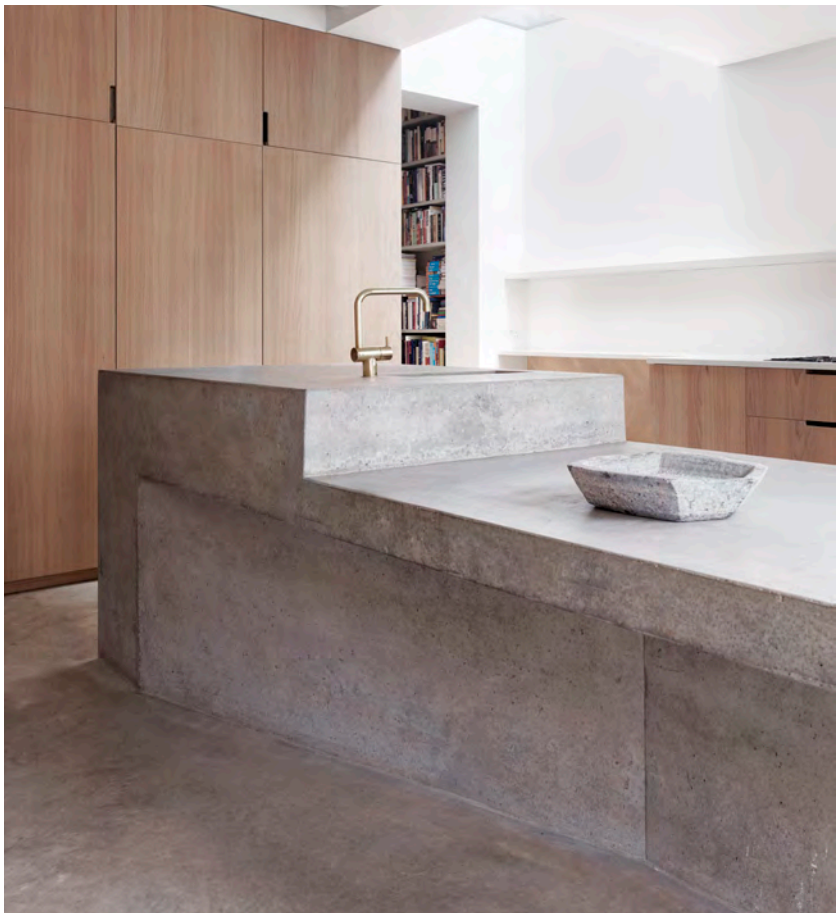
Following the process of approved benchmark remedial works, a full schedule of works should be collated prior to protecting or re-covering surfaces. Projects that commit to a fully agreed schedule of works tend to support the concrete aesthetic more in the long run, limiting "mission creep" that can lead to over-repairing.

Schedules of work detail position, type and location including a "before" image of the concrete. The post-finishing specialist is best placed to collate all before, during and after imagery, compiling reports for handover. This can also be used as a record of concrete condition, limiting liability should further damage be caused by others.

Sealing, handover and O&M manual

Sealers may be used as dust binders, for lessening maintenance regimes or as anti-graffiti protection. Although not essential, sealers provide a degree of protection especially in the public realm. Proposed types should be trialled on the mock-up and tested for suitability, with the following key characteristics noted: maintained or enhanced surface appearance, performance levels in terms of penetration, breathability, dust suppression, hydrophobic nature and light reflectivity.

Jonathan Reid is a remediation consultant and practitioner at GreyMatter Concrete







Photos: Richard Leeney; GreyMatter Concrete

SEALED AND DELIVERED

CLOCKWISE FROM LEFT
The kitchen island at McLaren Excell's Ingersoll Road project in London was finished with a surface impregantor; Food-safe sealers are available for countertops; A sealed/unsealed surface

Jonathan Reid explains what to look out for when it comes to choosing sealant types

When it comes to protecting finished visual concrete, choosing the most appropriate type of sealer can be confusing. First, do you need to seal the concrete at all? This depends upon the maintenance demands of the work to be protected and whether sealing the concrete is worth the time and expense. For domestic projects, sealing may be much less of a priority than for a public building where the surface patina may develop more quickly with regular use. In both scenarios, using sealers as dust binders can be useful, as is sealing floors and countertops.

To start with, it is helpful to narrow down the choice by dividing sealers into two broad categories: penetrative sealers and topical sealers.

■ **Penetrative sealers** chemically react deep within the concrete pores with minimal change to the appearance. The particle size is small to allow for penetration while maintaining breathability. Types of penetrative sealer include silicate densifiers, silane and siloxane hybrids and siliconates.

