THE MAGAZINE OF THE CONCRETE SOCIETY

CONCRETE

Volume 58, Issue 9 November 2024

SLIPPING AND CLIMBING?

Projects using cranes that climb within the core while slipforming continues

TESTING CONCRETE

Alkali–silica reaction: widespread but manageable

CONSTRUCTING CURZON VIADUCT

The challenge of large-scale temporary works for HS2 project


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"Reducing hook time is crucial when working on multistorey projects. That's why we decided to use the RCS CL system, as we could lift the external platforms and shutters hydraulically. It's efficient, safe and reliable."
Stewart Burns | Assistant Project Manager, Heyrod Construction Ltd
Hydraulic climbing from PERI
for more efficient construction sites
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A report on what is believed to be a UK first – two projects with slipforms containing climbing cranes, which climb within the core while slipforming continues.

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CONCRETE magazine is produced in-house by The Concrete Society, a not-for-profit, independent membership organisation dedicated to supporting the use of concrete, the most widely used building material in the world.

Established in 1966, and with members from around the world, The Society has built on its technical base to become a leading provider of information, serving the needs of clients, architects, engineers, specifiers, suppliers, contractors and users of concrete.

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The Concrete Society

The Concrete Society

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THE CONCRETE SOCIETY is an independent membership organisation dedicated to supporting the use of concrete – the most widely used building material in the world.

Established in 1966, The Society encourages innovation and the exchange of knowledge and experience across all disciplines. The Society works through the co-operation of our members, who come from all sectors of the industry to exchange information and experience, and to enhance the performance, productivity and quality of concrete as a construction medium. Supported by the technical and administrative staff of The Society, our members collaborate to produce and disseminate state-of-the-art reports, recommendations and practical guidance.

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FROM THE EDITOR

ON THE ROAD TO NET ZERO

There's a story in *Concrete's* news section this month regarding Innovate UK's £3.2m investment in seven projects that are working on low-carbon cement and concrete technologies. Incredibly worthy endeavours to transform the sector. In addition, most of the major concrete suppliers trumpet low-carbon material innovations, with clever marketing brands. On the road to net zero, tackling the direct root emissions from industry and changing minds is an obvious starting point.

A follow-on encouragement is the news (page 4) from a research report looking into attitudes to low-carbon materials by people with purchasing authority at 259 organisations. For concrete, 40% of respondents said that they are willing to pay a premium for CO_2 reductions exceeding 25% and 49% would be willing to pay a premium for CO_2 reductions exceeding 50%.

How many of these intentions turn into actual sales is, of course, another matter. Sales data on low-carbon brands, from all major suppliers, would provide clearer evidence if it were available. But it is a huge positive that the work being carried out to decarbonise the sector through material choices is having a notable influence. For the next stage is to ramp up progress, so that developers, investors and Government cannot ignore the industry's transformation.

Saving emissions from low-carbon cement and concrete is but one action towards net zero. Industry roadmaps provide several methods that when combined should (it is hoped) decarbonise the sector fully. Data is important here. The MPA–UK Concrete roadmap plots a course that low-carbon technology can reduce emissions by 12%, or 76kgCO_2/tonne, by 2050. Worldwide, the Global Cement and Concrete Association (GCCA) roadmap shows a 9% reduction from such tech, with some 350Mt of CO_2 saved.

But by far the biggest contributor to net zero 2050 is carbon capture utilisation and storage (CCUS). A 61% reduction in emissions (390kgCO_2/tonne) from CCUS is planned for in the UK roadmap. In the GCCA map (using a different methodology), CCUS is worth more than a third of the whole target.

The Government's announcement last month of major funding for two carbon-capture sites in the industrial heartlands of the north-west and north-east of England has rightly drawn industry plaudits. As has Labour's confirmation of £22bn of funding over 25 years to boost CCUS and hydrogen technologies (would it be churlish to point out that the latter is a recycled announcement, originally coming as it did from the previous administration?).

Taking a big step such as this to decarbonise industry is significant news. But, again, the data is important here. For a sector that cannot yet agree on a clear definition of CO_2e/ECO_2 (equivalent? embedded? embodied?), there cannot be any hint of sugarcoating, fudging or greenwashing the data for fledgling CCUS. It needs transparent and exact measurement of carbon savings.

The road to net zero will not be straightforward but sticking to the task is clearly imperative. Christopher Benfey, an American author, once wrote, "Sometimes, the shortest path between two points is serpentine." Exactly.

Enjoy the issue!

James Luckey, Editor
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NEWS IN BRIEF

UK • 3D printing
Advanced materials group Versarien has signed an agreement with Balfour Beatty to develop a range of low-carbon, graphene-infused, 3D-printable mortars suitable for civil construction.

USA • Cement
Holcim has invested in Sublime Systems, a US low-carbon cement technology start-up. Its technology is based on a proprietary CO_2-free electrochemical system; it uses electricity and carbon-free raw materials for cement production. It is currently building a commercial-scale manufacturing plant to produce 27,000 tonnes/year of cement as of 2026.

UK • Mineral paints
Society member Keim Mineral Paints has extended its range of paints for residential and commercial spaces. Metallic effect paint is manufactured using mineral pigments, giving concrete, walls etc, iridescent reflections to add accents and visual impact.

Switzerland • Cement
ABB has signed an MoU with Carbon Re, an industrial AI provider, to assess ways to accelerate the decarbonisation of cement while improving productivity.

UK • Washwater
The British Concrete Transport Association has published a White Paper on off-site disposal of concrete washwater. Concrete washwater is a waste material and should be treated in accordance with UK legislation relating to the storage, transport and disposal of waste. Visit: ***https://tinyurl.com/mts433zj***.

UK • Testing
Materials testing firm Socotec has opened a new north-west hub facility in Altrincham, near Manchester. The location will house several of key business units, including materials testing, geotechnical investigations and geophysics, air and emissions, and environmental consultancy.

UK • Surveying
Survipod Engineering has launched its Survipod Innogain Former, a precise surveying tool. The company claims its new design can reduce surveying errors by as much as 200%, improving accuracy, speed and stability in the setting out process.

Investment to help concrete decarbonise

INNOVATE UK, the UK's innovation agency, is to invest £3.2 million in seven innovative projects to help propel the decarbonisation of the UK's concrete industry. The seven projects receiving funding are:

- Cemcor – The funding will aid development of calcined clay from low-grade sources, to produce a new generation of low-carbon cement and concrete
- Cocoon Carbon – The funding will support work scaling the production of a novel cementitious material from electric arc furnace steel production
- Skanska UK – to continue repurposing excavated London Clay in concrete applications
- CEMEX UK Operations – aid development of combining micronised limestone and graphene (CoMLaG), which reduces the carbon footprint of concrete
- John Sisk & Son – support Ecocem's ACT, providing low-carbon concrete solutions to site
- EFC Green Concrete Technology UK – support the scale up and implementation of LowCast geopolymer cement technology
- Materials Processing Institute – support development of recycled concrete fines as a low-carbon cement substitute.

As well as receiving funding, these projects will link with Innovate UK's Concrete Commitment Cohort, contributing to ongoing work developing an Advance Market Commitment (AMC) for concrete. AMCs are commitments, often from Government or private donors, to buy or subsidise products such as low-carbon concrete, as soon as they are successfully developed, to incentivise further production.

The Contracts for Innovation Decarbonising Concrete competition aims to make commercial adoption of low-carbon concrete happen faster. In doing so, the competition also aims to enable higher engagement between innovative projects and end-users. The project is funded via Innovate UK's current Net Zero Systems programme.

2025 UK CONCRETE SHOW REGISTRATION OPEN

RETURNING for its 13th edition, the UK Concrete Show (UKCS) takes place on 26–27 February 2025 at the NEC Birmingham. Registration for the exhibition is now open at: ***https://tinyurl.com/yzzbb9z2***. The Concrete Society is a supporting partner of the show for a second year.

Following event owner QMJ's acquisition of the Concrete Expo earlier this year, the UKCS is the only UK exhibition dedicated to the concrete industry.

In addition to product and equipment manufacturers, suppliers and service providers taking part, there is the Concrete Connect Theatre, featuring free-to-attend seminar sessions across both show days.

UK'S FIRST NET-ZERO BUILDINGS STANDARD

A PILOT version of the UK's first cross-industry Standard for net-zero carbon-aligned buildings has been launched. Organisations BBP, BRE, the Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS and UKGBC have joined forces to champion the initiative.

The UK Net Zero Carbon Buildings Standard is a free-to-access technical Standard aimed to enable the built environment to prove that built assets align with the UK's carbon and energy budgets. Up to this point, there has been no single, agreed methodology for defining what 'net-zero carbon' means. Consequently, the area has been rife with claims around the topic. Visit: ***https://tinyurl.com/af645b76***.

BYRNE Group, comprising Byrne Bros, Ellmer Construction and O'Keefe Construction, has increased pre-tax profits by 9% to £7.4m from a turnover of £170.6m, for the financial year to June 2024. RC frame contractor Byrne Bros has increased its turnover by 32% with a corresponding increase in pre-tax profit of £4.2m. The business has recently secured 'TVC Centre' for Stanhope in White City, 'The Hub' for Balfour Beatty at AWE Aldermaston and multiple HS2 structures for BBV.

PLACING 15 BRIDGE BEAMS AT HS2 STATION

BALFOUR Beatty VINCI marked a major milestone at HS2's Interchange Station in Solihull after a 20-strong team carefully lifted 15 colossal bridge beams into position.

Hoisted into place onto existing abutments and piers using a 650-tonne crane, the concrete beams form the 'building blocks' of a road bridge that will take vehicles over the high-speed railway and onto the station car parks.

