CONCRETE QUARTERLY

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SWISS MUSEUM SPECIAL
Three major gallery extensions from the land where concrete is always the main attraction

INSIDE OUTHOUSE
Loyn & Co continues to redefine the rural British home with its stunning Manser Medal winner

SETTING THE PACE
High-quality structural solutions for when time is of the essence

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AGENDA

Guy Thompson
Head of architecture, housing and sustainability, The Concrete Centre

Method in our modernisation

Good ideas to increase housing supply must be welcome given the scale of the crisis now facing the UK. So welcome indeed is the Farmer Review, the latest in a long line of government commissioned reports that attempt to get to the bottom of the construction industry's under-performance. It is a perceptive, fearless and bracing analysis, as the subtitle "Modernise or Die" makes clear from the first page.

While manufacturing has improved productivity by 50% in the last two decades, construction has stagnated, Farmer points out. Of course, what manufacturing doesn't have to contend with is the extreme cyclical nature of the property market, along with a range of other factors. These do not encourage long-term investment decisions, such as in precast facilities – our Focus feature (pages 12-14) explores a number of precast solutions that can dramatically reduce build programmes.

If the government could use its might to even out demand, that would give confidence to those investing in all parts of construction. As Farmer writes: "Government has a strategic choice to make about the future role of grant funded social housing, which has historically been used as a counter-cyclical demand tool." Such confidence in demand would support investment.

INFLUENCING THE MARKET IS A DELICATE BUSINESS, PRONE TO UNINTENDED CONSEQUENCES

But influencing the market is a delicate business, prone to unintended consequences. For example, one of Farmer's proposals is an equivalent to the "carrier bag tax" on those procuring construction work via traditional methods. Investment in innovation is a good thing, but there are dangers to incentivising one part of the market over another. Such a tax could shut out those who are already addressing the market requirement through use of existing methods that are perfectly good. Traditional methods deliver the vast majority of current housebuilding. To increase housing starts, we need to grow capacity in these and premanufactured methods: we need both.

And such a tax could overlook the need for resilient homes. Given the challenges that a changing climate and ageing demographic present, we must not lose sight of this urgent issue. There are already proven techniques for building such homes – our priority should be to train more workers to deliver them, as well as increasing capacity in resilient off-site methods, but without throwing away centuries of know-how in a blind rush for speed.

this is concrete

HEALTH BEGINS AT HOME

There can hardly be a more important place to design for health and wellbeing than our homes, says This is Concrete blogger Guy Thompson – after all, "it is where most people spend most of their lives, especially the young and old". The UK Green Building Council evidently agrees, its Healthy Homes report exploring a range of contributing behavioural and environmental factors. "Many 'miracle' solutions to the housing crisis take no account of these performance aspects," warns Thompson. "Political drivers lead (perhaps inadvertently) to a short-term view, where factors such as air quality, thermal comfort, noise and resilience to climate change are not adequately considered."

Join the debate at www.thisisconcrete.co.uk

CONCRETE QUARTERLY

On the cover:
Swiss National Museum in Zurich. Photo by Roman Keller

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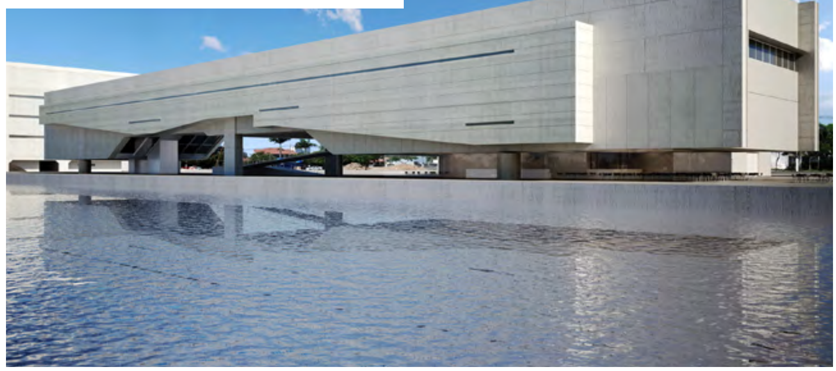
The Mendes touch, part 1

Grafton Architects' mighty UTEC university campus in Lima, Peru has been shortlisted for both the Design Museum's Design of the Year and the RIBA's new International Prize. The powerful concrete design was inspired by the work of Paulo Mendes da Rocha, who …

The Mendes touch, part 2

… has been awarded the 2017 RIBA Gold Medal. The 87-year-old Brazilian architect is known for a particular style of tropical brutalism, with projects including the Paulistano Athletic Club in São Paulo and Cais das Artes in Vitória (pictured).



Photos: Iwan Baan; Metro Arquitetos; AA Summer DLAB; Nicola Lyn Evans

Branching out

This year's Architectural Association Summer DLAB programme explored the use of robot fabrication with concrete. The completed work, designed by 21 participants from 11 countries, was an amorphous "tree" of interwoven concrete structures.

Now arriving …

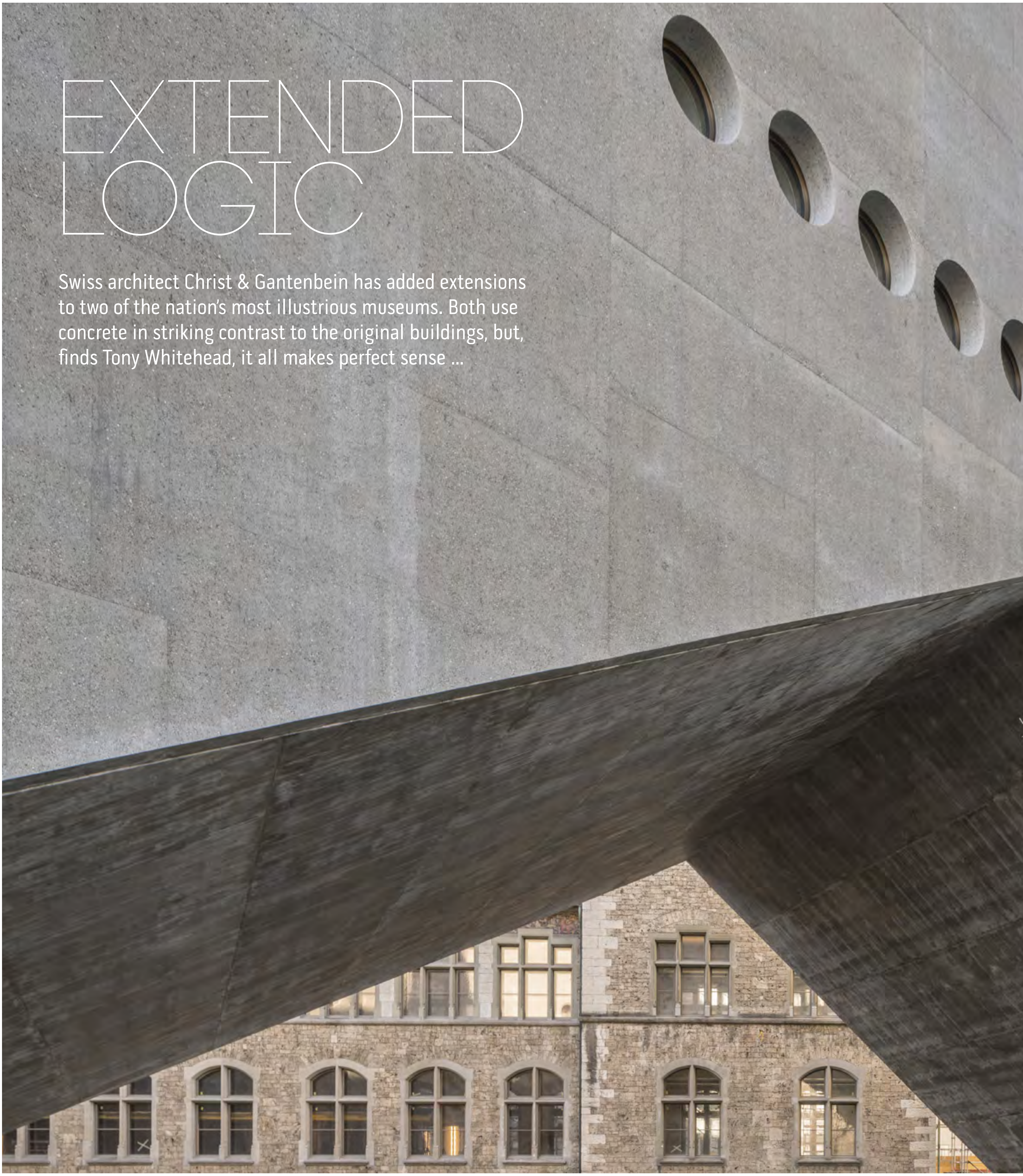
The street-level concourse at London Bridge station, designed by Grimshaw and WSP, has opened. The highlight of the design is an arcade of in-situ concrete arches, which echo the original brick vaults.