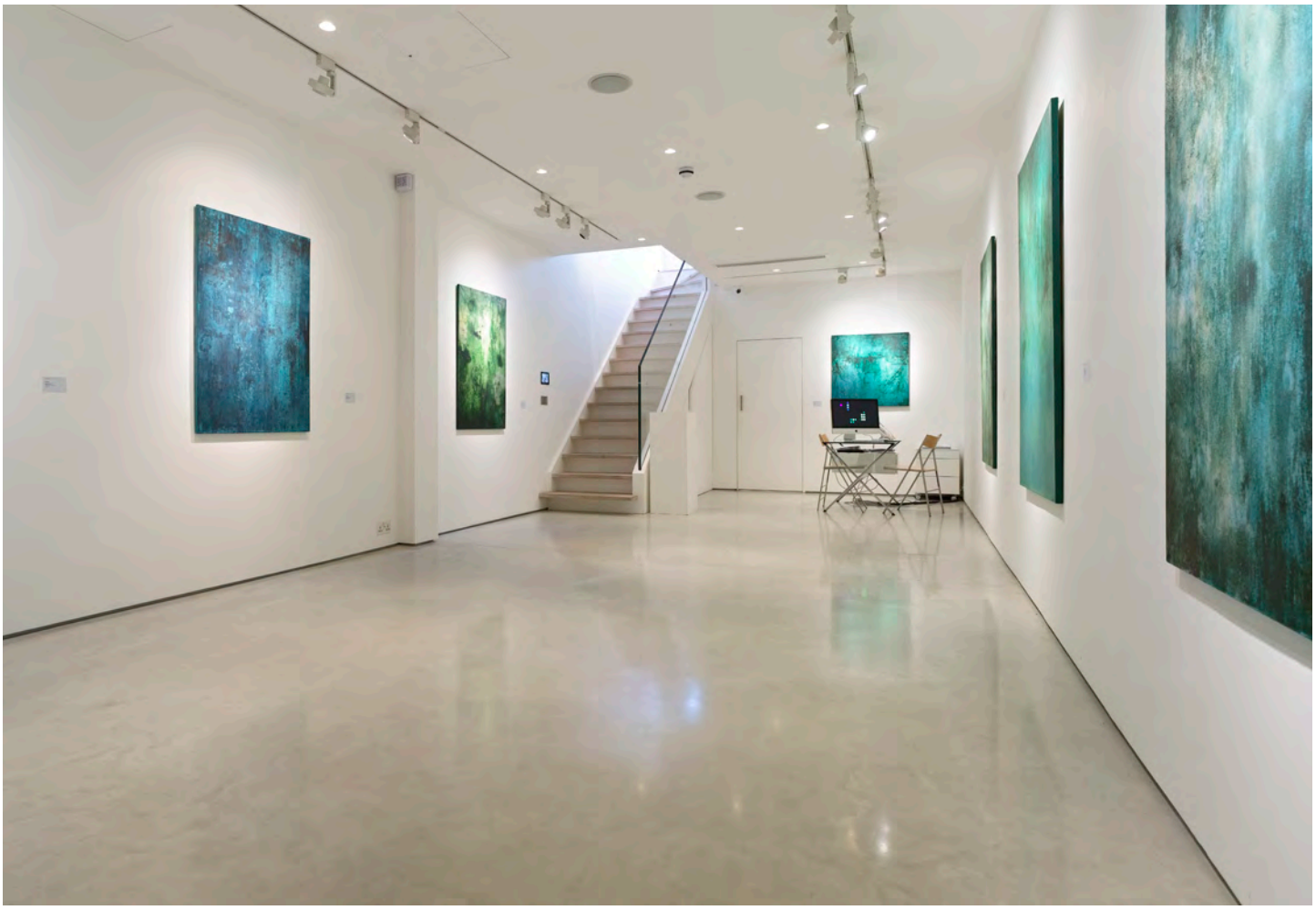
■ **Topical sealers** are made up of larger particles and they are often described as a coating. While penetrative sealers are designed to reduce common issues such as staining, topical sealers are designed to prevent them in the first place. Topical sealers will alter the natural appearance of the concrete – for example, adding a sheen or intensifying the colour. Some can be hard to apply and can become slippery when wet. Topical sealers include acrylics, epoxies and associated mixtures of epoxies coated with urethanes or polyaspatic coatings.

Silane/siloxane penetrative sealers are often used to protect walls, columns, ceilings and external elements where minimal appearance change is required and the concrete needs hydrophobic protection from weather, water or other liquids, or graffiti. Polished concrete can benefit from the use of a silicate such as lithium silicate to harden and densify the surface, with a penetrative sealer added to boost performance. Food-safe sealers are available for polished concrete countertops.

Topical sealers vary in robustness. Acrylics are often used for less expensive coatings, or to enhance colour or sheen. Their use is associated with stamped concrete and external floors and patios, whereas epoxy systems are more suitable for industrial environments such as warehouses or garage floors.

The guiding principle for sealer selection should be the desired aesthetic performance of the concrete in the immediate and longer term. Either it will be necessary to leave the concrete and its evolving patina in its most natural form, to use a sealer that will cause minimal change to its appearance, or to enhance protection, potentially changing the look and feel of the material. In any event, it is prudent to carry out sample tests to ensure the most appropriate balance is struck between performance, protection and the aesthetic requirements of the project.