The beams weigh a total of 565 tonnes and are the foundation of the two-lane bridge, which will stretch 63.5m once finished. Due to be completed in early 2025, the next phase of construction will see a concrete deck placed, before parapet walls are installed and surfacing work can take place.

It represents the most significant structure yet built as part of the new station development.

PAYING A PREMIUM FOR LOW-EMISSION MATERIALS

NEW research from Climate Group and Ramboll reveals close to 50% of global businesses are prepared to pay a premium for lower-emission steel and concrete.

The report *The Steel and Concrete Transformation: 2024 market outlook on lower-emission steel and concrete* comes after over 250 companies globally from 42 countries and 21 industries were surveyed on their current readiness to use and willingness to pay for lower-emission steel and concrete.

While the outlook is broadly positive, the report also focused on the greatest barriers to adoption, which businesses stated remain cost (84%), industry conservatism (37%) and lack of knowledge (33%). Financial levers such as tax incentives, credits and subsidies (69%), carbon pricing (50%) as well as minimum product standards or embodied carbon limits (43%) were identified as crucial policies to be prioritised. Visit: ***https://tinyurl.com/5n8stz6e***.

NEWS IN BRIEF

UK • Graphene
Molten Ventures has co-led a £3m round in Concretene – a nanomaterial technology firm. The investment will fund the development of the Concretene product – a graphene-enhanced admixture – to take the business through product certification and onto upscale revenue. Alongside its new investors, also including LocalGlobe, Concretene is working with ground engineering firm Roger Bullivant and CEMEX on specific formulations for low-carbon CEM II/III cements.

UK • Fly ash
Hive Aggregates has received planning consent for its Retford Circular Economy Project (RCEP) in northern England. The project will extract fly ash from a landfill site in Retford, to be used as a cement replacement. Following the closure of Ratcliffe-on-Soar, the UK's last coal-fired power station, RCEP will provide a new source of fly ash to the construction industry. As well as producing fly ash, the project includes plans to restore the site, promoting biodiversity and natural landscapes.

Colombia • High-strength
CEMEX is the primary concrete supplier for the construction of Line 1 of the Bogotá Metro in Colombia. The project requires 870,000m³ of high-strength concrete. Led by Metro Línea 1, the concrete will be used to construct high-strength prestressed piles, U-beam systems, columns, capitals and eight stations of Line 1 of the Bogotá Metro. The project aims to enhance the daily commute of over a million residents in Colombia's largest city by providing more efficient and sustainable transportation options.

Saudi Arabia • SCM
UK- and UAE-based firm Next Generation SCM has partnered with Nizak Mining Company for the production of low-carbon concrete in Saudi Arabia. The venture is to build Saudi's first calcined clay supplementary cementitious material production facility, with an initial annual capacity of 350,000 tonnes, aiming to double this by the second year. It will use patented technology from Danish company CemGreen, which has developed processes for calcinating clay.

Structural elements of Scheldt Tunnel ready

BASIC construction of the structural elements for the Scheldt Tunnel in The Netherlands has been completed. Dutch engineering firm Jan De Nul, as part of TM ROCO, has been manufacturing the tunnel elements.

The Scheldt Tunnel forms the most important element of the Oosterweel Link and will complete the Antwerp Ring Road on the northern side. With a total length of 1.8km it is being constructed in line with the immersed tube tunnel method.

Overall, up to 200,000m³ of concrete and 50,000 tonnes of steel were used for the realisation of the tunnel elements. Each part weighs approximately 60,000 tonnes and consists of two shafts for car traffic, a 6m-wide bicycle shaft and an escape shaft. Together these elements form the Scheldt Tunnel, providing an additional crossing beneath the River Scheldt and as such completing the Ring Road.

The works in the construction dock of Zeebrugge started in January 2023, with the first concrete pour for the tunnel elements. Now, more than a year and a half later, and well on schedule, the works have been completed with the last concrete pouring.

The Scheldt tunnel will be finished in 2028; traffic will be able to drive through the tunnel in 2030.

SOCIETY member and construction chemical supplier Oscrete has appointed new materials and testing apprentice, Rennison Forrest-Parkinson, who joins the laboratory team in his first full-time role since leaving Guiseley High School. Rennison (19) already has a construction background after shadowing a construction site manager and undertaking work experience at a local construction firm.

REPORT REVIEWS EUROPEAN STANDARDS

A NEW report from the Alliance for Low-Carbon Cement and Concrete (ALCCC) argues that European Standards have not kept pace with the speed of technology in the low-carbon cement and concrete sector, and are hampering development.

The ALCCC aims to shape the policy, legislative, standardisation and financing foundations necessary to make low-carbon cement and concrete the norm. Its latest report suggests that the challenge of decarbonising is not technological but regulatory.

Safe, scalable and low-carbon solutions exist – and Standards have the potential to make them the norm. However, they are preventing these solutions from market entrance.

The lack of harmonisation of the main European concrete Standard (EN 206) creates significant barriers to trade for low-carbon cement and concrete. Visit: ***https://tinyurl.com/597yc4ka***.

CDM PRODUCTS, LOWER-CARBON PAVERS AND FOAM

AGGREGATE Industries has introduced ECOCycle to the UK market. A circular approach is applied to products that contain at least 10% construction and demolition materials (CDM) content, following an independent verification, to ensure they are compliant with the applicable clauses of ISO 14021. Products with ECOCycle can contain 10–100% of CDM. Meanwhile, two of the company's subsidiary firms have launched new products. Bradstone has unveiled Piccolo Setts – a concrete block paving product offering a direct alternative to Dutch clay pavers. The company says its manufacture produces approximately 50% less carbon compared with traditional clay pavers. In addition, subsidiary London Concrete recently launched products in its new foamed concrete Airium range: Airium Roadfill and Airium Voidfill.

'CONCRETE IN LIFE' PHOTO COMPETITION OPEN

THE Global Cement and Concrete Association has launched its annual 'Concrete in Life' photo competition, which highlights the sustainability, essential nature and beauty of concrete. The competition is open to everyone – professionals, amateurs, or anyone with a smartphone. There are four categories: urban concrete, concrete infrastructure, concrete in daily life and beauty and design. The closing date is 30 November; winners will be announced in March 2025. Visit: ***https://tinyurl.com/3bd3zs8p***.

FUNDING FOR CARBON-NEGATIVE AGGREGATES

LOW Carbon Materials (LCM) has secured £3 million funding, via Ada Ventures, with additional participation from Green Angel Ventures, Northstar Ventures, an Innovate UK grant and sponsorship and skill-based support from Deloitte.

LCM designs and manufactures carbon-negative aggregates. This funding round will allow the company to scale its operations and accelerate its impact in decarbonising the construction industry. The company was a finalist for the prestigious Earthshot Prize.

NORTH LONDON HEAT AND POWER PROJECT

The North London Heat and Power Project (NLHPP) is an ambitious initiative by the North London Waste Authority (NLWA) aimed at transforming waste management in North London. The centrepiece of this project is the Energy Recovery Facility (ERF), designed to process 700,000 tonnes of waste annually and generate up to 78MW of heat and energy – enough to power 127,000 homes. This modern facility not only addresses waste management but also contributes significantly to local energy needs and environmental sustainability. **Darragh McInerney** of **Byrne Bros** reports.

In January 2022, the ERF contract was awarded to Acciona, with Byrne Bros subsequently being selected to undertake the civil works and deliver the groundworks, services and reinforced concrete structure. A prominent element of the build is the main waste bunker – a sizable structure dimensioned at 70 × 30m, with an overall height of 31m. Featuring a challenging geometry, with numerous perpendicular buttresses, varying wall heights, capping upstands, encapsulated columns, tipping hall chute openings and a variety of wall thicknesses ranging from 500 to 1000mm, it required innovative construction techniques to capture both complexity and structural integrity.

SLIPFORM CONSTRUCTION

The construction of the bunker was divided into two equal sections, resulting in U-shaped footprints, to best manage the efficiency of material supply, labour and access. Each section was built using the slipform method where concrete is continuously poured into a moving form and the working platforms, or 'rig', hydraulically

MAIN IMAGE, TOP: NLHPP waste bunker and slipform construction.

ABOVE, LEFT AND RIGHT: External access stair arrangements.

LEFT AND FAR LEFT: Top deck for reinforcement and concrete placement.

pulls itself upwards. The separate operations ran 24 hours for maximum programme gain, with actual concrete placement taking only 11 days for each. This approach facilitated 1164 tonnes of reinforcement to be fixed and a total concrete placement of 6722.5m^3 for the completed bunker.

The slipform rig was designed in-house, for rapid adaptions and minimal downtime, while catering for the specific design geometry and low-level wall terminations. When several changes occurred over a short vertical distance, cleated, structural-steel support columns were embedded in the concrete adjacent to the climbing tubes, to provide additional restraint and allowing the full slipform rig to climb continuously without stopping for further adaptions.

Since the completion of the bunker, a further eight ERF satellite cores ranging in height from 35 to 56m, have benefited from the slipform proficiency.

SOLUTIONS

Byrne Bros leveraged its extensive knowledge in slipforming large structures to optimise the construction of the waste bunker. Key innovations included:

- Materials – use of Byrne Bros' proprietary slipform kit facilitated the development of fully tailored solutions to effectively meet the project's unique requirements.
- Internal design – Byrne Bros' temporary works design department, equipped with deep knowledge of slipform techniques and complex temporary works, played a crucial role in enhancing the construction process.
- Early design identification – various intersections necessitated reinforcement that fell outside of standard slipform detailing procedure. While most could be rationalised with a coupler-bar arrangement, some over-length bars required a modification to the slipform rig hoarding, with scaffold 'pods' being built specifically to allow safe extension of the bar beyond the standard hoarding line.
- External staircase access – to overcome access restrictions within the U-shaped rig, a modular external staircase was designed for use in multiple locations around the slipform. This enabled unrestricted movement between the top, working and trailing decks without encroaching on the working platforms.
- Top deck access hatches – due to the limited deck space, standard hatches for passing reinforcement and concrete pipelines were impractical. Instead, letterbox-style slits were used within the top deck for fixing reinforcement and task-specific raised access points employed for the concrete pipelines, allowing for efficient material handling without blocking access.
- Bespoke truss beams – to stabilise the temporary open-ended U-shaped wall arrangement, truss beams were designed to bridge the 30m distance between the walls. These trusses included walkways to reduce access

ABOVE, LEFT AND RIGHT: Truss beams and access pods on the south bunker section.