BEST OF HEALTH

Architect AHMM, engineer AKTII and developer Derwent London shared their insights on the design and construction of the White Collar Factory at The Concrete Centre's Healthy Buildings seminar in October. The innovative workplace on Old Street, London, was designed with a focus on natural ventilation, healthy working, smart servicing and future adaptability.

To watch a video of the event, go to www.concretecentre.com

Photos: Derwent London



EXTENDED LOGIC

Swiss architect Christ & Gantenbein has added extensions to two of the nation's most illustrious museums. Both use concrete in striking contrast to the original buildings, but, finds Tony Whitehead, it all makes perfect sense ...

Photo: Roman Keller

Although it may not figure prominently among global galleries, the importance of the Swiss National Museum in its own country can hardly be overstated. Designed by Gustav Gull and completed in 1898, it is one of Switzerland's signature buildings. It forms part of the national identity, and has a special place in the affections of the people whose art and history it curates.

So designing a 7,400m^2 extension to such an icon was a very big deal indeed – so much so in fact that it took 11 years to plan, four to build, and when it opened in Zurich this summer, 23,000 people came along to celebrate.

At first glance, the extension could hardly be more different to the original. Whereas the latter takes the form of a French renaissance chateau, the new build, designed by Swiss practice Christ & Gantenbein, features large planes of concrete set at angles. Walls and rooflines have an irregular geometry, creating unusual shapes and spaces both inside and out.

There are similarities, however. The new build's 940mm-thick walls echo the castle-like walls of the original, and the new concrete facade features exposed tuff aggregate – a volcanic stone also used on the facade of the older building. Finally, the extension's floors and staircases, though concrete, are all polished to produce a similarly hard and smooth aesthetic to the terrazzo tiling of the 19th-century galleries.

So concrete is very much the dominant material, aesthetically and also structurally, as Christ & Gantenbein project director Mona Farag, explains: "The building has no columns: it is supported by the slabs, the concrete walls and the roof slabs all acting together. All are made from standard structural reinforced concrete, poured in situ."

In effect then, the building's structure is something like a tube, albeit one that zigzags in both vertical and horizontal planes. Farag says that the brute strength of the concrete helps distribute the unusual load paths, "but still, without the roof it wouldn't work. This meant we had to use a massive amount of scaffolding to provide support until the roof was completed".

This was particularly vital for the extension's most striking feature, an asymmetrical triangular bridge. This houses exhibition space in its own right, but also contains a monumental polished concrete staircase that takes visitors to the top (second) floor of the extension.

To create the sloping slabs for this structure, scaffolding was used in conjunction with proprietary Doka system formwork. Heavy reinforcement was laid parallel to the sloping timber forms and the slabs poured in sections on top. The triple-height staircase is an integral part of the bridge structure – a particular challenge for the construction team. "When you step on the staircase, you are stepping directly onto the structure, and like the rest of the bridge, it is formed from in-situ concrete," says Farag. "To polish the steps required about 10mm to be taken off the concrete, and then the top step had to match exactly with the level of the floor of the upper exhibition space. There was virtually no tolerance in this procedure and the contractor did very well to make it work."

The walls of the bridge, like those elsewhere in the building, comprise a 210mm-thick outer facade of in-situ concrete with exposed tuff aggregate, a 330mm layer of insulation, and a 400mm inner wall of structural concrete. Interim floor slabs and the roof slab are also 400mm thick.

The programme for constructing the bridge was determined by formwork and access issues as much as by structural considerations. "For all the vertical walls we were able to pour the inner walls first, and add the facade later," says Farag. "But for the underside of the bridge, because of its angle, we had to pour the facade first, then apply the insulation, and then pour the sloping structural slab."

A forest of scaffolding then supported the bridge, and only when the roof had cured could it be removed. This meant that the facade under the bridge remained in formwork for more than a year.

Farag adds that with the scaffolding at the bridge removed, the weight of the facade effectively hangs on the inner structure. "Elsewhere in the building, the facade supports its own weight off the ground, and is only tied back to the inner concrete wall to help it remain stable and vertical."

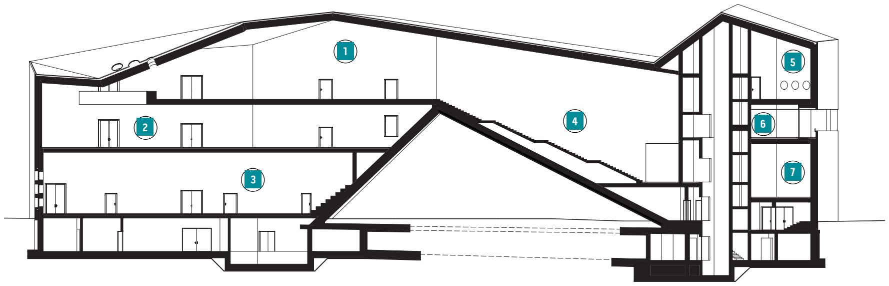
Considerable care was taken with the concrete mix for the facade to ensure its appearance was sympathetic to the stonework of the original building. "We did a lot of research – trying different things with cements, how much lime and tuff to use and varying the size of the aggregate," explains Farag. "At one point we changed the supplier for the cement, but the colour shading was not consistent so we reverted to the original." Fly ash replaced a proportion of the Portland cement in the mix to allow a reduction in water content and to reduce early thermal movements. This meant that the entire facade could be poured without joints.

Finally, about a month after the formwork was eventually removed from the facade, the concrete was water-jetted to remove the crust of cement coating to show the tuff and lime aggregates and leave a pleasingly monolithic appearance. Inside, however, a different approach has been taken.

"Here we wanted to display the logic of the construction," says Farag. "So for the interior walls we used standard timber formwork – plates 500mm wide and in varying lengths, usually between 1.5m and 2.5m – and avoided all additional cut-outs."

The resulting rows of rectangular board marks define the interior walls, and with the visible

THE BUILDING HAS NO COLUMNS: IT IS SUPPORTED BY THE SLABS, THE CONCRETE WALLS AND THE ROOF SLABS ALL ACTING TOGETHER



IN SECTION

1 Exhibition space
2 Exhibition space
3 Auditorium
4 Grand staircase
5 Exhibition space
6 Study centre
7 Exhibition space

lighting and services installations on the ceilings give a rather industrial look: "There is no other decoration," notes Farag. "Just what is necessary to enable the building to function as exhibition space."

Unlike the facade, a standard structural concrete mix containing recycled aggregate is used for these inner walls. It is also exposed – not only on the walls but on the soffits and the polished concrete floors. "The thermal mass of the concrete evens out temperature differentials, helping to cool the building in summer and retain heat in winter," she says. Together with the very thick layer of insulation, and a piped water cooling system embedded in the slab that uses water from the nearby river to dissipate heat, this helps the new building achieve the highest Swiss rating for sustainability – the Minergie P Eco – broadly the equivalent of BREEAM Outstanding.