Jonathan Reid is a remediation consultant and practitioner at GreyMatter Concrete



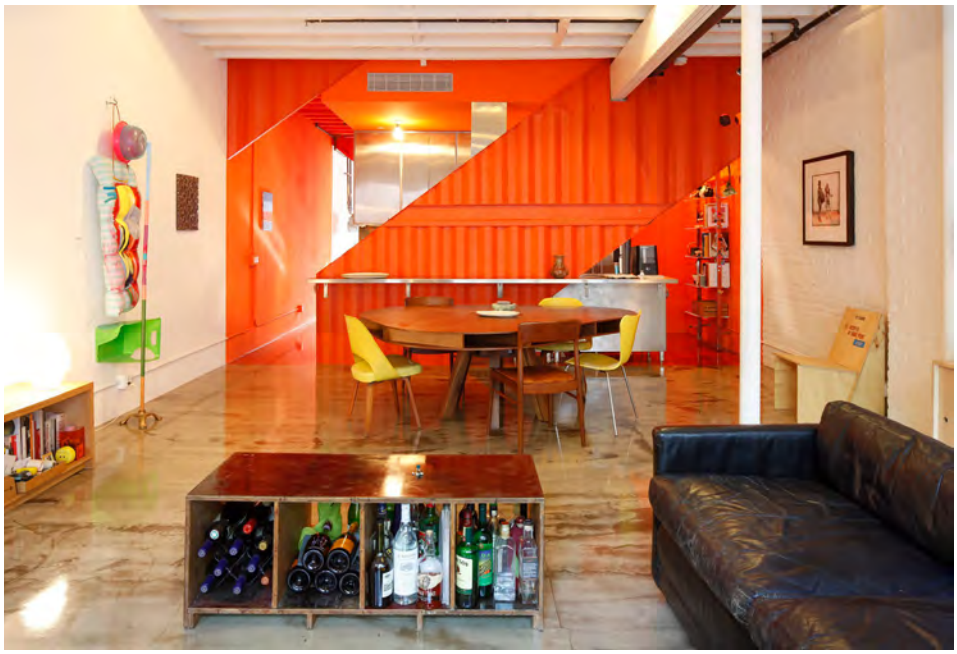
FLOORING IT

Elaine Toogood shares her specification tips for achieving top-notch polished concrete floors

It sounds like a simple matter to describe the type of smooth concrete floor finish that you wish to achieve, but there are a number of variables to consider. Diamond-ground polished concrete floors are ground progressively smoother, a process which removes the surface of the concrete. The aggregate is usually exposed, the extent and size depending on the depth of surface removed. Alternatively, power-trowelled floors are also referred to as polished concrete, but give a smooth, dense surface and a "solid" colour finish with minimal aggregate exposure. Each requires a significantly different specification and installation and, importantly, has different programming implications.

Below is a set of key parameters to achieve best results:

- Establish your aesthetic and visit examples to benchmark the type and quality required, bearing in mind that every polished concrete floor has a unique finish with variations across its surface.
- Consider its function and likely maintenance regime. An industrial floor with wheeled traffic, for example, is likely to require greater crack control.
- Where aesthetics are important, appoint a specialist installer to carry out the work and seek pre-tender advice. Most contractors have their own specification and method statements adapted to suit project particulars, including the concrete supply – because control of the delivery and quality of the concrete is critical. Typically the concrete should have a minimum 350kg/m^3 CEM I, with well-graded aggregates.
- For diamond-ground floors, the choice of aggregate is critical to the appearance and options should be discussed with the specialist installer. Unlike terrazzo floors, uneven aggregate distribution should be expected.
- Allow 100mm depth for an unbonded concrete topping (screed) to reduce risk of curling. If heating pipes are embedded, this depth is to the top of insulation, ie it includes the depth of the pipes.
- Don't be too specific about the exact shade of grey of the floor. This will save time and cost. Colours vary around the country depending on source of local natural materials and colour of cement. The process of burnishing or trowelling also changes the tone when compared to a formed face cast using the same mix.
- If you want to be specific about the tone or colour, consider using pigmented dry shake toppings. These proprietary powders combine surface hardeners, cement and pigments and are broadcast onto the fresh concrete to be floated or trowelled in. They can be specified to any RAL colour but there will still be tonal variation in the surface, as with any concrete surface. It is also possible to add pigment to the mix to provide a through colour. This is worth considering for a ground polished floor or where steps or other formed features are incorporated into the design.
- Concrete shrinks as it cures, so non-structural cracks are to be expected. To minimise cracking, joints should be created either using screed rails to isolate areas of pour, or by saw-cutting into the concrete afterwards to induce crack location.





CLOCKWISE FROM LEFT
At the Andipa gallery in Knightsbridge, contractor Lazenby installed an Off White concrete floor, finished with a satin sealant and a matching mastic colour in the joints; Highly polished concrete floors complement a roof extension made from shipping containers at the Irving Place Carriage House in Brooklyn by Lot-Ek; McLaren Excell's Kew House in London has polished concrete floors throughout the interior; At Christ & Gantenbein's extension to the Swiss National Museum in Zurich, the floors were given a deep polish to resemble the terrazzo finishes of the original 19th-century galleries

Designers should provide design intent drawings for discussion with installers. A useful rule of thumb for 100mm depth is to place a joint at approximate 4m centres, ideally creating as square an area as possible. Joints should also be placed to separate areas that are likely to dry at different rates, such as dog legs, ingress corners or between shaded or sunny areas. Underfloor heating needs to be commissioned at a steady slow rate, but only once the concrete has cured sufficiently. Anything that might inhibit shrinkage could lead to cracking so attention is required to perimeter details and any abrupt variations under the concrete. Reinforcement mats (mesh) can help limit cracking and sometimes fibres are used. Proprietary low-shrink mixes are available.