RIGHT AND FAR RIGHT: Dedicated storage solutions.

		Pre Construction Specified Concrete Mix Design			BBF Actual Mix Design		
Mix	Qty (m^3)	tCO_2e	$kgCO_2e/m^3$	Comment	tCO_2e	$kgCO_2e/m^3$	Comment
SL-4	1,095	363.54	332.00	Min cement content based off concrete mix Technical Note, remaining elements matched to actual mix design.	269.52	246	45% SCM replacement
SL-6	2,982	989.86	332.00		728.90	244	
SL-8	3,129	1,038.66	332.00		772.56	247	
	7,205	2,392			1,771		
					-621	-26% ECO_2e reduction	

ABOVE:
Table 1 – comparison of embodied carbon of specified versus actual concrete used.

BELOW:
NLHPP waste bunker in October 2024 and the project team.

times and hanging access pods below the trailing deck to assist in dismantling and removal.

- Efficient storage solutions – with a limited footprint on the main working deck, novel storage solutions were implemented to maintain a clean and organised workspace.

ENVIRONMENTAL CREDENTIALS

Byrne Bros' environmental objectives were demonstrated through the embodied carbon savings achieved in the concrete used for the bunker walls. Understanding the carbon intensity of the concrete is based on the firm's long history of tracking and interrogating its concrete carbon data. By understanding the carbon intensity of each load delivered, we established a reliable baseline of concrete carbon data. This insight enabled better decision-making in material selection and construction practices, ultimately contributing to more sustainable building methods.

From this, the average and lowest embodied carbon equivalent (CO_2e/m^3) for each application is known from which ambitious carbon reduction targets can then be set.

For the NLHPP, Byrne Bros analysed Acciona's proposed mix specifications against its own historical data set and forecast volumes. By making use of the type and range of cement compositions allowed within current Standards and with no impact to cost or programme, a 26% reduction in CO_2e/m^3 was achieved, an equivalent saving of 621 tonnes of carbon (tCO_2e) when compared with the original preconstruction specified concrete mix designs (see Table 1) for the waste bunker. Byrne Bros used its project-specific concrete mix tracker, which allows for the monitoring and reporting of the CO_2e savings achieved by mix designs.

CONCLUDING REMARKS

The North London Heat and Power Project represents a major step forward in sustainable waste management, with the ERF, being a critical component of North London's waste strategy. The construction techniques and carbon reduction initiatives used by Byrne Bros underscore the project's commitment to sustainability and efficiency. The NLHPP stands as a model for future waste management projects, showcasing the potential for large-scale infrastructure to contribute positively to environmental goals.

Using the slipform technique for the construction of the NLHPP waste bunker, and the inclusion of innovative solutions, showcases a blend of creativity and efficiency, as well as a commitment to optimising construction processes for sustainable and efficient large-scale construction projects.

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SLIPPING AND CLIMBING?

In what is believed to be a UK first, **Stephenson** is currently completing two projects with slipforms containing climbing cranes, which climb within the core while slipforming continues. **Eric Vere** reports.

It has become an ever-more common scenario for a project's footprint to extend to all boundaries on-site, which can become problematic when trying to plan logistics and especially cranage on-site. These issues can have a bearing on the chosen method of construction for such projects and sometimes they require some out-of-the-box thinking.

Hawthorne House in Stratford, London, has a large core located centrally to the reinforced concrete frame, standing some 120m tall and circa 22 × 8m on plan. As is common, the core reduced in size as works proceeded, with adaptations at levels six and seven as the cores reduced, and new walls starting at level seven requiring some temporary works to support the commencement of the slip.

CRANE AND STAIRWELLS

An aspiration of the main contractor was not to leave openings within the 38 floorplates, which would prevent follow-on trades and achieving a watertight building, and it was therefore decided to place the crane within one of the stairwells. Due to the size and location of the required crane mast, this decision ruled out a possible jumpform solution, making slipform the preferred method of construction for the core.

The crane mast was too tall to free stand and in order not to become jib bound and allow the slipform to continue uninterrupted to the full height, it would have been necessary to increase the height of the crane as the works proceeded. Rather than a traditional crane climb, which would have required a mast section too large for the core, crane specialist JR Crane Services suggested that the crane could be climbed within the core concurrent with the slipforming process, thus reducing the overall required mast height and size.

MAIN IMAGE, RIGHT:
Figure 1 – a long shot looking at the reduction in size of the core at levels six and seven, along with the introduction of new riser walls at level seven.

TOP:
Figure 2 – the outer rams retract leaving the crane suspended on the central pocket; the central ram lifts the crane until the outer rams are in line with the next set of pockets 4m higher, whereby they then bear the load of the crane and the central ram moves up.

ABOVE:
Figure 3 – stairs and landings are cast just behind the slipform rig or below the suspended crane.


group
STEPHENSON
STEPHENSON

Climbing within the core was achieved by forming two opposing rows of pockets in the slipform core walls, which the crane would use to climb up through the core, using its in-built hydraulic beam lifting system. Due to the extreme loading taken on the middle pockets while the jacking of the crane took place, the reinforced concrete core walls had to be specifically designed from a reinforcement perspective to accommodate these openings within the walls, being designed much more like a column than a wall. Furthermore, the slipform rig itself had to be designed to ensure no climbing tubes or jacks clashed with the crane tower.

The crane is climbed every five to six levels and it is crucially important to ensure that the concrete on the floors below has reached the design strength prior to the climbing process being undertaken, so on-site cube testing is undertaken to ensure compliance with the design strength.

This methodology is not without its difficulties. One such problem that has been encountered is that the walls adjacent to the crane mast are very problematic to finish once extruded out of the slipform, where a better than a 'standard slipform' finish is required.

GUIDANCE

While there is no precise definition of a slipform finish, further guidance can be found in The Concrete Society Advice Note 70: *Vertical slipform surface finish*[1]. Generally, though, a slipform finish is reasonably similar to that of an Ordinary finish as defined by the *National Structural Concrete Specification*[2] but will generally show signs of dragging normally floated off once extruded from beneath the form on a hanging deck.

As noted, due to the mast location and proximity to the walls, this wet finishing has not been possible and it will require some making good/decoration at a later date once the staircases have been installed. Furthermore, there are six jump pockets in the walls that have to be infilled every 4m up through the core up to level 23 (at which point the crane can oversail the rig and no further jumping is required).

One benefit, however, of taking the crane up with the slipform core is that it allows us to work in what is in effect any empty stairwell below the suspended crane base platform. Rather than wait for the crane to be removed, we can install the permanent stairform and landings, as well as infilling the crane pockets and undertaking further making good as necessary.

TOLERANCES

As always with slipform, the achievable tolerances must be noted and the climbing pockets themselves had to be cast within ±10mm of each other to allow the crane to jump. We achieved this with non-shrink grout and steel plates set to level, which could be recycled up through the floors.

As the crane is not attached to the rig itself, the rig cannot be twisted or moved out of position while lifting. However, when at its maximum height prior to climbing, care must be taken to ensure that the crane mast and slipform rig do not come into contact through the natural movement of the crane when under load.

We now have two more projects in the pipeline where we will be using the same slipform and crane system again, and having worked out the wrinkles with the climbing process, it should be easy slipping all the way to the topping out.

References:

1. DAY, R. *Vertical slipform surface finish*. CONCRETE Advice No.70, The Concrete Society, Camberley, May 2022.
2. CONSTRUCT. *National Structural Concrete Specification for Building Construction. Fourth edition complying with BS EN 13670:2009*. The Concrete Centre, Camberley, 2010.

LEFT:
Figure 4 – a shot from below showing the three rams and climbing pockets.

Project: 2 Ruskin Square, East Croydon
Providing hidden support for precast stairs with integral half landings, TSS connectors (circled) enhanced the visual impact of fair-faced concrete inside both stair cores. Bespoke FERBOX was used to connect the external floor slabs, and the main (covered) landings, which were cast in situ. Programme was accelerated, and structural requirements were satisfied with minimal material usage and wastage. Risks were also reduced, improving health and safety on site.

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(All photos: Doka.)

DokaXdek panel pre-reinforcement at Linz in Austria.

CREATING A PLATFORM FOR SAFER, SMARTER CONSTRUCTION

The requirement for slab (sometimes known as floor) formwork is fundamental to many contemporary building practices. The well-established process helps to shape and strengthen a concrete frame or civil structure essential to many construction projects but has evolved little in the past few decades. New approaches have gradually improved how slab formwork is used, as it evolves from traditional formwork methods towards more systemised approaches. James Hurst looks at the development of one new system recently introduced to the UK market: Doka's 'DokaXdek' slab formwork family.

Formwork panel mid-installation progress at Linz in Austria.

The challenges associated with traditional slab formwork are well known. They include working at height, which due to falls, accounted for 40 deaths and more than 5000 injuries between 2022 and 2023 in UK workplaces, according to the HSE[1]. In terms of building efficiencies, traditional slab formwork involves a welter of components that increase the opportunity for error, increasing the potential for delays and longer build times. This process also extends forming times and with plywood a staple of traditional formwork, its relatively short lifespan could negatively impact a project's sustainability credentials.