Punched into the walls on the bridge and elsewhere are a series of port-hole style windows. Their Meccano-like appearance supports the rather technical aesthetic, and also reveals the

FAR LEFT A refurbished staircase in the original Gustav Gull building

LEFT The port-hole style windows on the bridge reveal the impressive thickness of the concrete walls

RIGHT At the Kunstmuseum, lighting is inserted between the precast-concrete ribs

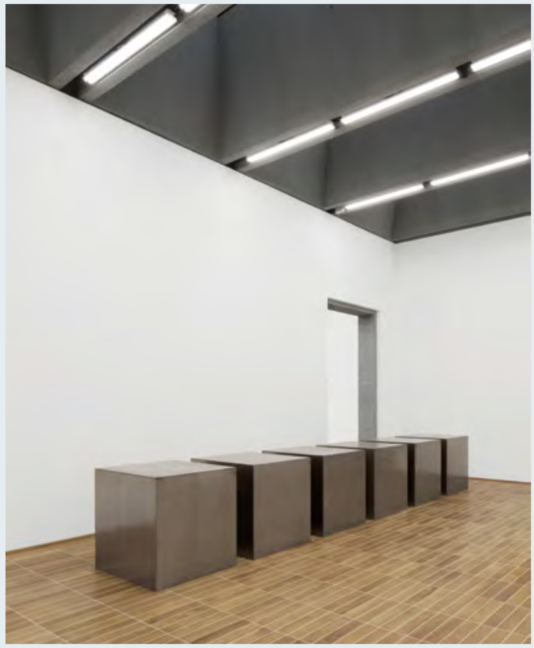
FAR RIGHT A skin of thin grey bricks faces the in-situ concrete structure

PROJECT TEAM
Architect Christ & Gantenbein
Structural engineer Schnetzer Puskas Ingenieure
Contractor Proplaning

extraordinary thickness of the walls. Farag explains: "To let the wall appear thicker we deepened the window reveal in the facade from 210mm to 400mm. That made the facade much stiffer around the circular openings, so we had to add more reinforcement in these areas to limit the size of any cracks."

She adds that while the round openings in the inner concrete wall were created by circular inserts in the formwork, the corresponding circles in the facade were drilled. "This enabled us to achieve a sharp edge to the exterior window reveals, and also, by angling the drill slightly, we could form a smooth sill that would not retain rainwater."

Such attention to detail is especially important in a building that eschews decorative features and celebrates plainness. The smooth precision of the window reveals speaks of superior design and workmanship, and helps suggest to visitors that they are in a special and important place. That is a vital quality for a building with an instant place in the pantheon of Switzerland's architecture.



Kunstmuseum Basel: An exhibition in concrete

Swiss architect Christ & Gantenbein has spotted there is something irritating about a lot of contemporary art galleries: art is hung on disconcertingly flimsy partition walls and the eye is easily distracted by finicky lighting and the blink of security and humidity control technology.

The practice's design for the Kunstmuseum in Basel is something of an antidote to this. The in-situ reinforced concrete walls are thick and load-bearing. The slabs too are concrete, and are braced by chunky spars or ribs of precast concrete. As architect Anette Schick says: "The massive load-bearing structure is space-defining. The walls, slabs and floors are immovable – the rooms thus have a strong physical presence. The goal was to build up these elements as clearly articulated, assembled pieces in order to provide them with a maximum tectonic presence."

Like its design for the Swiss National Museum in Zurich, Christ & Gantenbein's project in Basel is a substantial extension of an existing gallery. It comprises three storeys and a basement providing a total of 8,079m^2 of new space. Each floor is connected vertically by a large cantilevered concrete staircase lit from above by a large circular roof light, or oculus. Schick explains: "The oculus was formed on site – a particular challenge in terms of the building of the formwork as it had to support the slab off the flight of stairs from the first to the second floors, overcoming a height of about 20m."

Since the building is supported by walls rather than internal columns, this has created some large open spaces. The floors above the exhibition spaces are made of precast-concrete elements, which span up to 10.5m on the first and second floors. In the event space in the basement, however, they span up to 19m.

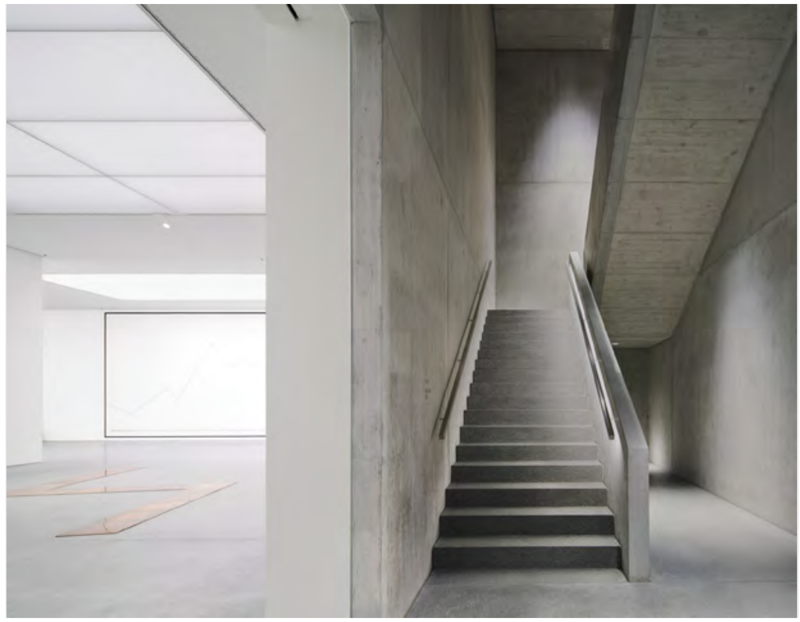
The peripheral wall, Schick explains, is double skin: "The inner skin is poured in-situ concrete using timber forms and recycled aggregate. These carry the precast elements which span above the exhibition spaces. The exterior skin is a self-supporting monolithic grey brick wall."

Visibly fronting the walls inside is a solid, 10cm-thick plasterboard wall that serves as both substrate and backdrop for the artwork. However, this is set back from the door and window edges. This means that each doorway reveals the thickness of the concrete that created it – or appears to. In fact the concrete is finished in grey, scraped plaster, but the aesthetic message remains: this building is solid, the walls support more than just the art, and they are not going to move.

Finally the issue of intrusive services has been cleverly addressed by, as much as possible, setting them into the concrete. In particular, the ambient lighting has been inserted into the precast-concrete ceiling ribs. White pigments have been added to the concrete used in the precast-ceiling elements, which results in a lighter, clearer tone. "This corresponds to the colour of grey scraped plaster on the walls," says Schick. "We have emphasised the effect by sand-blasting the precast surfaces."

PROJECT TEAM
Architect Christ & Gantenbein
Structural engineer ZPF Ingenieure
Construction manager FS Architekten
Contractor Peter Stocker

Photos: Stefano Graziani (Kunstmuseum); Roman Keller (National Museum)



Photos: Simon Menges

PERFECTLY WRAPPED

CLOCKWISE FROM TOP LEFT
The facade is made of 500mm² precast-concrete tiles; white-cube galleries contrast with the in-situ concrete stairs; steel service doors continue the geometric pattern of the concrete tiles

PROJECT TEAM
Architect Barozzi Veiga
Structural engineer Ingenieur-buro Flutsch
Project manager Walter Dietsche Baumanagement

Barcelona architect Barozzi Veiga has dropped a mysterious sealed box in the courtyard of a Swiss art gallery. Nick Jones peeks inside

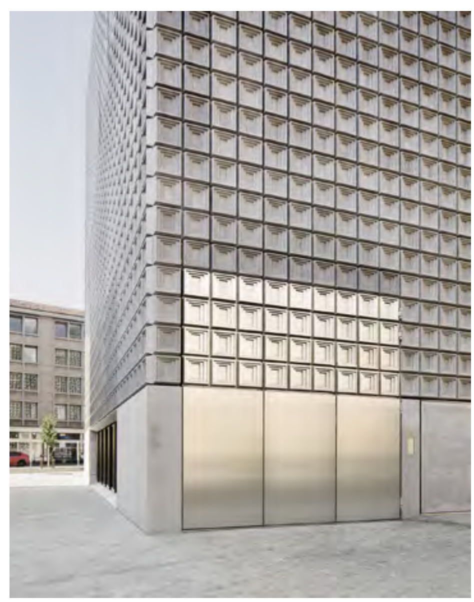
"We knew we wanted to do a building with concrete," says Alberto Veiga. "It's part of working in Switzerland. It has good quarries but at the same time there is a link with the character of the people. And we felt that a material that changes with time, that works with depth, with shadows, would be perfect for this museum."

The museum in question is an extension to the Bundner Kunstmuseum in the Swiss town of Chur. Barcelona-based architect Barozzi Veiga – which won the EU's top architecture prize, the Mies van der Rohe award, last year for its translucent Szczecin Philharmonic Hall in Poland – has built a mysterious cube wrapped in a skin of large concrete tiles. The repetitive, geometric decoration, Veiga explains, is a response to the museum's existing building, which combines the rigid formality of a Palladian villa with elements of Oriental-influenced ornamentation. The effect is elegant and perfectly controlled, so it is a surprise to learn that this is the first time the practice has worked with concrete.