■ Joints can be left as a shadow gap or filled afterwards with steel or brass rods or more commonly with flexible grout or mastic. Linings can hide the perimeter isolation gap at wall junctions.

■ Since power trowelling takes place within hours of the concrete floor being placed, planning and timing of operations is essential. Careful scheduling, usually with early morning pours, will help reduce the need for power trowelling late into the night with the associated risk of sloppy workmanship. Diamond grinding takes place once the concrete is sufficiently cured, nominally after about a month.

■ The time taken to trowel or grind any floor will depend not only on area, but on the length of perimeter walls, where smaller equipment is needed. Ideally internal walls should be installed after the concrete is complete. It is worth noting that skill is required to limit the visual impact of different tools, and a difference in finish around the boundary is to be expected. A dry shake finish produces less tonal variation.

■ Recessed door tracks and floor boxes are best installed after the concrete floor, using knock-out ply-box spacers to create accurate voids in the floor. Attention to detail at thresholds is essential.

■ Once the floor is polished or trowelled smooth it will be left to cure. Some installers favour whole-room curing; others place mats on top for protection. The timing of each is critical and should be discussed with the contractor and programmed in advance. Be aware that any isolated item placed on fresh concrete can create a permanent dark patch due to differential curing.

■ Finally, the floor should be sealed to improve maintenance and possibly enhance the sheen.



Photos: Jeremy Phillips, Danny Bright, Simone Bossi, Roman Keller



ABOVE This bold extension to a ground-floor flat in Herne Hill, south London by architect Nimtim uses Forticrete's Splitface architectural masonry in ivory

BLOCK BEAUTY

With the right specification, exposed blockwork can not only be durable and cost-effective, but beautiful too, writes Elaine Toogood

The specification and detailing of concrete blockwork masonry is more akin to brickwork than other concrete products, and focuses on product selection rather than custom design. Choosing the right block is critical. A wide range of colours and textures are available, and while block dimensions are standardised, it is possible to commission bespoke shapes for special elements in a design. New products are also constantly evolving.

Types of block

Architectural facing masonry is blockwork specifically designed and manufactured to be left exposed, combining structure and surface finish. Its uses range from landscaping features and robust internal partitions to the external or inner leaf of cavity wall construction. An assortment of natural stone colours and textures, such as split-faced or shot-blasted, are available, providing a cost-effective alternative to stone, but the aesthetic options extend much further to include a range of bold solid colours and polished and honed surfaces.

The typical grey blocks used for internal structural walls can also be left exposed without detriment to structural performance, but a more appropriate aesthetic solution is to specify paint-grade or fair-faced blocks, which have a smooth, more closed texture. If more than one face is to be exposed, this must be stipulated from the outset. Where continuity of colour is required, fair-faced blocks should be sourced from a single location.

Design guidance

The choice of bond is a fundamental aesthetic and structural design decision. The simplest, most cost-effective option is stretcher bond but other patterns and arrangements are possible. Some blocks are available with profiles to help mask the typical stretcher bond pattern – for example, those with grooves to mimic stack bonding. Setting out walls and openings to suit coursing and unit dimensions is critical and should be considered as early as possible. It is essential to elevate walls to identify the need for any special sizes and to avoid or minimise cut blocks. Factory-cut blocks are recommended for visual blockwork.

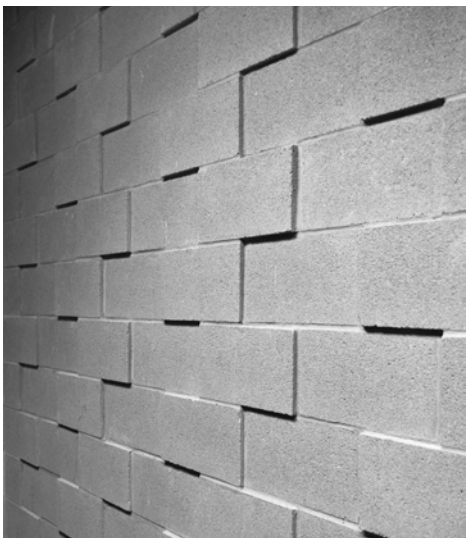
Mortar joints should be specified and installed carefully to achieve not only the correct strength but also colour consistency and weathering performance. Dry silo or ready-to-use mortars are recommended. The joint profile, whether bucket handle, flush, struck or weathered is a key aesthetic decision and should take into account both the surface texture of the block and exposure conditions. It can be a challenge to achieve a quality finish using flush joints, especially with textured blocks; thus they are not normally recommended for fair-faced blockwork.

Consideration should also be given to the location of vertical and horizontal movement joints so that they are integrated into the overall design, rather than being an afterthought. Vertical joints have the most visual impact and are typically required every 6-7m. They are also recommended at changes in wall heights, loading conditions and at abutments with other structures. It should be noted that the movement joints are required for shrinkage, rather than the expansion that is found in clay bricks. Bed joint reinforcement helps to reduce the need for additional movement joints in areas of higher risk. This includes between courses of dissimilar materials or below long windows where the aspect ratio of the walls exceeds 3:1.