SYSTEMISED BENEFITS

Although not an innovation, systemised slab formwork has proved revelatory. Lightweight in design, modular formwork reduces the need to work at height. Fewer materials are required for the formwork's effective assembly, thus the potential for error is minimised. Systemised slab formwork's composition offers a further benefit to site operatives and the end user. It includes plastic-coated plywood, a durable material, which can also be lighter and easier to handle. These properties help reduce the need for cranage and additional labour. Therefore, systemised slab formwork lays a foundation for a safer, more productive building process that not only offers a consistently high-quality concrete finish but also may lead to greater overall value for contractors.

COMPLEMENTARY PRODUCTS

'DokaXdek' unifies the construction process by offering a range of complementary products – table, panel and I-frame. These are designed to combine seamlessly or work independently, with flexibility being key to their ability to overcome construction site challenges involving safety and ergonomics.

Evolution in the form of a fully integrated smart anti-uplift feature is available with this new slab formwork system, which offers protection against high winds and as a safety feature during assembly. A mechanism that provides automatic connectivity between panels and the props themselves locks them down to prevent uplift during windy weather. This operation can be carried out even though the final assembly process has yet to be completed. Although

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DokaXdek panel mid-installation progress in Germany.

Formwork panel concrete finish for soffit in Germany.

always active during regular use, the anti-uplift feature can be temporarily deactivated. This allows individual panels to be removed or reorientated in the middle of the slab without disrupting the entire deck. Such flexibility accommodates mid-project design changes, ensuring work schedules are not significantly impacted.

The challenges when forming using systemised solutions are usually centred around the integration of these systems in more complex zones and areas, such as around columns and slab edges. These challenges are overcome with the new system due to a range of designed elements that can integrate infill area support using standard Doka rental equipment. H20 beams, for example, can integrate without needing excessive additional props to support.

To overcome the challenge of systemised solutions around the outside of the structure – with the largest crane-handled table sized at 5 × 2.5m – the edges of slabs are easily and safely completed without the requirement for more traditional methods. Just as importantly, this process can be carried out with edge protection preinstalled at ground level. A cantilever solution is already available to enable post-tensioning concrete processes using the large tables and the development of similar solutions are also underway for the smaller panel variant, as part of the drive to instigate ever-higher slab formwork performance levels.

AUTOMATION SYSTEM

In addition to the elements that touch the concrete, a prototype automation system DokaXbot is a semi-automated shifting device currently under development. It aims to offer site teams forming productivity improvements, labour efficiencies and enhanced safety and ergonomics. For the installation and removal of a DokaXdek panel up to 5.20m in slab height, safety at the slab edge and building precision are very much to the fore in its design.

Systemised slab formwork has helped redefine a most crucial aspect of the building process. Safer, less labour-intensive, more rapid and efficient, the modular approach has many benefits. However, if the UK is to deliver buildings of the scale and quality required to safely and comfortably accommodate an ever-growing population as the century progresses, our perspective must be that slab formwork's evolution has only just begun.

EUROPE-WIDE PROJECTS

DokaXdek has already been successfully deployed on a range of building projects across Europe. The table was selected for the 'Dalgårdstunet' residential development in Norway. Its ease of use and durability optimised the supply of 9000m^3 of in-situ concrete on all slab surfaces for the creation of 115 flats, spread across four buildings and 14 terraced homes.

The table form is available in sizes between 4 × 2m and 5 × 2.5m. The system's compact hot-dip galvanised steel frame, which stands just 120mm high, offers a long product life cycle and optimised transportation. This capability can help reduce the product's CO_2 footprint.

Jostein Flatås, owner of the development company delivering the Dalgårdstunet project, says, "We particularly like the four logical table formats. The slab system has a modular structure that allows the tables to be combined as required."

Three projects in Germany are also benefitting from the formwork system. For construction of a new four-storey commercial property with an underground car park in Bavaria, a modern, clean, exposed concrete aesthetic was required. The assembly and repositioning of DokaXdek formwork, facilitated by its slab tables, was integral to achieving the concrete's smooth appearance. The system's low construction height also led to reduced transportation and project costs.

In Munich, slab formwork was specified for a development comprising 250 residential units with balconies, an underground car park and commercial properties. Michael Drexler, senior foreman at S Pöttinger, which is overseeing the project, says, "We used the tables from the basement to the roof and for the balcony. The system's easy handling saved us not only time and money but also nerves." The Munich project was also notable for DokaXdek's permanently installed side protection, optimising operative safety during the assembly of balconies and pergolas. This feature also eliminated the need for additional façade scaffolding. C

Reference:

1. HEALTH AND SAFETY EXECUTIVE, *Health and safety statistics*. Available at: *www.hse.gov.uk/statistics/index.htm*, 2024.

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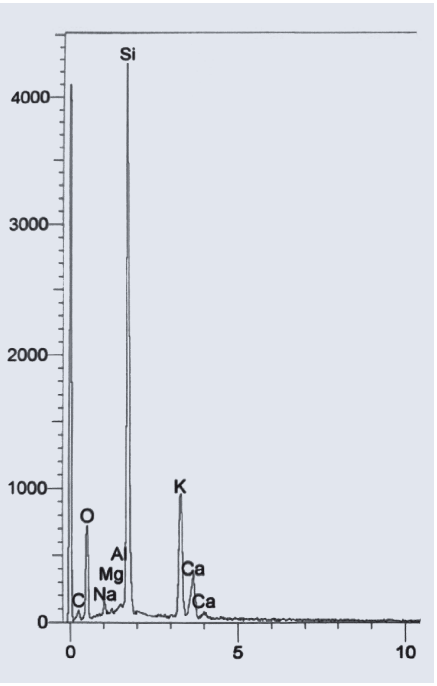
ALKALI–SILICA REACTIONS: WIDESPREAD BUT MANAGEABLE

Alkali–silica reaction (ASR), a highly visible pattern of cracking created by a deleterious reaction within the concrete itself, was originally documented in the 1940s. George Korobokis of Ian Farmer Associates (part of RSK Group) shares how his recent work suggests that this reaction and its consequences are far more widespread than previously understood and how they can be best managed.

BELOW LEFT:
ASR surface cracking with gel leaking out.

BELOW RIGHT:
X-ray diffraction of ASR gel-afflicted concrete.



ASR has been one of the major concerns regarding concrete durability since it was first diagnosed in the USA back in the 1940s, leading to high maintenance and reconstruction costs. Its occurrence in various structures all over the world indicates the need for more research on detection and mitigation at the initial stage of the reaction in new and existing structures. However, it remains poorly understood.

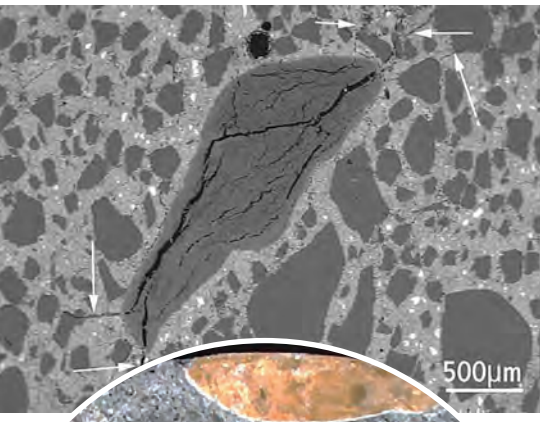
Within concrete, silica in the aggregates reacts with the alkaline solution created by the cement reaction when in the presence of water, which is a vital part of the mixture. This forms a gel that absorbs water, which expands and grows within the hardened concrete. The gel exerts force outwards from within the concrete, forming micro-fractures that grow and eventually hit the surface, where they form the distinctive 'concrete cancer' map cracking and cause a loss in strength. The problem first appeared in the UK back in the 1980s and resulted in several high-profile demolitions. Studies show that 35% of the concrete's compressive strength and up to 24% of its tensile strength can be lost once the ASR gel reaches the surface of the concrete[1].

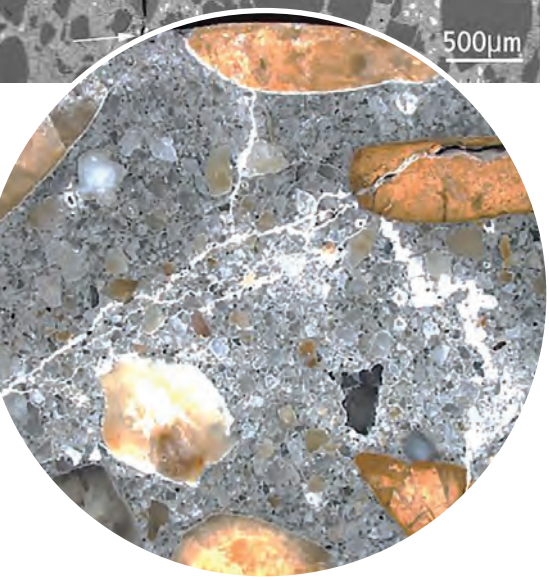
AGGREGATES

Initially, the ASR was believed to be related to large reactive aggregates, with coarse non-reactive aggregates considered safe (eg, basalt, granite and diorite, among others), but what we know now is that almost all concretes will eventually be impacted. Some aggregates will react more slowly than others, with the degree of ASR gel expansion increasing in proportion to the amount of reactive aggregates present, but all concretes will eventually react and produce micro-fracturing. Often, these concretes look unremarkable on the outside, but almost every specimen of concrete that the author has looked at in the past two years has had some degree of ASR-associated micro-fracturing.

This is obviously a problem, given that concrete is the single most widely used material in the world. With that in mind, why has the same high-profile attention not been given to the ASR as has been given to reinforced aerated autoclaved concrete (RAAC)?