"When you don't know something it's a little bit scary," says Veiga. "In the beginning we were dreaming of casting each tile individually, but the cost would have been prohibitive so we decided to use precast concrete." Each tile is 500mm² and 150mm deep and they were cast in panels of either four or six by three. Veiga says the architects were more concerned with getting the geometry right than the colour or texture of the concrete. "The formwork was made with timber, and we didn't know the limits of the timber. We needed to understand how big, how thin, how deep the elements should be, how rounded the corners. We were afraid we could lose something of the character of the concrete working with precast but in the end I think it was good."

The facade appears largely sealed: only two of the elevations feature anything that could be described as windows, in this case a vertical arrangement of hollowed-out tiles. The air of mystery is heightened by the main entrance, a deliberately oversized doorway made of three slabs of precast concrete. "You need to have an element that everybody can easily identify and think 'I want to go in'. The entrance works as a kind of attractor – that is why we played a little bit with the scale and concealed the real dimensions inside the building."

The inside is actually even more concealed than this suggests. The galleries are all below ground in three storeys of white-cube spaces that link back to the original museum. Above ground, the extension contains four storeys of public spaces arranged around two in-situ concrete circulation cores. The exposed concrete, which shows evidence of its timber formwork, is a deliberate contrast with the precision of the exterior. "Inside it is more expressive, more vibrant, more natural," says Veiga. "Experts might see faults with the finish, but for us it's perfect."



Photos: Quintin Lake Photography

WOLFSON REVISITED

CLOCKWISE FROM TOP LEFT
The auditorium's raking in-situ concrete beams; precast granite-based cladding on the academic wing, with the ventilation chimney in the background; the curved GRC reception desk

Powell and Moya's granite Oxford college has been updated in the spirit of the original, writes Nick Jones

Few architects did more to reshape the traditional image of the Oxbridge college in the 1960s and 70s than Powell and Moya. From St John's in Cambridge to Brasenose in Oxford, the practice left a trail of elegantly proportioned concrete grids amid the neat lawns and classical cloisters. But perhaps its crowning achievement was an entirely new college, Wolfson, completed in 1974 by the river Cherwell in north Oxford. Over the past 40 years, Wolfson's campus of granite-faced concrete has become much loved, and fiercely defended, by staff and students. In 2011 it was listed, just as architect Berman Guedes Stretton was working up plans for the site's first major extension: an auditorium, new entrance and academic wing.

That BGS's design was barely affected by the listing says a lot for its engagement with the spirit of the campus. "We were acutely aware that it was a very important piece of architecture, and were surprised it wasn't listed already," says Marion Brereton, director at BGS. The precast cladding on the academic wing uses the same Cornish Blue granite, with the aggregate placed by hand. The strong horizontal banding – an external expression of the floor slabs – is also reprised with structural precast beams in the same granite finish.

But this is no simple homage. BGS also had to address a number of problems with the original design, not least its propensity to leak heat through the cold bridges of its expressed structure. The college, alarmed at its rising energy bills, had already upgraded the insulation on the existing blocks and was determined that the extension would take a more energy-efficient approach. The academic wing's structural beams are therefore set back from the floor slab, highly insulated and reinforced with stainless steel – far less conductive than conventional reinforcement. Meanwhile, the auditorium is snugly wrapped in foamglass and insulated render. The overall U-value for the extension is an impressive $0.15W/m^2K$.

The horizontal banding posed another challenge, as it restricted BGS to the same floor-to-ceiling heights as the adjacent buildings. "We didn't want a very obvious extension where you had to ramp up or ramp down," says Brereton. Structural engineer Price & Myers therefore had to devise a slab that kept depth to a minimum while supporting the long spans required in the open cafe area. Services were cast in, but the nearby library meant that some areas also needed a 38mm acoustic plaster. "We had to be very mindful that the ceiling level was coming down all the time," says Brereton.

The extension incorporates a range of concrete techniques: a retarded, white-pebble finish for exterior columns; precast, acid-etched columns in the auditorium; a curved glassfibre-reinforced concrete (GRC) reception desk; and expanses of exposed in-situ structure, including the auditorium's dramatic raking beams. The exposed structure, which used a 40% GGBS mix, also plays a key role in the energy strategy, its thermal mass used in harness with night-time purging through the auditorium's ventilation chimney.

The chimney also helps to solve another of Wolfson's longstanding problems. Unusually for a listed building, BGS's extension is at the front of the campus, which was an area where Phillip Powell felt he had failed, describing the entrance as "not very obvious or welcoming". BGS's chimney has been placed on an axis with the residential road leading up to the college. It is a powerful signal of Wolfson's presence – Powell would surely feel that it finally has the entrance it deserves.

PROJECT TEAM
Architect Berman Guedes Stretton
Structural engineer Price and Myers
Main contractor Benfield and Loxley
In-situ concrete subcontractor SCS Building
Precast manufacturer Minsterstone

Photos: Charles Hosea

BURIED TREASURE

Embedded in a Forest of Dean hillside, Loyn & Co's Manser Medal winner is changing public attitudes to concrete housing. By Pamela Buxton

Outhouse, the first private house to be nominated for the Stirling Prize in 10 years, defies lazy stereotypes of the perfect home for an elderly couple in the heart of the English countryside. Loyn & Co's design eschews any hint of a quaint, rustic aesthetic, instead creating a boldly contemporary home and studios that maximises the tremendous views of the surrounding Forest of Dean. And while concrete is the overwhelming material both inside and out, Outhouse's earth-sheltered rear and planted roofs ensure that it is quite literally, and harmoniously, bedded into the landscape.

Outhouse follows Loyn & Co's Manser Medal-winning Stormy Castle in Gower, Wales, which also featured a contemporary, concrete-led aesthetic. But while both respond to Areas of Outstanding Natural Beauty settings with earth-sheltered designs that make the most of the fantastic prospects, there are also great differences.

The design of Outhouse was a very particular response to site conditions that included not only the natural setting but the previous three existing buildings. The architects spent a lot of time getting to know the south-facing site, says Chris Loyn, in order to understand "how to anchor something much bigger and give it a relevance without it feeling as if a spaceship had just landed".

The new single-storey building needed to function not only as a home for the two artists but as a workspace, with both requiring their own studio. The solution was to push the 490m² new building to the rear of the site against the hill and provide a green roof that continues the surrounding field over the house and greatly minimises the impact of the new build when seen from the road above. A gallery spine runs through the building from east to west, with north-facing top-lit studio space and guest rooms to the rear, and domestic living space at the front overlooking the valley. The configuration is also driven by the decision to leave "memories" of the previous buildings on the site as outlines forming a series of sheltered courtyards serving both the domestic and studio spaces.

> WE HAD TO GIVE THE HOUSE A RELEVANCE TO THE SITE WITHOUT IT FEELING AS IF A SPACESHIP HAD JUST LANDED

Concrete was the obvious choice for the structure. "Once the decision was made for an earth-sheltered house, it was the only logical structural solution," says Loyn. The sustainability of the material was considered and 33% of the cement was replaced with fly ash. The concrete was also sourced from a local plant – Bardon Concrete – just four miles away. The bottom line, Loyn says, for both architect and client was the material's longevity.

Added to this was the clients' love of the concrete aesthetic, which they felt created the best backdrop for their art. The result is extensive use of exposed concrete for the floors, walls and ceiling both internally and externally, with the exception of areas of vertical strips of charred timber used for facing on non-loadbearing infill panels.

ABOVE LEFT The clients felt that exposed concrete was the best backdrop for their art

ABOVE RIGHT A green roof allows the surrounding fields to continue over the house

LEFT Imprints of ferns and grasses decorate the concrete walkway beneath the fascia

OPPOSITE The glass and concrete envelope exceeds Passivhaus requirements

PROJECT TEAM
Architect Loyn & Co
Structural engineer WL2
Landscape architect Morgan Henshaw
Main contractor Chris Milliner/Forest Eco Systems

Loyn is in no doubt about the suitability of concrete in a domestic interior, with the many different treatments giving tonal and textural variety. "What I love about concrete is its unpredictable and beautiful swirls and pattern – it is liquid stone. It surprises me that people don't always appreciate it," he says.