It is good practice to build a control panel before works start to agree workmanship quality and assist with final detailing decisions. The panel should ideally be in a position where it can remain for reference throughout the project.

With the right materials and construction approach, beautiful, durable walls are easily achieved using exposed blockwork, especially when combined with good, creative detailing.

Further information about blockwork is available from the Modern Masonry Alliance: www.modernmasonry.co.uk



ABOVE Reach Architects' pavilion at South East Skyline Ball Park in San Antonio, Texas, features carefully detailed masonry blocks that shift to create a textured surface

Photos: Forticrete; Reach Architects

PUMP IT UP

There are many great examples of exposed in-situ finishes created using self-compacting concrete. Elaine Toogood explains how



To achieve a good standard of finish with exposed concrete, an appropriate mix is essential. This includes sufficient cementitious content (generally 350kg/m^3), the right balance and proportion of graded fine and course aggregates and importantly a low water-cement ratio (0.5 maximum). The mix is ideally pumpable, and so to achieve this without adding water, the concrete supplier adds a plasticising admixture. The resultant fluidity facilitates correct placement of the concrete, but careful and consistent compaction is still an essential part of the process to achieve a good standard of surface finish.

That is, unless self-compacting concrete (SCC) is used. SCC does exactly what its name suggests. The mix is supplied in a very fluid, almost liquid state, enabling it to flow unassisted into all areas of the mould.

Omitting the compaction stage has numerous advantages, including time and labour savings, but more specifically for visual concrete, less reliance on workmanship to achieve a good standard of surface finish. This is especially useful, and sometimes essential, when the formwork is congested with reinforcement and services, allowing little space for the vibration rod to be consistently effective. Potential damage to the formwork facing from the vibration rod is also avoided, giving more chance of reusing the facing, and avoiding marks on the concrete where the boards are damaged.

SCC is so fluid that it can also be pumped from low level up into the formwork – useful when access from above is limited. In such circumstances, the location of the pump needs to be carefully considered to reduce the visual impact of the 120mm or so round hole in the formwork where the supply is connected.

SCC for visual concrete is normally specified as a proprietary concrete – that is, a product developed by the concrete supplier for a specific application, such as 'exposed concrete walls' or 'exposed floors (self-levelling concrete)'. The mix is tailored to meet all the usual performance criteria stipulated by the design team in terms of strength, exposure and use of cementitious replacements, such as ground granulated blast-furnace slag or fly ash.

The fluidity is achieved using a combination of super-plasticiser admixture and carefully graded aggregates. The composition of the concrete is such that at the molecular level the particles repel each other, creating the fluidity without adversely affecting curing times or strength gain. The aggregate need not always be smaller, but this may be necessary for congested formwork. SCC can also be specified as a designed concrete, provided the engineer is sufficiently proficient in concrete technology, or has obtained the appropriate advice.

SCC may be a relatively recent development in concrete technology, but it has already opened up new possibilities in the detailed design and specification of visual concrete.

The Concrete Centre's YouTube channel has a short film in which structural engineer Will York of Price & Myers explains SCC. The video is an extract from a lecture about the award-winning Juergen Teller Studio: www.youtube.com/c/TheConcreteCentrevideos

SCC on the farm

Combe Manor Farm is an extraordinary house, nestled into the landscape of the Sussex/Kent border. Its recent completion follows a decade of careful construction and attention to detail by its Danish designer, contractor, client and now occupant. Sustainability was high on the list of considerations for both material selection and performance. The house is designed to Passivhaus principles, with high levels of thermal insulation and airtightness and very low energy use, assisted by the thermal mass of the exposed concrete structure. The concrete itself is pigmented, waterproofed and self-compacting, an innovative combination of concrete technologies. SCC was chosen to overcome areas of construction where vibration would have been challenging, and to achieve a high quality of finish.

Bodin and Nielsen was the designer and contractor and Price & Myers the structural engineer.



Photos: Bodin and Nielsen







Photos: Rory Gardiner

INTO THE ROUGH

Roughly textured concrete is enjoying a renaissance. Elaine Toogood explores the different aesthetics and the techniques used to create them