The difference is that ASR reactions are not going to cause sudden catastrophic collapse. Until the cracks begin to propagate out onto the surface of concrete, the micro-cracking and gel formation do not have a huge negative impact on the strength of the concrete. In addition, while RAAC can be addressed only by reinforcing the structure or replacing the concrete, ASR-infected concrete can be reinstated or the reaction can be slowed, potentially by many years.





ABOVE LEFT:
SEM chart internal cracks due to ASR extending to the surrounding matrix.

ABOVE:
ASR in precast panels at Cow Green reservoir.

INSET LEFT:
ASR gel micro-cracking.

The first step is to slow the ASR reaction as much as possible from the moment the concrete is laid, by preventing ingress of water. Gel and micro-fractures form because of water within the concrete, but this can be exacerbated by the porous nature of concrete. In dry, arid climates, such as the Middle East (as we see in samples from the UAE and Saudi Arabia), ASR-associated micro-fractures can take an exceptionally long time to form – upwards of 100 years. By contrast, concrete that is within the splash zone of water can have visible cracking from the ASR within a single year of being placed. Therefore, waterproofing membranes will extend the lifespan of the concrete.

In previously laid concrete, we want to prevent cracks from reaching the surface. That means first confirming the presence and extent of ASR gel and micro-fractures. The best technique for identifying the ASR is the examination of thin concrete sections (30µm thick) using a petrographic microscope with plane-polarised, cross-polarised and ultraviolet light.

X-RAY DIFFRACTION

A more recent technique is X-ray diffraction, which is used for the quantitative determination of the principal phases in hydrated cement paste. It's a versatile, rapid, quantitative analytical technique used to analyse the crystal structure of a finely ground powder sample of concrete. The diffraction pattern is a plot of the intensity of the diffracted X-rays versus the scattering angle and this can be used to identify the mineral composition of the tested material. Peaks on the plot – for example, for silica and calcium – can be seen, which confirms the presence of the ASR.

Alternatively, polished sections of concrete can be examined with a more sophisticated testing technique – scanning electron microscopy using back-scattered electron imaging, which is used to investigate and evaluate the micro-structure of the concrete at magnifications ranging from ×15 to ×50,000. This has the advantage of enabling the ASR gel to be analysed using X-ray micro-analysis in order to confirm the presence beyond any doubt.

These techniques show the extent of ASR within the concrete and once this is confirmed, structural engineers get involved. It is possible to use certain sealers, such as silane, on the surface of concrete that has been affected by typical ASR-associated map cracking. This provides insulation from external relative humidity. A spray of lithium nitrate to seal the ASR surface cracks, or electrochemical penetration of lithium ions on concrete structures, can be used.

For longer-lasting repairs, ASR-afflicted concrete can be reinstated. The upper part of the concrete, where the cracks have reached the surface, must be removed and replaced with a new, fresh layer of concrete. Of course, this is only temporary and because the ASR is still present in the heart of the concrete, eventually it will penetrate the new cover. However, it can extend the life of the building or structure. Best practice would be to take the layer back past the reinforcement and reinstate as much as possible, but this isn't always feasible.

Long term, there are trials using concretes that include extra air voids or hollow plastic fibres, with the intention that instead of cracking the concrete, the alkali–silica gel has a place to go inside the concrete structure so that the energy can be dissipated. The use of pozzolans in the concrete – such as slag, fly ash, metakaolin, silica fume and others – as a partial cement replacement can reduce the likelihood of the ASR occurring, as they reduce the alkalinity of the pore fluid. Time will tell how successful these are.

GREATER UNDERSTANDING

In the meantime, as an industry, we need a greater understanding of the ASR and its prevalence in the built environment around us. Due to the slow-forming nature of ASR gel and the fact that it can be reinstated, we can avoid a crisis similar to that of RAAC. Unfortunately, ASR-afflicted concrete is so widespread and there is not enough awareness of it that we are in danger of ending up in a situation where the proper industry knowledge of how to prevent, diagnose and reinstate afflicted concrete is simply not there, leaving us unable to act quickly or effectively. C

Reference:

1. CHANA, P.S. and KOROBOKIS, G.A. *The structural performance of reinforced concrete affected by alkali silica reaction: Phase I*. Technical Report, British and Cement Association, Wexham Springs, 1992.

DRIVING UP STANDARDS IN CONCRETE TESTING AND CERTIFICATION

Edwin AR Trout provides an update on the **Institute of Concrete Technology's** (**ICT**) training initiatives for concrete technicians.

November last year saw the publication of the revised British Standard for concrete (BS 8500-1[1]). Among its various new provisions, the Standard introduces an expectation that personnel are to be competent and qualified to an appropriate level, citing an illustration for the first time: the ACI–ICT Concrete Field-Testing Technician (CFTT) Certificate offered in the UK and elsewhere in Europe by the ICT.

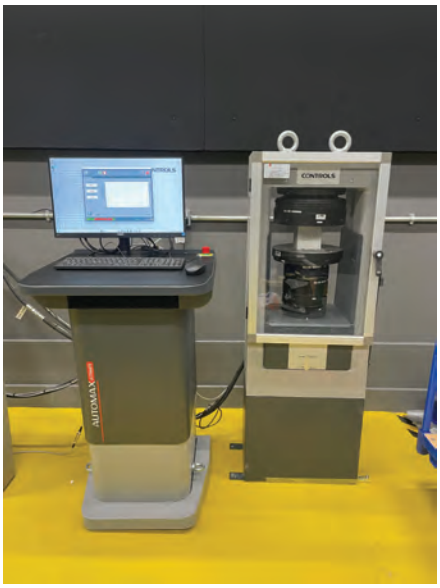
The commentary on provision B.1 in Annex B – Identity testing for slump, flow table, slump-flow, air content, density, additional requirements for compressive strength and consistence retention – includes the following guidance: "All personnel involved in the testing of fresh concrete for identity testing and/or the manufacture of concrete specimens for compressive strength identity criteria are expected to be competent and qualified to an appropriate level (for example, the ACI–ICT Concrete Field-Testing Technician Certificate, or other equivalent third-party competency assessment)".

Jointly accredited and administered by the American Concrete Institute (ACI) and ICT, this programme offers candidates the opportunity to gain internationally recognised certification in relation to concrete field testing. Certification may be arranged as an in-house event for employees or as a public session open to all. For details of the certification scheme, visit: *www.theict.org.uk/Certification.asp*.

Over the past year – in addition to delivering this certification to clients in locations as widespread as Belfast, Bournemouth, Dublin, Dukinfield, Retford, Welwyn and Woking – the ICT and its partners have developed two further programmes.

SITE ACCEPTANCE OF CONCRETE

In one direction, the ICT has encouraged and endorsed the development of an introductory training course by QSRMC, aimed at site personnel responsible for the acceptance of fresh concrete. It aims to raise awareness of and instil basic good practice, to bridge the quality gap that can arise from the disjunction between the delivery of ready-mixed concrete and its acceptance and testing by the contractor. It also points the way for attendees to achieve more formal qualification through the ICT's



OPPOSITE, FAR LEFT:
Taking specimen measurements as part of the practical assessment.

LEFT:
Concrete cubes before and after testing.

ABOVE:
Compression testing equipment.

RIGHT:
Site staff attending the QSRMC course in Birmingham.

Concrete Practice certificate or the certification described above.

Launched during the summer, three cohorts of contractors' staff have so far attended one of these half-day sessions and received jointly badged CPD certificates. QSRMC is actively seeking expressions of interest from contractors in hosting this ICT-approved short course.

The other initiative coming to fruition over the summer is an extension of ACI–ICT certification from field-testing technicians to compressive strength testing.

COMPRESSIVE STRENGTH TESTING TECHNICIANS

Conceived as a parallel programme directed at the testing of concrete in its hardened, rather than fresh, state, the scope of this certification is tightly focused and requires a working knowledge of the three following European Standards:

- EN 12390-1[2]
- EN 12390-3[3]
- EN 12390-7[4].

It additionally requires and tests candidates' competence in the practical performance of these three tests. Limited to three tests, this certification takes place over a single day, rather than the two required for CFTT, and the registration fee is pitched accordingly.

Given the success of the CFTT scheme, the idea of a second strand of certification was promoted by the ICT as a formalisation of an existing training programme and allied to the ACI's long-established examination and assessment processes. The accompanying workbook was adapted to the requirements of a jointly agreed job task analysis and questions were developed that would thoroughly and fairly test candidates' knowledge of the Standards. A pilot session was held in April, with representatives of the ICT and ACI present to gauge the effectiveness of both the delivery and assessment; the occasion also provided the opportunity to qualify an initial corps of future examiners. With adjustments made in light of this experience, the formalities of a jointly sponsored and co-badged certification scheme were concluded in September. The first of these sessions is being held this November, with a national roll-out undertaken throughout 2025.

A training video is also in prospect, to supplement the ICT's existing suite of industry-sponsored videos for testing fresh concrete; these can be viewed at: *www.theict.org.uk/CFTT-training-video.asp*.

So, in one year since the inclusion of competence and qualification as requirements of BS 8500, considerable progress has been made to widen the range of options available to industry. C

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1. BRITISH STANDARDS INSTITUTION, BS 8500-1. *Concrete. Complementary British Standard to BS EN 206. Part 1 – Method of specifying and guidance for the specifier*. BSI, London, 2023.
2. BRITISH STANDARDS INSTITUTION, BS EN 12390-1. *Testing Hardened Concrete. Part 1 – Shape, Dimensions and Other Requirements for Specimens and Moulds*. BSI, London, 2021.
3. BRITISH STANDARDS INSTITUTION, BS EN 12390-3. *Testing Hardened Concrete. Part 3 – Compressive Strength Testing of Specimens (cubes)*. BSI, London, 2019.
4. BRITISH STANDARDS INSTITUTION, BS EN 12390-7. *Testing Hardened Concrete. Part 7 – Density of Hardened Concrete (water displacement method)*. BSI, London, 2019.