The slab for the rear portion of the house is ground-bearing while the front is suspended. The majority of the concrete was cast in situ. Reinforced retaining walls were 250mm thick with a further 300mm of insulation externally, while internal loadbearing concrete walls were 200mm thick. However concrete panels – precast on site – were used to form the 800mm-high, 150mm-thick fascia that runs 53m across the front of the house. This was due to site constraints from the falling ground that would have made it challenging to cast in situ.

In order to allow the courtyard walls that define the location of the original buildings to read differently to the new work, Loyn & Co introduced a black pigment into the concrete mix, which the practice was advised would work better with self-compacting concrete. These walls were a total of 550mm thick, consisting of two skins of concrete with 225mm of insulation in between. To avoid visible formwork bolt holes, Thermomass low-conductivity ties were used to hold the insulation in place and enable both the outer and inner skins of the wall to be cast in one operation.

Great attention was paid to the quality of the finishes, with architect and clients visiting the University of the West of England to research various surface textures and grades of finish as well as referring to the then on-site Stormy Castle before arriving at the final design.

Apart from the stone floor of the gallery, floors are power-floated and buffed to achieve a highly reflective finish. This contrasts with the walls and ceiling, which have a self-finish from the phenolic-faced boarding. A great deal of thought was given to how to fix the art to the 2.4m-high walls without drilling into the concrete. The solution was a cast-in recessed detail at the top of the walls that created a contemporary picture rail for stainless steel hangers to ensure that pictures can be hung anywhere along the gallery.

During casting of the ceiling, a couple of leaves serendipitously fluttered in, leaving fossil-like imprints in the surface. Delighted with the effect, client and architect decided to repeat it in the base of the walkway beneath the fascia. Here, they gathered ferns and grasses from the garden and pressed them into the screed to capture their imprint before removing them.

Aside from its structural and aesthetic uses, concrete also contributed to Outhouse's A+ EPC rating, and not only through its thermal mass. "Our experience is that concrete is a beautiful material to achieve good quality airtightness," says Loyn, adding that the $0.49m^3/h.m^2$ is even better than Passivhaus standard.

Outhouse's sustainability credentials also include use of local contractors along with triple glazing, LED lighting, ground source heat pump, MVHR, and solar thermal and photovoltaic panels.

In the end, it was pipped by the Newport Street Gallery to the Stirling Prize, though it did overwhelmingly win a BBC News people's vote on the shortlist, as well as scooping the 2016 Manser Medal for the best new house. Loyn is hugely heartened by the support for Outhouse, and hopes this indicates a shift in public attitude towards concrete: "To have the British public vote for a contemporary concrete house is a massive sea-change."

BUILT FOR SPEED

Time is money on a construction project. Concrete can speed up the process in a number of ways, says Elaine Toogood, from design to practical completion

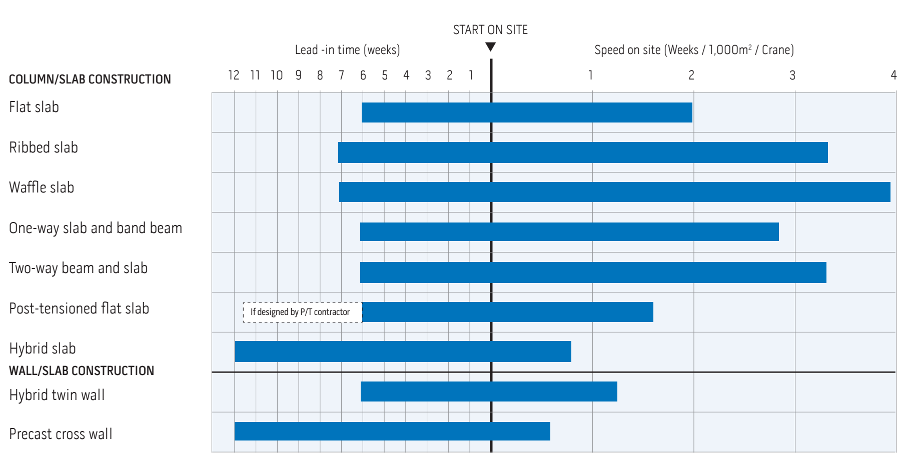
Concrete is highly compatible with fast construction, from rapid mobilisation with readily available materials on demand, through to modern methods of construction, including sophisticated formwork systems, post-tensioning and precast elements. Fast programmes can be associated with reduced costs for site preliminaries, less disruption to neighbours and potentially earlier occupation or practical completion. Speed of construction is not, however, always an overriding necessity for every project or even every element of construction. Managing the pace of a build can be driven by cash flow, for example. For large housing developments, bringing the product to market at the right moment may be more critical. In this instance, the local and ready availability of concrete and masonry products is an advantage, with short order times possible to enable a client to respond to sudden changes in programme.

Generally, buildings with in-situ concrete frames take no longer to construct than steel-framed buildings. Indeed, they can be faster, as shown by cost and programme studies carried out by Davis Langdon to compare structural frame options for different building types. For example, flat slab concrete construction for a commercial building gave an eight-week saving in lead time during which the site would have been established and 75% of the substructure could be constructed.

Of course, the speed of construction is also influenced by the pace of the decision-making process – factors such as agreeing the detailed design or the room layout for services – combined with the procurement route and type of contract. For example, construction management and design-and-build approaches lend themselves to concrete construction, because the ability to accommodate late information and variations is particularly beneficial and the work package can be let before the design of following packages has been finalised.

It can be more important to consider the whole project programme rather than just the speed of one element. There is little benefit in putting up a frame very quickly if the walls and roof can't keep pace, and this situation may even be detrimental for some structural materials, vulnerable to damage if left exposed or subjected to extended periods in changing weather conditions. Such exposure is typically not a problem for concrete.

FIGURE 1: LEAD-IN TIMES AND SPEED OF CONSTRUCTION FOR VARIOUS CONCRETE-FRAME SOLUTIONS



Source: Concrete Framed Buildings, published by The Concrete Centre (2016), based on studies commissioned from Davis Langdon

STANDARDISED FORMWORK SYSTEMS ARE SIMPLE AND QUICK TO ERECT AND MOVE. IT IS NOW STANDARD TO ACHIEVE 500M^2 PER WEEK PER CRANE

With its inherent robustness and resilience to all types of weather it is a natural contender for early installation on site, to provide a safe working environment and protected conditions, allowing services installation and follow-on trades to commence early in the programme. The potentially self-finished, fire-proof nature of concrete also reduces or even eliminates the need for some follow-on trades and minimises fire risks during the construction phase.

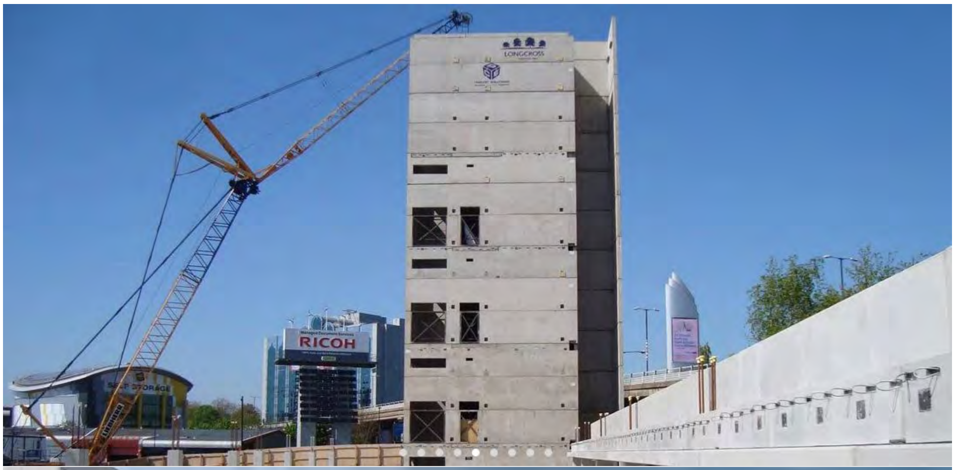
Concrete construction has undergone a revolution in speed and efficiency in recent years. Prerequisites for fast construction in any material are design discipline, repetition, integration, simplification and standardisation of design details, and this also applies to concrete. Forming the concrete into shape could potentially be the most costly and labour-intensive part of the process. However, modern high-efficiency modular formwork standardises and mechanises this process, both on and off site. Ready-mixed concrete is usually available for next-day delivery and on site standardised formwork systems are simple and quick to erect and move. It is now standard to achieve 500m^2 per week per crane. Rationalising reinforcement, or prefabricating it, also helps.