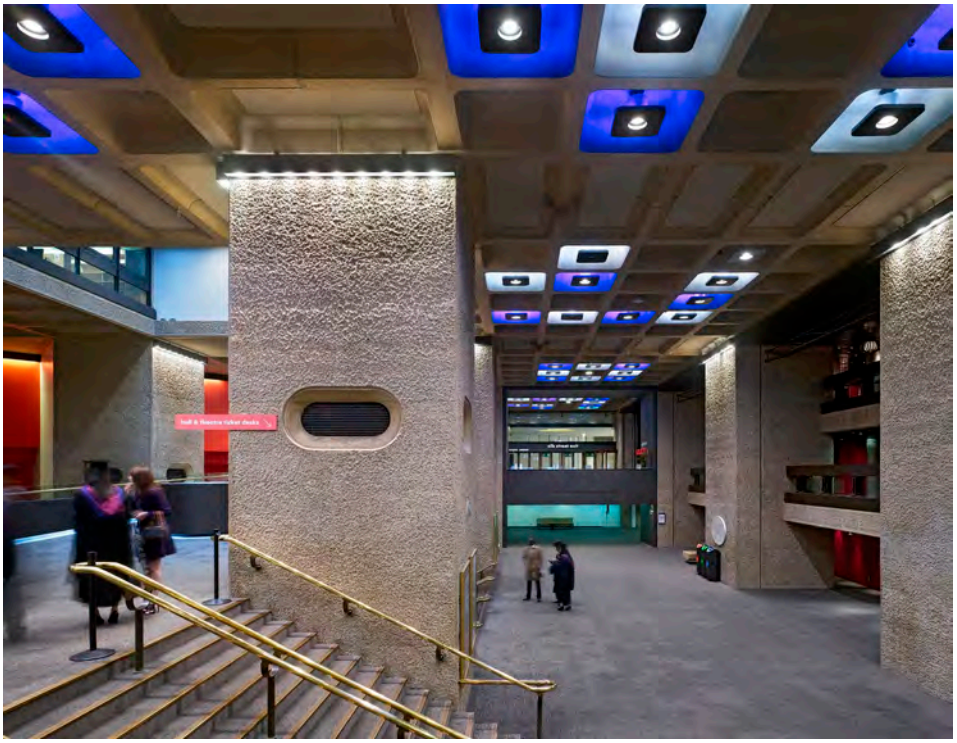
Contemporary construction methods often dictate that the surface of formed concrete is smooth. But rough textures offer a variety of alternative aesthetics, which are becoming increasingly popular. Arguably, the simplest means of creating heavily textured concrete is to cast it against a textured surface. A huge range of effects can be achieved with flexible form liners, either pre-formed or bespoke. The defining characteristic of this process is that the surface remains intact, with aggregates hidden behind a smooth paste of cements. For deep textures, the best results are produced by casting horizontally with liners placed in the base of the mould, which reduces the risk of leaving the recesses unfilled.

Smooth concrete can also be given a rough texture after the formwork has been struck with "post-finishing" techniques to remove or break part of the surface and expose the aggregate. Depending on the technique used, the texture can vary considerably.

OPPOSITE The textured internal concrete surfaces of Mole Architects' The Houseboat were created by shot-blasting the in-situ concrete surfaces to reveal natural aggregates. The external photo shows the concrete frame under construction

RIGHT Bush-hammered concrete is one of the defining characteristics of the Barbican estate in London

BELOW Peter Zumthor's Bruder Klaus Field Chapel in Germany, created from rammed concrete made using aggregates from the surrounding fields



Photos: Getty Images/VIEW Pictures; Seier+Seier/Flickr

Surface retarders are proprietary liquids or gels that prevent the surface of new concrete from hardening. For formed concrete, a coating (known as a negative retarder) is applied to the inside of the formwork in place of a release agent. Once the formwork is struck, the soft surface of the unset mortar that has not set is washed or brushed away to reveal a plane of exposed aggregate. The amount of surface removed or "depth of etch" is controlled through the grade or strength of retarder, with the option to reveal much of the undamaged shape of the coarse aggregate. Timing is critical with this method and a warmer ambient temperature and higher strength of concrete will reduce the window of opportunity to remove the surface before it starts to harden again. This technique is therefore more often used in the controlled conditions of a precast factory rather than on site, although retardants are commonly used for unformed in-situ concrete.



Shot and grit-blasting can be used to create rough textures on hardened concrete, including in-situ concrete. Such abrasive blasting is generally used to remove surface coatings but can also reveal either small or large aggregate, depending on the amount of mortar removed. Workmanship should be tested in advance to agree standards and techniques. The Concrete Society publication Visual Concrete – Finishes suggests that a heavy, or deep, abrasive blast is best carried out when the concrete is still relatively weak – for example, one to two days after placement – whereas a light abrasive blast may take place between three and seven days later. Concrete can of course be abraded much later than this, but the process, like the concrete, will be that much harder.

As with any post-finishing technique, an allowance for extra cover is required to ensure the minimum designed depth is maintained, and of course the size and type of aggregate used is in the mix is fundamental to the final aesthetic. The textured internal concrete surfaces of The Houseboat in Poole by Mole Architects were created by shot-blasting the in-situ concrete surfaces to reveal natural aggregates from the Mendip hills.

There are many examples of mid-20th century precast and in-situ concrete structures featuring heavily textured surfaces, many created by tooling the concrete once it had hardened. These finishes include bush-hammering and point-tooling as well as those with a needle-gun finish. All are

RAMMED CONCRETE IS RATHER NICHE, BUT HAS A STRONG AESTHETIC APPEAL REQUIRING CLOSE ATTENTION TO MIX, PROCESS AND TESTING

appropriate for creating a rusticated, bumpy surface that may or may not reveal the shape of the coarse aggregate. More recently, health and safety concerns have limited the use of these techniques to very controlled situations, often factory-based. A notable recent in-situ example is 21 Caroline Place by Amin Taha Architects (CQ 260, summer 2017), where the specifically sourced white aggregate was exposed on the soffit and walls of the basement interior by bush-hammering away 30mm of the surface. Another example is the hammered ribs found at Walmer Yard, a housing development in London by Peter Salter.