THE IMPORTANCE OF UNDERSTANDING CONCRETE'S PERFORMANCE IN FIRE AND HOW TO PROTECT IT

Concrete might not be the first thing you would consider when thinking about designing in fire safety to a construction project. But where a refurbishment or change of use project aims to form a new building around an existing concrete structure, the structural integrity of reinforced concrete can be vulnerable to fire. Here, **Joshua Slack** of **Promat** looks at how the need for fire protection of concrete is evaluated and the available options.

MAIN IMAGE, LEFT:
Passive fire protection can be essential to refurbishment projects.

ABOVE:
A refurbishment project, using existing frame, underway.

RIGHT:
Cutaway showing installation of fire protection boards.

With the introduction of the Building Safety Act, there is an unprecedented level of scrutiny around the fire performance of the building materials used in construction projects. Concrete achieves an A1 non-combustible fire rating and therefore has minimal contribution to the overall fire load. Although concrete itself does not burn, its structural integrity can be compromised under fire conditions, potentially causing a building to collapse.

Where new-builds are concerned, structural integrity under fire conditions is routinely designed into the reinforced concrete structure. But where buildings are being repurposed, and especially where there is a change of use, the old concrete structure may be a risk. This can happen if it does not meet current fire performance standards for the building's new intended use or, as is often the case, where the concrete has degraded.

Wear and tear over decades can reduce the cross-sectional area of reinforced concrete beams and columns or expose the reinforcement. This can be a real issue, as steel starts to lose tensile strength dramatically at temperatures above 300°C, reducing the load-bearing capability of structural concrete accordingly.

SPALLING

It is also important to understand how the concrete itself behaves at high temperatures and in particular how 'spalling' occurs. Spalling is used as a catch-all term and there are a number of different effects that cause this. Concrete contains moisture, which boils when heated, quickly increasing in volume and explosively blowing the concrete apart. Different rates of thermal expansion in different parts of the element as it heats up can also cause large cracks to form and at very high temperatures, chemical reactions occur, which alter the structure of the concrete, weakening it significantly.

As the cost and sustainability benefits of repurposing old buildings become ever more compelling, the construction industry needs to deal with these potential risks. This means accurately evaluating the status of existing concrete structures, so that appropriate measures can be taken where necessary. The challenge here is that assessing the risk is rarely straightforward. Factors such as how close reinforcement within different parts of the structure sits to the surface and the effects of any repairs, additions and modifications, can all add significant complexity.

This means that any specialist survey commissioned, or inspection

undertaken by a fire safety engineer, can often lead to the conclusion that passive fire protection should be applied to some or all load-bearing elements of a building's concrete structure. It is essential that a survey is carried out at the early stages of a project to ascertain the condition of the concrete and how it would be expected to perform in the event of a fire, highlighting any potential issues such as existing degradation or the potential for spalling. This needs to be a key part of ensuring building safety.

Where any weakness is identified, the principal designer, or a fire engineer, will need to ensure adequate fire protection is put in place in line with Part B regulations to ensure structural integrity in the event of a fire breaking out.

PASSIVE PROTECTION

Passive fire protection systems cover the concrete in a continuous layer to insulate it from the heat of a fire for a specified length of time, protecting it from fire damage and preserving its load-bearing capacity. This effectively upgrades the concrete to meet modern standards, at a far lower cost than either replacing concrete or undertaking concrete upgrade work. Different levels of protection can be specified to maintain acceptable temperatures within the reinforced concrete structure for a particular length of time, creating a window of opportunity for evacuation of the building and firefighting to take place.

There are a number of options when it comes to which particular passive fire protection systems to apply in a given situation. The main categories are spray coatings, intumescent paints and fire protective boards. It is important to work with manufacturers and installers who can offer in-depth knowledge about the types and applications of passive fire protection – and can provide third-party certification to prove the performance of the system for a particular end use. Getting it right first time will be imperative with the introduction of the Building Safety Act.

PAINTS

Intumescent paint works via a chemical reaction, which occurs under fire conditions, making the coating swell up and form a protective barrier. Paints can be relatively inexpensive but require space around them to be maintained to allow the protective barrier to form. They also have a relatively short working life compared with other passive fire protection options. Both paint and spray applications require a suitably prepared substrate to apply the material in order to ensure a satisfactory bond is formed. The environmental conditions at the time of application are also crucial to ensure the product application is successful and wet trades need to be allowed adequate time to dry. Care needs to be taken not to 'overspray' intumescent paint and it is also important to protect other elements during the process. A further consideration is that the application of intumescent paint means that often the work cannot be carried out alongside other trades.

For these reasons, Promat recommends the use of fire protective boards for the passive fire protection of concrete structures in most situations, with calcium silicate boards available in different thicknesses to provide a range of fire protection ratings from 30 to 240 minutes. These boards are specifically engineered to offer the mechanical strength and heat resistance to protect concrete and are third-party certified for this specific application to all relevant BS EN Standards.

Boards are easy to work with and provide a smooth finish. Promat offers on-site support and technical training to ensure correct installation. Once installed, finishes can be applied in the same way as they can over drywall systems.

ABOVE LEFT AND RIGHT:
Repurposed concrete – the existing frame has been covered with fire protection panels and prepared for finishing work.

TAKING MEASURES

While concrete might not actually burn, in many cases measures must be taken to ensure the reinforced concrete's load-bearing performance is maintained under fire conditions. By specifying the correct level of passive fire protection, the structural integrity of the building and the safety of its occupants can be protected in the most cost-effective way, allowing the reuse of buildings to support sustainability but also bringing new life to historic buildings.

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GRENFELL REPORT CALLS 'TIME' ON TOXIC BEHAVIOUR

Sir Martin Moore-Bick's damning report into the Grenfell Tower fire made for painful and humbling reading. Lee Brankley of the UK Certification Authority for Reinforcing Steels (CARES) says that part of the construction industry's response must be the introduction of a culture of clarity, transparency and change at pace.

It's time for change – or something similar – is the default phrase of politicians on the hunt for votes, but very few of them set out their stalls as supporters of revolution, even when seismic, irreversible events are happening under their noses.

That may explain why it took decades for economists and historians such as Arnold Toynbee to coin the phrase 'Industrial Revolution', describing the upheaval that shaped Britain and is now at a point of turning full circle.

ERA-ENDING

Closure of Britain's last coal-fired power plant and Tata's closure of its last blast-furnace in South Wales, came as the Government started to try to come to terms with the era-ending conclusions of the Grenfell Report[1]. At the same time, the United Nations decided it was time to abandon the use of paper to share data on safety-critical construction products.

Add in the rapidly accelerating momentum towards off-site engineering solutions and you have all the ingredients for a fully formed revolution in the way we create our future infrastructure.

Unfortunately, there is a risk that we will not learn from perhaps the most powerful lesson of that earlier industrial revolution – the need for clarity and pace in decision making. At CARES we have seen how such a lack of clarity in who does what in Government stymies action: engagement on elements of building safety regulation – tackling the ambiguity on whether steel reinforcement ought to be subject to the same independent safety and performance test as other products covered by the Building Safety Act – proved frustratingly difficult. Levelling up and business departments, with subsidiary regulatory entities, succeeded only in making clear that each were not responsible – let alone accountable – for dealing with it.

OVERARCHING DRIVERS

The Grenfell Report's recommendations are crystal clear on tackling this: accountability and transparency must be overarching drivers in construction policy. Clarity as to who does what, in the shape of an all-powerful construction regulator drawing together this point and others, is much needed. As is the requirement for manufacturers' test results used in certification to be made readily available.

This is an area where CARES has already made rapid strides with global stakeholders. We have reached a point where digital solutions, via the CARES Cloud App, are entering the statute book in other countries. The UAE, through its Ministry of Industry and Advanced Technology (MoIAT), has recently made this CARES digital record a regulatory requirement in project specification and procurement. Others, in South-East Asia and Australasia, are on a similar trajectory.

Yet for years, we have faced reluctance to fully shine the product provenance spotlight on safety steels at the heart of all concrete reinforcement in this country. Part of the problem has undoubtedly been another area confronted by Grenfell – culture.

The toxic behaviours so shockingly exposed in the tragedy's final report represent a dark stain on construction's recent history. Transparency and accountability also mean that the puzzling need for wriggle room some have clung to, through their insistence on retaining outdated paper certificates, is rapidly disappearing.

Well before the word 'Covid' entered everyday use, alarm bells were ringing at CARES over the rise in 'anomalies' or so-called 'data errors' slipping into certificates attached to batches of steel products found by our audit teams. In some cases, eagle-eyed clients raised questions.

We took the strategic decision to move to wholly digital operations. It didn't come a moment too soon as lockdown triggered an accelerated shift. The upheaval was worth it. We now have a digital ecosystem giving full product provenance, from steelmaking through to fabrication and site delivery.

Despite truly transformational progress – it is now possible, for example, to see the full back story of each batch of reinforcement with just a smartphone swipe – some remain resistant to change.