Precast concrete can offer further programme savings, depending on the type of system used. Pre-made standardised products such as blockwork or paving are readily available; bespoke structural systems require a longer lead time but can be quickly assembled on site straight from the delivery vehicle.

▶ Motel One

Manchester, Hodder + Partners, 2015

This 330-bed hotel faces Manchester Piccadilly station, and is just outside the Whitworth Street conservation area. The site wraps around a corner pub and sits opposite a grade II-listed fire station. Mindful of the need to reconcile the scale differences between the surrounding buildings, the architect chose to use clean forms and a repetitive facade, with a restrained palette of honed concrete and bronze anodised aluminium. The contractor was Russells Construction, which used a crosswall system and architectural precast cladding supplied by FP McCann. The build programme for the entire structure and cladding was originally 35 weeks, but was completed in just 22.



Photos: PCE

▲ Volkswagen Sales and Services Centre

West London, Bond Bryan, 2014

Intended as a "centre of excellence" for the Volkswagen brand in the UK, this four-storey dealership was constructed on a small site in Brentford, beside the M4 motorway. To create the suspended structure, more than 1,500 precast concrete components, some weighing over 20 tonnes, were manufactured by PCE in six different factories and delivered to site on a just-in-time basis. Using a precast concrete box solution for the three stair and lift shafts, rather than individual panels, enabled full-height construction in less than eight days. Throughout most of the elevated showroom and car service areas, the concrete finishes are not left exposed. Instead, hollowcore flooring units were covered with an in-situ structural concrete topping, supported by a precast frame, to make services installation easier and maximise floor-to-ceiling heights. In the car showroom, circular columns cast in white concrete were specified to provide an attractive visual element.

The project was constructed in just 18 weeks on site.

Hybrid concrete construction combines the best of both precast and in-situ concrete, by taking a proportion of site work into the factory and reducing the duration of programme-critical operations.

In the following sections, we outline a selection of concrete construction solutions and some of their programme benefits.

Crosswall construction

This modern and efficient method of off-site concrete solution is particularly effective for facilitating speed in residential buildings such as hotel and student accommodation. The system of factory precast walls, floors, stairs and even bathroom pods are custom-designed requiring only assembly, or stitching together, on site. Such structures can be built at a rate of 50 bedrooms per week and can be combined with other types of concrete construction as required.

Hybrid concrete construction

Combining precast and in-situ concrete offers opportunities to tailor the design to optimise the programme. Hybrid or composite concrete elements are also available, using precast permanent formwork for in-situ walls and floors, such as twin-wall and lattice girder slabs.

Precast cladding

Bespoke pre-finished cladding elements are available in a range of finishes, including factory-made brick facing and mortar joints. Large panels facilitate quick assembly of durable facades, with the option of including pre-applied insulation and windows.

Thin joint masonry walls

An innovative lightweight blockwork system using thin mortar joints offers the opportunity to take the outer skin of brickwork off the critical path in cavity-wall construction, which means that the building can be tested for airtightness earlier in the programme and finishing works can begin sooner.

Insulated concrete formwork (ICF)

Pre-manufactured formwork systems using blocks or panels of insulation can be quickly assembled on site in preparation for next-day delivery of concrete, again providing an opportunity for early weather-tightness.

Solid wall with external insulation

This provides an early weathertight enclosure, either in masonry or concrete.

Jump-form and slip-form

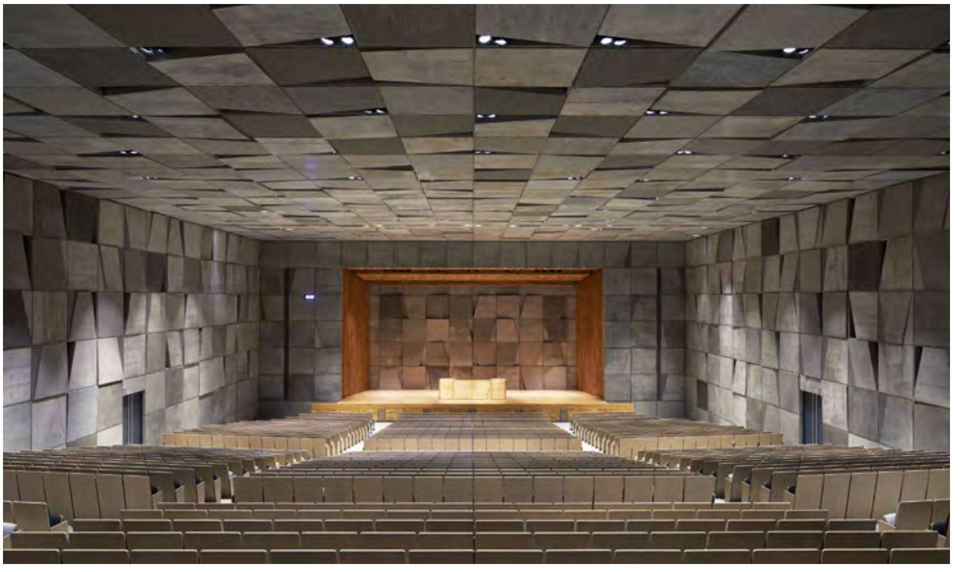
These modular formwork systems encompassing working platforms are typically used for fast construction of five storeys or more, rising continuously (slip-form) or repeatedly (jump-form) up the structure. Fast rates of pour are possible but total speed can be affected by the size of the core, and allowable working hours.

Key references

The Concrete Centre has produced a number of relevant publications, including:

- Concrete Framed Buildings, 2016
- Crosswall Construction, 2007
- Hybrid Concrete Construction, 2010
- Formwork for Modern Efficient Concrete Construction, BRE, 2007

All are free to download from www.concretecentre.com, in addition to cost-model studies for various building types, such as schools, hospitals and commercial buildings.



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.

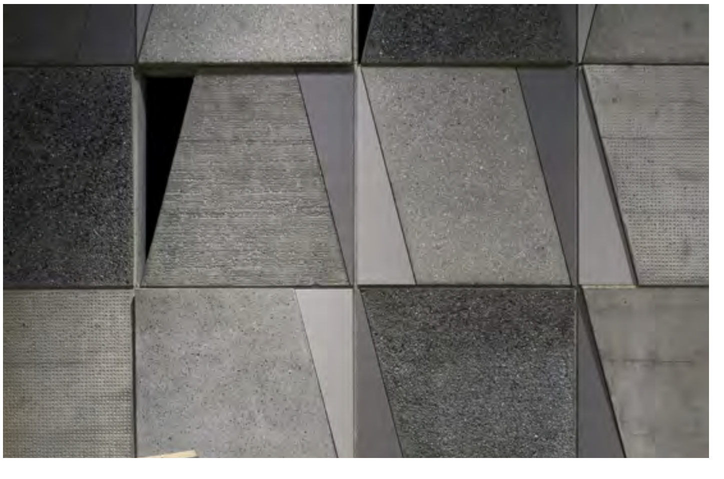
Surface retardants offer an alternative, controlled means of revealing the aggregate. These can be applied to the face of the formwork or to freshly struck concrete, although the latter is more common for unformed faces. In both situations, the retardant prevents the surface laitance from hardening, 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

SPECIFYING FLOOR-LEVELLING SCREEDS

Screeds form a flat surface above a concrete base on which to lay flooring. Paul Gregory explains how to keep things on the level

Levelling screeds are principally used to level or raise the level of an existing concrete floor and to provide protection to an insulation layer. They are not intended to act as a wearing surface, and should always be covered with appropriate flooring.

Common types of flooring laid over levelling screeds include carpet and carpet tiles, PVC tiles and sheeting, wood blocks, and ceramic and terrazzo tiles. They do not usually provide suitable bases for synthetic resin flooring or polymer-modified cementitious wearing screeds.