It is also possible to achieve texture within the cast surface of the concrete itself simply by lack of compaction or by using special mixes to create holes or gaps, such as no-fines concrete. Rammed concrete would fall into this category. Rammed concrete is a method for compacting fairly dry, hand-batched concrete, rammed manually into the formwork in layers to create a highly individual stratified and often crumbly textured concrete. A well-documented example is the Bruder Klaus Field Chapel in Mechernich, Germany, designed by Peter Zumthor using aggregates from the surrounding fields. This method of placing concrete is not suitable for reinforced concrete, and so walls must be wide enough to provide the necessary stability to support themselves, as well as to provide sufficient space in the mould for the concrete to be tamped. The amount of concrete that can be placed in one day is restricted, thereby creating numerous horizontal layers. This combination of labour intensity and structural limitation renders the method difficult to produce at scale. It is therefore rather niche, but has a strong aesthetic appeal requiring close attention to mix, process and testing to create the desired effect. It has been specified by Zumthor again for the walls of Secular Retreat, a project currently under construction in the Devon countryside.

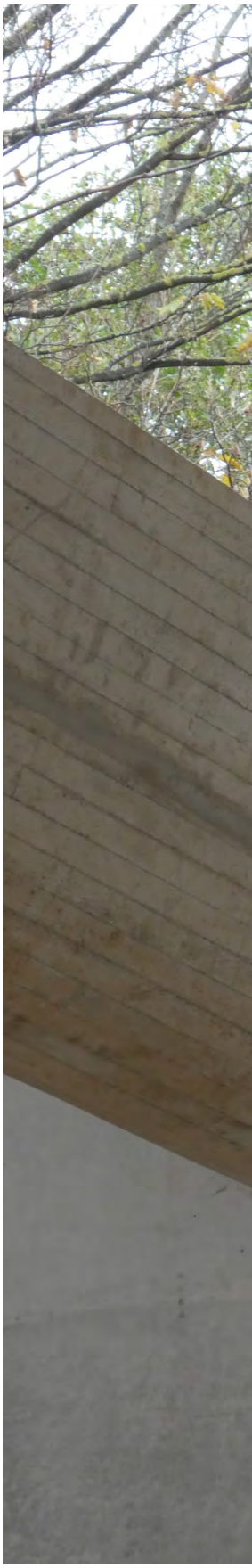
At a recent Concrete Elegance presentation for The Concrete Centre, Ian Bramwell of Mole Architects, the architect of The Houseboat and executive architect of both Secular Retreat and Walmer Yard, referred to creating the concrete as an "artisan" process. This is a term often used in the food world for activities such as bread-making, and usually intended to express care, expertise and quality of ingredients. As Bramwell says, perhaps creating highly textured concrete is less about being rough and more like baking very "well-bred bread".

For guidance on achieving exposed concrete, download Visual Concrete at concretecentre.com/publications









TOP The new visitor centre at Yorkshire Sculpture Park is set into the landscape of a former quarry

MIDDLE Its sawtooth roof is formed as a series of inclined reinforced concrete beams spanning 10.5m over the gallery

ABOVE Within each 1.2m lift of formwork are four sub-layers, each containing a different concrete mix

RIGHT The concrete beams have curved profiles that draw light into the gallery and across their board-marked surfaces

PROJECT TEAM
Architect Feilden Fowles
Structural engineer engineersHRW
Main contractor William Birch & Sons
Concrete contractor Northfield Construction



◀ Visitor Centre and Gallery, Yorkshire Sculpture Park

The new gallery and visitor centre at the Yorkshire Sculpture Park is set into the hillside of a former quarry, a location that has informed and inspired its construction and appearance. It was conceived as "a sculptural element, emerging from the earth", says Fergus Feilden of architect Feilden Fowles. 'We wanted the building to read as being 'of the land' with texture and layers like geological strata."

Cement-stabilised, rammed earth was investigated as an option, but was discounted due to detailing constraints dictated by the material, which would have compromised the architectural design intent and reduced durability in comparison to concrete. "Rammed earth needs to be protected to be durable," explains project engineer Chris Stobbart at engineersHRW. "Walls using this technique are typically made with 'good boots and a good hat', with the rammed earth raised above the external ground on an upstand with well-drained footings and with generous overhanging eaves at the top to protect the walls. Concrete was able to offer increased durability with less risk to the client and more flexibility to achieve the desired architectural finish."

Rather than physically ram the concrete in place, the walls were constructed using reinforced concrete poured in shallow layers. Within each 1.2m lift of formwork are four sub-layers, each containing a different concrete mix with varying pigments and aggregate. The formwork was pre-treated with retardant so that, once struck, the face of the concrete could be jet-washed to expose the aggregate and provide the layers of rough texture required.

engineersHRW specified structural parameters for the mix within typical limits for reinforced concrete. By testing and developing sample panels, the contractor determined that it could achieve the desired architectural appearance with a standard S3 consistence class. This provided a mix that was well graded to give an even distribution of aggregates without segregation.

The compressive strength of each mix was confirmed by cube testing. The sub-layers within a 1.2m lift were each poured before the sub-layer below was fully cured thereby allowing them to blend together to give a better shear interface. "Some small variation in stiffness between layers is expected due to the use of different aggregate types," says Stobbart, "but since each layer is relatively long and consistent between vertical joints, local stiff points within a wall panel are avoided. Otherwise, they could lead to cracking."