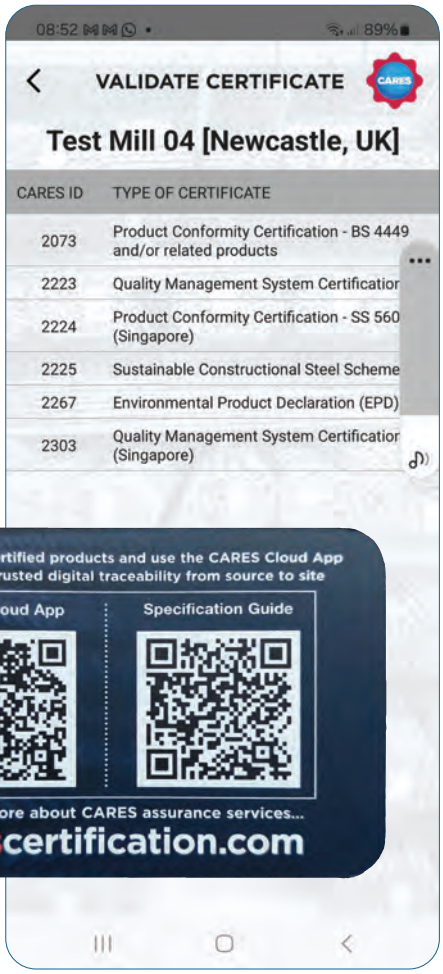
A recent investigation by the UN Centre for Trade Facilitation and Electronic Business (UN/CEFACT) is unequivocal. Its 66-page report[2], published by the UN's Economic Commission for Europe, warns that the risk of manipulation of documents "provide potentially false assurance for purchasers and regulators." Data-based solutions are vital, says the report.

UNCOMFORTABLE MOMENT

The timing of the UN's verdict represents another uncomfortable moment for those who still place commercial advantage over transparency in construction supply chains. This and the Grenfell Report may well terminate the activities of those bent on 'gaming' systems not contractually watertight. Hard to do when a smartphone screen sets out the transparent truth of safety products' provenance.

We must wait for the new Government to absorb all this information. There are encouraging signs, particularly in the steel sector where a new strategy is promised 'in the spring' charting a way forward for those of us who share a commitment not only to its survival but also a secure long-term for the UK steel industry.

Yet as the march of off-site solutions, fully digital transactions and the relentless demand for proven sustainability information gathers pace, let us hope that the wait is not overlong. When the directors of the Liverpool and Manchester Railway set their '£500 premium' public challenge aimed at engineers and iron founders prepared to build a better 'locomotive engine' almost 200 years ago those, such as Stephenson, who held full confidence in their technology went straight into action. When we look back at construction's 'Information Revolution', will we remember those lasting lessons, or ask instead why it was that other nations stepped up to set the pace? C



TOP:
CARES Cloud App screenshot – full details of a reinforcement batch's history at a smartphone swipe.

ABOVE:
Card-carrying QR – instant digital information by app and specification guide.

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Fixings for reinforcement cage design

Aside from tie wire and welding, Trevor Larkin of Ischebeck-Titan considers a third method of connectivity for reinforcement cages – clamping.

Structural concrete requires the use of steel reinforcement, working in tension within concrete, which works in compression, to achieve a structurally sound concrete element.

Therefore, the stability of a reinforcement cage is vitally important to achieve a load-bearing structural concrete member.

A reinforcement cage is set inside the external concrete geometry. For durability, the concrete member requires a concrete cover zone to all faces of the element. This zone varies in thickness depending on the exposure conditions to each concrete face.

CHALLENGES

A cage of reinforcement can be created in different ways, from prefabricated cages manufactured in factory conditions, to on-site fabrication using a team of steel fixers. All of these methods have various challenges for site supply and meeting the contractor's programme.

Before any fabrication is undertaken, a reinforcement cage design is generated. This design caters for the permanent works load-bearing requirements of the reinforcement cage and the structural concrete element in its permanent state, ie, reinforcing bar weights, diameters, centres of reinforcing bar, load and direction of load, anchorage lengths and fixing requirements. In addition, the fabrication of the cage also requires consideration, ie, lifting position, temporary works reinforcement, dynamic loading effects of the cage and its fixings, etc.

FIXINGS AND CONNECTIONS

Thus, many different fixings can be adopted within a reinforcement cage design. For example, a factory-manufactured prefabricated reinforcement cage would generally use either tie-wire fixings or welded bar-to-bar connections, with the odd clamp dotted here and there. The same steel fixing methods might not necessarily be used on-site.

Welding on-site poses the following challenges:

- Electric shocks (primary and secondary) – in damp and cramped working conditions.
- Noise exposure – welding can affect hearing long-term, as it can generate in excess of 100dB(A).
- Exposure to UV and IR radiation (arc eye) – a long-lasting, debilitating injury.
- Exposure to gases and fumes – pneumonia, asthma, cancer, metal fume fever and lung irritations.
- Burns – from welding arcs, UV rays and molten metal.
- Weather dependent – large amounts of programme time can be lost if it rains or with increased levels of humidity.
- Hot works certification – requires a two-person working crew, with a qualified engineering sign-off or hot works certificate.

ABOVE:
A clamp should offer efficiencies in the fabrication of reinforcement cages.

Tie-wire connections in reinforcement cages offer a practical solution to connect reinforcement bar to bar. However, the following considerations of tie wire need to be understood before being used:

- Low structural load capacity for a tie-wire connection, as opposed to a clamp or a welded connection.
- Material suitability of the tie wire.
- Wire thickness (varies).
- Ductility (temperature can affect the brittle nature of tie wire)
- Movement (mm) against load (kN).

- Checking and approving the tying method (how many turns and type of tie required).
- Dynamic loading considerations (wind, loading movement, etc) as stretching of the tie wire will loosen the bar-to-bar connection.

Clamping reinforcement is another alternative for connecting reinforcing bar. A clamp should offer efficiencies in the fabrication of reinforcement cages. It should offer the end user an increased safe working load (SWL) compared with tie wire, less administration and less practical set-up compared with welding on-site. It should be versatile and connect many sizes

> "The stability of a reinforcement cage is vitally important to achieve a load-bearing structural concrete member."

and orientations of reinforcing bar. It should be easy to install and apply correctly in whatever arrangement of reinforcement is designed. It should be independently tested and have full transparency in SWL capabilities and torque tightening requirements.

If the above criteria are met, then there will be labour savings, site efficiencies and a sustainable way to connect reinforcing bars.

Ischebeck Inform has a proven and trusted bar-to-bar clamping system, called RECO clamp. The RECO clamp was initially developed to help transfer wet concrete load, from a deep base pour, back into the permanent works reinforcement layers, with only minor movement on take-up of load. This enables the contractor to have a self-supporting temporary works stop-end solution for all concrete-to-concrete construction joints, within the permanent works, thus significantly increasing the speed of the build and improving sustainability (less material use, less time on-site, less cost, less labour and less CO_2).

ADDITIONAL APPLICATIONS

Since its initial development, the RECO clamp has been used for many applications where a high SWL to connect reinforcement is desired. Additional applications currently include:

- Holding down ducting from uplift within a concrete pour.
- Providing a method of creating a working platform within a reinforcement cage, to enable contractors to work at high levels without the need for access towers etc.
- Providing full connectivity of embedment plates back to the permanent works reinforcement.
- Providing a proven solution for connecting piling feet to stop the loss of reinforcement anchorage at the top of the cage should the weld crack and the cage fall to the bottom of the excavation and for connecting large piling cages.
- To assist in the connection of reinforcing bar between precast and in-situ concrete elements (within a stitch panel).
- Reinforcing bar stability of reinforcement cages, prior to concreting.
- Lifting large reinforcement cages across site.

Certain documents and governing bodies have already approved and certified the use of the RECO clamp on many of the largest civil engineering projects in the UK, including Temporary Works Forum, Nuclear New Build, HS2, etc. The product has been approved for many applications where stabilising the reinforcement cages, prior to concreting, is imperative. Many of these sites have seen the advantages of this third method of reinforcement connectivity (tie wire and welding being the first and second).

BELOW LEFT:
RECO clamp has been used in applications where a high SWL to connect reinforcement is desired.

BELOW RIGHT, BOTTOM:
The RECO clamp product shown in-situ and for reinforcement cage.

WORLD FIRST: 3D PRINTING FOR CONCRETE BEAMS SHOWCASED IN PILOT FOOTBRIDGE

3D concrete printing, historically used mainly to construct walls for houses, has now been used for the first time for a completely new and innovative application – printing the concrete permanent formwork for single-span beams for large-scale construction. Andy Coward and Sarah Blake of minimass report.

Figure 1 – COBOD BOD2 3D printer printing the bridge beams.

3D printing is used to precisely place the minimum quantity of concrete required by the design; using less material through design optimisation is considered one of the best ways to reduce embodied carbon in construction.

Until recently, there have been two significant hurdles for 3D construction printing, which have meant it has only been used for compression-only structures such as walls. First, only a high-cement mortar could be used, containing no aggregates. To comply with the Eurocodes for concrete, aggregates are required. Second, historically it's been difficult to incorporate reinforcement into 3D-printed concrete structures.

These two problems have been overcome by fabricating an innovative new type of beam – the minimass beam – using a COBOD BOD2 printer, operated by Harcourt Technologies Ltd. The perimeter is printed to create a permanent load-bearing structural formwork (Figure 1), with zero waste as no plywood/steel formwork is required and only the concrete required is used. The printer can use any mix of concrete required for the design – typically a C40/50 code-compliant strength-class to BS 8500[1], which includes aggregates of 6–10mm. This is crucial as it reduces the cement content of the mix, enabling this 3D-printed concrete to be similar in carbon content to traditional poured concretes. The concrete can be sourced from any ready-mixed concrete supplier, so the supply chain already exists. Standard mild steel reinforcement cages can then be positioned inside the printed permanent formwork and then any suitable mix of concrete is poured into the cavity, which can include low-carbon options.

> "The bridge... provides an embodied carbon of 30% and a supply cost saving of 40% vs traditional steel or concrete footbridge designs."