There are many factors to be considered in the specification of a levelling screed, including:

- The condition of the concrete base slab and how it will be prepared
- The type of levelling screed construction: bonded, unbonded or floating
- The type of screed material. This affects the screed drying rate, shrinkage and how the flooring is laid
- The screed thickness and tolerances
- Required strength. This should be specified by the in-situ crushing resistance (ISCR) categories of A, B or C, contained in table 3 of BS 8204-1, rather than by material proportions or properties. Category A screeds should be specified for floors that take very heavy foot traffic and/or heavy trolleys and where failures are unacceptable. Category B screeds are suitable for floors taking heavy foot traffic, such as public areas. Category C screeds are for lightly trafficked floors such as those in domestic settings
- How the screed will be prepared to receive flooring
- Surface regularity (SR) of the screed. Specified by quoting the class SR1, SR2 or SR3, contained in BS 8204-1 6.8.3. SR2 tolerance should be selected for ordinary screed and SR1 where flatness is of special importance, such as where a thin flooring is to be applied
- The minimum moisture level before the flooring can be laid. Specify the relative humidity (RH) value. A maximum of 75% RH is considered suitable for screeds that are to be covered with impervious flooring. A 50mm-thick traditional cement-sand screed may take two months to dry to a suitable level but there are proprietary screeds that may dry in less than 10 days.
- Movement joints and/or reinforcement to control cracking. Specify movement joint spacing and/or reinforcement type and their location
- Heating pipes in the screed.

Screeds will only provide a satisfactory base for flooring if they are placed, compacted and cured properly. Guidance is provided in BS 8000-9:2003: Workmanship on building sites.

Screeding materials

Screeds may be made from traditional cement-sand, modified cement-sand, self-smoothing or lightweight aggregate.

Two distinct types of binder are used: one based on Portland cement (CEM I) and the other based on calcium sulfate of either the hemi-hydrate or anhydrite form. Calcium sulfate binders are similar in nature to gypsum and will soften if continuously wet. For this reason, they should not be used if the floor is frequently wet.

Cement paste can chemically break down if it is in contact with a calcium sulfate screed when water is present. For this reason it is recommended that a water-resistant barrier is placed between a concrete base and a calcium sulfate screed, and that a cementitious mortar or grout is not used to bed flooring tiles onto a calcium sulfate screed.

A traditional hand-laid Portland cement and sand mortar screed has a stiff consistency with proportions by volume in the range 1:3 to 1:5 (cement:sand). Sand is a fine aggregate with a maximum size of 4mm. Fine concrete where the maximum aggregate size is 10mm may be used for screeds in excess of 50mm thickness. Where there is a need to reduce loadings, a no-fines concrete with lightweight aggregate should be selected. The properties of screeds can be significantly enhanced by the addition of water-reducing admixtures, polymers or special cements.

Calcium sulfate based screeds are typically supplied as a self-smoothing screed but can also be supplied as a traditional hand-laid screed system.

Proprietary pumpable self-smoothing screeds, often known as self-levelling, are available based on both cementitious and calcium sulfate binders. In all cases where proprietary screeds or additives are used, the manufacturer's recommendations must be followed.

A table comparing screed materials and types of build-up is available at www.concretecentre.com.

Unmodified cement-sand screeding mortar

Traditional cement-sand screeds of stiff consistency can be compacted and finished by simple hand and machine methods to adequate standards of smoothness, flatness and levelness without the repeated trowelling used to finish concrete floors.

Unmodified cement-sand screeds are generally less expensive than other materials, and should be selected where the screed thickness is not more than about 75mm, and where there are no special structural or service loading limits.

Modified cement-sand screeding mortar

All ready-to-use screeding mortar is supplied with a retarding admixture, which keeps the

Photo: Tarmac

ABOVE Surface regularity of screeds is classified under BS 8204-1, and specified by quoting classes SR1, SR2 or SR3

material workable for long enough to be laid and compacted properly.

Water-reducing admixtures provide the normal level of workability at a significantly reduced water-cement ratio. This reduces shrinkage and drying time, and increases strength and resistance to indentation.

Some suppliers offer screeding mortar containing steel or polypropylene fibres, which increase the screed's toughness and impact resistance, and improve its tensile properties. Adding polymers such as styrene butadiene rubber (SBR) or acrylics can increase flexural strength and impact resistance, and may reduce the water-cement ratio and permeability of the screed. Select these forms of modified screeding mortar when toughness and flexural strength are especially important.

Lightweight fine concrete

Lightweight concrete screeds should be selected for suspended floors where there is a need to reduce loadings. One common type uses lightweight foamed coarse aggregate particles bound with cement grout to form a no-fines concrete. This is then topped with 15-20mm of cement-sand screed to form a flat and level surface. There are many different materials that are suitable for lightweight screeds. Refer to industry guidance and material suppliers for further advice.

Pumpable self-smoothing screeds

These are proprietary screeds laid by approved subcontractors. They are self-smoothing and self-compacting and do not need to be trowelled. The mortar is pumped through a hose from a special mixer, flowing out to a typical thickness of 10-15 mm for a bonded screed with no heating pipes. Select this form of screed where the base has good surface regularity and speed of laying and early drying are important.

Bagged and ready-mixed screeds

Producers of bagged or ready-mixed screeds must declare the compressive and flexural strength and the type of binder according to BS EN 13813: Screed material and floor screeds. The compressive strength is designated by a letter C and the flexural strength with an F. This strength information can be used as a guide to predicting which ISCR category a proprietary screed will satisfy.

Screed construction

The choice of a bonded, unbonded or floating construction will depend on the type of base, the location of the damp-proof membrane and the need to incorporate acoustic or thermal insulation.

Bonded screed

Select this type of screed to minimise the risk of curling and shrinkage, and where an efficient bond with the base can be ensured. Traditional screeds should be 25-40mm thick, but modified/proprietary screeds can be thinner. A minimum thickness of 3mm can be achieved with free-flowing products. The specified nominal thickness should allow for the tolerance in the finished base level. There is an increasing risk of loss of adhesion for screeds thicker than 40mm, and thick screeds may be better formed as unbonded screeds.

Drying shrinkage of cement-sand mortars and normal and lightweight concretes may lead to cracking. The greater loss of moisture from the surface of the screed compared with its underside causes more shrinkage at the surface. This difference in shrinkage can induce an upward curling movement at the corners and edges of bays of screed, leading to irregularities and hollowness.

Both shrinkage and curling tend to increase with richer mixes and with higher water:cement ratios. If the screed has a good bond with the base slab, the curling can be eliminated and the overall shrinkage reduced.

Unbonded screed

Select this type of screed where it is impossible or difficult to form a bond with the base slab, for example where a damp-proof membrane is used or because of oil or other contamination of the surface of the base. An unbonded screed may also be selected where the cost of surface preparation would not be justified.

The minimum thickness of an unbonded screed should be 50mm for a cementitious screed and 30mm for a calcium sulfate screed, but select the greatest thickness possible up to about 80mm. Unbonded screeds have an increased risk of curling and shrinkage when compared with bonded screeds, and the greater thickness is required to resist curling. Increasing the thickness of the screed produces a greater self-weight to counteract the curling forces, but cannot eliminate the risk of curling.

Provided it does not cause lipping of more than about 1mm at joints, curling of an unbonded screed is acceptable and should not be regarded as a failure, or as grounds for removal and replacement.

Floating screed

This type of screed should be selected where acoustic or thermal insulation is required within the build-up of the floor. The screed is termed "floating" because it rests on relatively weak and compressible material that gives no firm support. Because it could potentially fail if punched through by trolley wheels, furniture legs and other service loads, a thick screed may be required. The thickness could be reduced by using rigid insulation boards. A minimum thickness of 65mm should be used for lightly loaded screeds and 75mm for heavily loaded screeds.

Concrete overslab

Where the required thickness of levelling screed is at least 100mm, a concrete overslab may be specified instead. An overslab is designed as a normal concrete slab, specified using BS 8500 and constructed on and commonly debonded from a hardened concrete base slab to provide a wearing surface or to receive flooring. The design, specification and construction of a concrete overslab are different to those of a levelling screed.

Types of base and surface finish

The aim is to provide a reasonably flat, level and smooth finish to the concrete base slab which can be easily prepared for bonding, or is suitable for the application of a damp-proof membrane, or provides a smooth and uniform support for insulation boards.

In-situ concrete bases

There are four types of unformed finish that can be specified in the National Structural Concrete Specification: basic, ordinary, plain and special.