The jet-blasting was accommodated by increased cover to the reinforcement bars. This increased cover together with the wide spacing of the reinforcement, also enabled adequate compaction of the textured concrete when poured in such shallow layers.

Concrete subcontractor Northfield Construction built four sample walls in its yard to test out different construction techniques, including tests for shot-blasting, types of retardant and curing times between pours. Part of the north wall in the building was also used as a construction trial. Only after such careful consideration and testing was the final combination of mixes and finishing processes scheduled for construction.

The project also includes structural concrete exposed internally with smooth, in-situ walls enclosing the gallery space. Its sawtooth roof is formed as a series of inclined reinforced concrete beams spanning 10.5m over the gallery. The curved profiles draw north light into the space and across their timber-board marked surface. Each profile incorporates a slotted lighting track and cast-in fixing points for the gallery to suspend artworks. As well as the gallery space, the building includes a restaurant, shop and public foyer. It is due to open in September.

Photos: Feilden Fowles



SEE FOR YOURSELF

A good visual concrete specification needs to refer to both current standards and built examples, writes Elaine Toogood

Successful visual concrete is dependent on a range of contributing factors, including design and detailing, the materials used and the quality of workmanship on site. But the starting point is the specification, which should clearly state the required surface quality. This should of course be written with reference to current standards, but there are other useful sources that specifiers can consult in order to achieve the best possible result and avoid unacceptable outcomes.

The current standard for visual concrete is BS EN 13670:2009 Execution of Concrete Structures, though the previous standard, BS 8110, is still used and recognised. BS EN 13670 describes types of surface finish as Basic, Ordinary, Plain or Special. Plain is where visual appearance is of some

importance, while Special requires that bespoke requirements are given.

BS 8110 classified surface finishes in two ways: by type of surface and by quality of finish. A type of surface is described as being left as-struck, either plain or profiled, or where the surface is to be removed or covered by another material. This is further divided into sub-types A, B and C giving more detail of aspects such as anticipated blemishes. The quality of finish is categorised as Class 2, 1 or Special class, where Class 1 covers most exposed concrete in buildings both inside and out and Special is reserved for the highest quality.

As BS EN 13670 only provides very brief descriptions, it also relies upon a specification of execution to define the quality and type of finish. One such specification is the National Structural Concrete Specification for Building Construction 4th Edition (NSCS), considered by many as an informal annex to the standard. The NSCS provides a detailed description of what can reasonably be expected by each type. Other standardised specifications include National Building Specification, Highways England Specification for Highway Works and Civil Engineering Specification for the Water Industry. Each has different terminology and requires different parameters.

A visual concrete specification should also make reference to built examples – relying on words alone leaves room for ambiguity, and reference to actual buildings helps to communicate aesthetic aspirations. For this purpose, test panels for reference have been produced in various locations around the country by Construct, the trade association for concrete contractors. Originally constructed to BS 8110, these panels have recently been reinterpreted to relate to the newer standard, representative of achievable quality of the Ordinary and Plain classes, using NSCS v4 with detailed descriptions provided. The Concrete Society publication Technical Report 52: Plain Formed Concrete Finishes is also a convenient reference document, containing 20 built examples created to different standards using different specification documents. It also has a useful introduction describing and comparing aspects of the most common specification standards in use in the UK.

But photographs are no substitute for the real thing. The Concrete Centre has compiled an online map of building case studies, many of which are publicly accessible (see link below). This enables design teams and clients to experience exposed concrete first-hand, and then agree on an example to include as a benchmark in the tender process – the basis upon which the Special specification is then built. This process is useful for managing and aligning expectations, recognising that concrete will always have natural variations in tone and acceptable blemishes such as small blow holes.

For a Special finish, it is recommended that a full-scale mock-up or trial panel be produced as early as possible to test the how the various aspects of one or two specification options (such as form facing material, release agent, concrete mix, workmanship) come together. It can then be agreed to represent a realistic level of quality or give an opportunity to try different parameters. For a Plain finish, NSCS v4 does not include a sample panel as standard, but a design team may still request one in order to de-risk the outcome. In this instance, the requirement for a sample panel should be made clear in the specification. It is also a good idea to specify a review process into the build, ideally after the first concrete is struck.

Whatever visual concrete finish is required, the key at this early stage in the process is for the design team to be clear on what is acceptable to the client and then to use all of the specification tools at their disposal to create the desired result.

To access The Concrete Centre's online map of case studies, go to www.concretecentre.com/casestudies

OPPOSITE AND BELOW
Graeme Massey Architects' Respite Pavilion at the North Ayrshire Community Hospital campus – one of the case studies on The Concrete Centre's online map



Photos: Russell Beard



FINAL FRAME: V&A DUNDEE

Designed by renowned Japanese architect Kengu Kuma, this extraordinary 8,000m² building looks (from some angles) like a ship about to sail off into the Firth of Tay, on whose banks it stands. None of its 21 elevations are vertical, and many of them are curved in two dimensions. Concrete walls up to 18m high incline outwards at various unlikely angles and onto these are attached no fewer than 2,429 precast-concrete elements weighing up to three tonnes each.

Photo: Hufton + Crow