Basic is the default finish, where the concrete surface is levelled by skip float or a similar process to produce a closed uniform surface. No further work is carried out and float marks and ridges will occur. An ordinary finish is typically produced by hand or power floating. It is free from ridges though fine float marks are to be expected. This may be a better option for floating screeds, where ridges are not acceptable as a base for insulation, and may require less preparation to receive a bonded screed. A plain finish where the concrete is finished by trowelling provides no benefit where a screed is to be applied. An in-situ concrete base can be directly finished to provide a wearing surface or to receive the flooring without the need for a screed.

Precast concrete bases

Concrete base slabs may be precast, such as beam-and-block systems, prestressed and other types of unit. Some precast units come with a rough finish suitable for bonded screeds and others have a smooth finish not suitable for bonding without some surface preparation.

Moisture condition

The moisture in a concrete base could take over a year to dry. A vapour-resistant membrane should be considered between the base and screed if impervious flooring is to be used to avoid affecting adhesives or causing blistering.

Screed thickness

The thickness of a screed is affected by the flatness and levelness of the concrete base and its possible deflection or upwards camber. The level of a concrete slab is usually specified at the supports. If a minimum screed thickness of 25mm is specified at the supports, the nominal screed thickness will need to be larger to allow for the construction tolerances in flatness and levelness. Deflection of the slab or a built-in upwards camber of precast units will cause the slab at mid-span to be either lower or higher than the slab level at the supports. For the case of upwards camber, the specified nominal cover would need to be increased.

Photo: BRE Group / Flickr

ABOVE Self-smoothing screed being laid at the low-energy Wienerberger e4brickhouse at the BRE Innovation Park in Watford

Surface preparation for a bonded screed

A screed cannot bond properly to the surface of an unprepared base. Inevitably there will be a layer of weak laitance, dust, dirt and debris on the surface and there may be oil or other contaminants present. These materials prevent adhesion. To obtain a high degree of bond between the base and the screed, the contaminants and surface mortar matrix must be removed so that sound, clean coarse aggregate is exposed, typically by scabbling or shot-blasting the hardened surface immediately before laying the screed.

Scabbling should be avoided or used with caution for suspended precast units, as cracking or other damage may be caused. Enclosed shot-blasting is generally regarded as the best method of surface preparation for large areas. It is fast and efficient, and the machine removes all dust and debris by vacuuming, leaving the surface very clean.

A bonding agent must be used to ensure a strong bond. The most common types are cement grouts, used with and without a polymer admixture, or resins such as epoxy. There are epoxy bonding agents that also act as a damp-proof membrane.

Reducing the risk of cracking

Traditionally laid screeds in large areas will crack, and the risk is higher with floating and heated screeds. The use of proprietary screeds or additives can reduce but not totally eliminate this risk.

Floor shape and plan area will influence the risk of cracking. Square panels are best; for rectangular panels the ratio of the length of the sides should preferably not exceed 1:5. Breaking the floor area into small areas by incorporating movement joints and perimeter isolation joints will also help. The incidence of shrinkage cracks will be reduced with movement joints at 6-8m centres both ways.

In cementitious screeds, fabric reinforcement can be used to help control cracking and increase the spacing between movement joints. Reinforcement over heating pipes is recommended. Bonded screeds do not normally require any reinforcement.

Calcium sulfate screeds are low shrinkage compared with traditional cement-sand, so spacing of movement joints can be larger. Steel reinforcement should not be used in these screeds as they are corrosive to steel in damp conditions.

Paul Gregory is a structural engineer at The Concrete Centre

FURTHER READING

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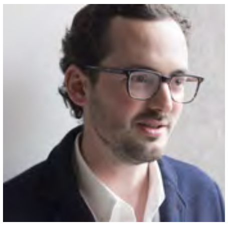
LASTING IMPRESSION ARTUR CARULLA

NEGATIVE SPACE AND THE GHOSTS OF FORMWORK



The most influential concrete creation I can think of is not a building but a sculpture – Bruce Nauman's A Cast Of The Space Under My Chair 1 (1965-8). It tells you that you can understand an object by the space it creates, rather than by its form or appearance.

Architects have always explored the plasticity of concrete, and Eero Saarinen's TWA terminal 2 in New York (1962) stands apart. The concrete retains all of its tectonic qualities, and yet it feels incredibly light and fluid. It presaged a number of projects where space circulation and walls, roofs and floors all become one. Perhaps less versatile but equally extraordinary is the Portuguese national pavilion by Àlvaro Siza for the 1998 Lisbon World Exposition. The concrete there has all its weight, and yet it's very agile. There's no clear boundary between architecture and structure, between the more intangible aspects of the building's quality and the pragmatic aspects that it needed to resolve.

Concrete is also a natural material – an artificial rock, but ultimately a rock. I really enjoy those buildings that exploit this aspect by blending with the landscape. The two best examples I can think of are Igualada cemetery by Enric Miralles and Carme Pinós (1994) near Barcelona, and Braga stadium 3 by Eduardo Souto de Moura (2003), particularly one of the grandstands which is very much embedded into the rock.

Formwork is the unsung hero of concrete. There are many examples where the actual engineering feat was in building the formwork, but once it's cast and cured it disappears, so there's the ghost of a building that leaves no trace. Félix Candela's Chapel Lomas de Cuernavaca 4 in Mexico (1958) is pretty much just the concrete shell with the lightest of enclosures, but an entire structure had to be put together to create it. Having admired that building for many years, I came across a picture of it under construction and it just blew me away. It makes you realise that some concrete buildings should never be finished.

Artur Carulla is a partner at Allies and Morrison

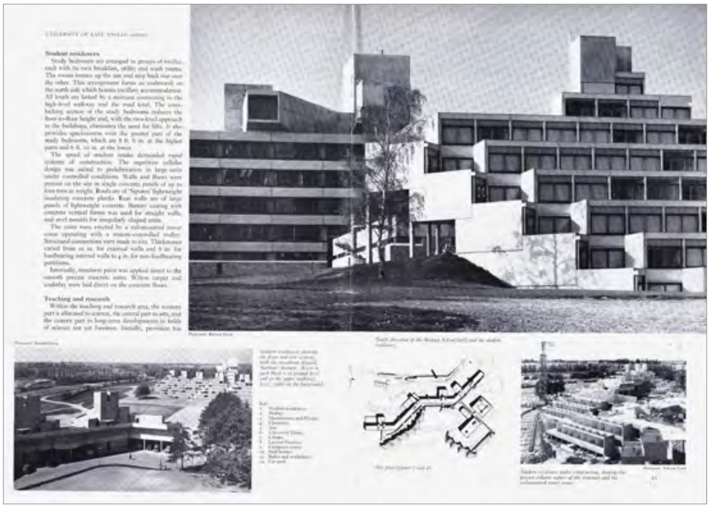
Photos: 1. Kröller-Müller Museum, Otterlo; 2. Nathan Willock/Getty Images; 3. Paulo Catrica; 4. Dorothy Candela; Portrait: Nick Guttridge

FROM THE ARCHIVE: WINTER 1969

LASDUN'S FLEXIBLE FORTRESS

Denys Lasdun's campus of "architectural hills and valleys" at the University of East Anglia was one of the most radical of all the university developments of the 1960s. The compact site was intended to be a "place where activities merge and where the individual can sense his identity with the whole". One of the most notable aspects of Lasdun's approach was that, despite its castle-like demeanour, it was one of the first academic institutions to acknowledge the need for layouts to adapt to changing uses. In keeping with the spirit of the age, education was expected to evolve fast (although no one could be sure quite what that evolution might entail ...)

The solution to this tricky problem rested on a precast concrete structural system, which formed the basis of all of the teaching blocks and comprised four large components: a U-shaped duct column, a duct spandrel, an edge beam spanning between columns, and a T-shaped floor beam. Variations in the requirements of schools were achieved by adjusting the position of the corridor and in-situ columns and beams. New buildings could also easily be added. CQ noted: "Each school has the possibility of altering its internal its internal arrangement or of being replaced in time by a different use – all within the basic system of structure and services."



Access the full CQ archive at www.concretecentre.com/cq

FINAL FRAME: CKK JORDANKI

The CKK Jordanki concert hall in Torun, Poland has been named joint winner of the 2016 WAN Concrete in Architecture Award. The building, designed by Spanish studio Menis Arquitectos, employs an innovative construction technique called "Picado", which mixes concrete with other materials before crushing it to create a broken mosaic effect. The exterior walls are built from in-situ pale concrete, which is cut away in places to reveal the earthy red Picado surfaces.

Photo: Fernando Menis