Post-tensioning steel cables are used in tension along the base of the beams, with anchors at either end. These allow the beams to take extra load. At the end of the manufacturing process, the cables are inserted and stressed for the first time to put the concrete into compression, tighten everything up and allow the beam to be moved around. The beams can be lifted, transported and installed seven days after printing. Once a beam is in position and the loads applied,

value proposition

example 9m beam, office loading	minimass (reinforced)	minimass (unreinforced)	concrete	steel	glulam
lead time (days)	7	7	28	90	-
embodied carbon (kg)*	875	640	2,020	1,780	630
total mass (kg)	2,950	2,870	9,200	1,125	2,250
supply cost (£)**	2,700	2,500	4,200	3,400	10,400

*Note: This is one example beam – savings in each case will differ. *Using ICE DB v3.0 and Arup recommended glulam factors; ** Estimate includes supply, fire protection & delivery. Cost comparison provided by Core 5 (London-based quantity surveyor), based on London prices from January 2023; using low-carbon material choices going forward would drive minimass further towards net-zero carbon.*

ABOVE:
Figure 2 – carbon, cost and lead-time comparison of minimass vs concrete, steel and glulam options – for an example 9m beam with office loading.

a second stressing is carried out to take out the deflection caused by the load.

The technology allows any geometry to rapidly be produced for no additional cost with minimal labour, providing mass customisation. This means huge savings in material quantities compared with traditional concrete or steel beam manufacture, which results in significant reductions in both embodied carbon and cost. Carbon emissions are reduced by up to 70% and supply cost by up to 35%, for equivalent performance, length and depth (Figure 2).

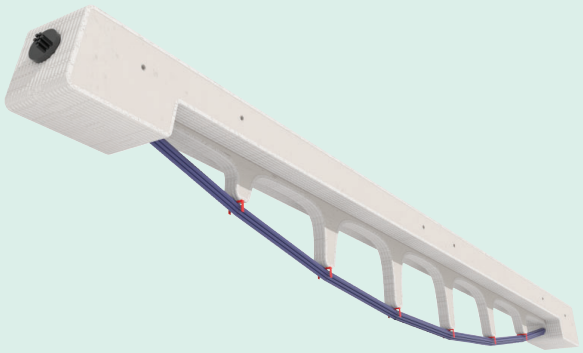
Compression and tension elements are separated in the beams – a bit like a hybrid concrete and steel truss. The aim is to use the right material, in the right place, for the right purpose – concrete in compression and steel in tension (Figure 3). Both the design of these beams and their additive manufacturing process are patented in the UK and these patents are being extended to cover Europe, the US, Canada and Australia.

PILOT DEMONSTRATION FOOTBRIDGE

minimass, a Buckinghamshire-based start-up, recently completed its first pilot project at the Norfolk site of Constructionarium, a not-for-profit educational centre providing immersive experiential learning to students and professionals in the built environment sector. This is a 10.8m-long showcase footbridge, funded mainly by an Innovate UK Net Zero pre-commercialisation grant. This is the first Eurocode-compliant structure to be made using 3D-printed formwork for concrete beams. It includes two minimass beams, Scottish glulam timber decking from the company Ecosystem and timber parapets, demonstrating the ideal combination of 3D-printed formwork for concrete beams and timber to create a highly functional low-carbon hybrid solution (Figure 5).

The bridge (excluding foundations and prelims) provides an embodied carbon of 30% and a supply cost saving of 40% vs traditional steel or concrete footbridge designs.

As the bridge is a world-first demonstrator project, the beams are fully instrumented to gather data on strain and temperature using fibre-optic sensors provided by infrastructure monitoring specialist Epsimon. Material uncertainty occurs in the early



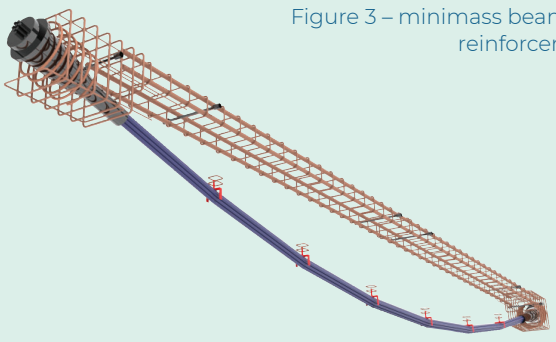


Figure 3 – minimass beam and steel reinforcement cage.

ABOVE:
Figure 4 – pilot footbridge at Constructionarium.

BELOW:
Figure 5 – minimass display beam.

life of a structure, mostly due to the unknowns regarding the sequence of construction. The testing will be carried out for six months to observe the period of greatest uncertainty. At this point, the majority of material strength gain and creep effects will have occurred, enabling extrapolation of the long-term future performance of the full design life with a high degree of confidence.

Constructionarium offers 17 iconic civil and structural engineering projects, along with net-zero and construction-related skills training. Once testing is complete, the bridge will be donated to Constructionarium; it has been designed to be easily disassembled and rebuilt to allow it to join the centre's project roster.

This will help educate the next generation of industry professionals on sustainable and innovative concrete construction solutions.

The project also gives the industry tangible proof of concept of the technical performance, procurement process, warranties and insurance, as well as the low-carbon and low-cost credentials of these beams.

GOING FORWARDS

Beyond simple beams, patents are pending for further minimass structural elements, including continuous beams, frames and floor slabs. Ultimately, the company aims to provide a complete kit of parts for large buildings and bridges, and to open its own UK manufacturing facility. Beyond bridges, the beams are applicable for a range of applications in which spans are at least 6m, including commercial, industrial, educational, retail and temporary structures.

3D printing is an enabling technology for these beams, given most projects involve bespoke designs in terms of loading and span. However, they can also be precast if there are sufficient identical elements required, eg, for an out-of-town car park.

INSET, ABOVE LEFT:
Figure 6 – the founding team and visitors on the demonstration bridge at Constructionarium.

(Photo: Transport Scotland.)

THE USE OF COUPLER AND CONTINUITY SYSTEMS IN INFRASTRUCTURE PROJECTS

In this Q&A, **Neil Loy** of **Leviat** shares his expertise on reinforcement continuity systems and considerations for their use in infrastructure projects.

ABOVE:
Bridge pier at Queensferry Crossing.

What factors should engineers consider when choosing between various reinforcement continuity options for a construction project?

When selecting a reinforcement continuity system, engineers must evaluate several performance-related factors. Strength and slip requirements are crucial, as well as considering whether fatigue will be present in the structure. Additionally, the level of accreditation required is a key consideration.In the UK, design Codes such as BS 8597[1] and BS EN 1992-1-1[2] (Eurocode 2) apply to reinforcement couplers and continuity systems. Other factors include ease of access for installation, the environment (such as saltwater or coastal conditions) and whether projecting bars can be adapted into a coupler or continuity system connection.

What are the key considerations when choosing between hybrid couplers, reinforcement continuity systems, threaded couplers and bolted couplers for a specific infrastructure project?

The type of application is the first deciding factor. For example, if you are strengthening or extending an existing structure, a remedial system such as bolted couplers would be suitable. In contrast, threaded coupler systems are often more cost-effective for new construction. Performance requirements are also critical; fatigue resistance is particularly important for infrastructure projects.

What are the main advantages of using mechanical splices in reinforced concrete construction for bridges?

Mechanical splices (reinforcement bar couplers) offer five key benefits:

- improved structural integrity
- no reliance on concrete for load transfer
- reduction of reinforcement bar congestion
- elimination of lap splice calculations
- reduced tonnage of reinforcement (for every 1000 couplers, 14.9 tonnes of CO_2 is saved, based on the DEFRA figure of the average global CO_2 for steel of 1571kg/tonne).

Coupler box hybrid continuity systems allow engineers the flexibility of being able to design connections without the traditional restrictions on bar length and diameter of traditional re-bend systems.

How do reinforcement continuity systems contribute to the flexibility of reinforcement design in infrastructure projects?

In areas with smaller diameters of non-fatigue-prone reinforcement, continuity systems provide a cost-effective and quick-to-install solution. They help ensure reinforcement continuity across construction joints, particularly in wall/slab or slab/slab connections. These systems simplify formwork design, save installation time and enhance health and safety by eliminating protruding bars, which can cause injuries.

In what scenarios might threaded or bolted couplers be preferred over other, more traditional, reinforcement connection methods in bridge construction?

Mechanical splices (reinforcement bar couplers) are a practical alternative to lap splices or welded connections, which are often challenging to implement on-site and come with stringent quality controls. Mechanical splices prevent

> “Mechanical splices (reinforcement bar couplers) are a practical alternative to lap splices or welded connections, which are often challenging to implement on-site and come with stringent quality controls.”

bar protrusion at joints, reduce congestion, save reinforcement bar length and protect formwork. Unlike lapped joints, which rely on concrete bonding for load transfer, reinforcement bar couplers function like a continuous length of reinforcement bar. This is a crucial feature in seismic designs or for bridge piers vulnerable to impacts from large vehicles or ships.

How do different types of reinforcement continuity systems compare in terms of installation methods and ease of use?

There are a variety of reinforcement continuity systems available to suit different applications. Some require the fixing of individual bars, while others come with multiple bars pre-fixed into carrier cases or flexible steel strips. Anchor systems, cast-in options and different connection methods – such as torqued (tapered thread), wrench-tightened (parallel), lock shear bolts (bolted) or restraightened (rebend) – are all straightforward to install. The type of project typically dictates which system is best. For example, bolted couplers are more suitable for remedial work but less practical for new construction in heavily congested areas.

How do threaded couplers impact the speed and efficiency of concrete reinforcement installation in bridge construction?

When compared with overlapped joints, reinforcement bar couplers (threaded or bolted) offer the following advantages:

- couplers reduce reinforcement congestion when compared with lapped joints, which can compromise the structural integrity of the structure
- degradation of concrete could affect the transfer of load with lapped joints
- less steel is used with coupled connections, resulting in material and cost savings
- cost and material efficiency results in a greener and ‘lighter’ building
- where used to connect starter bars, couplers help avoid damage to formwork.

Can you describe the key differences between parallel-threaded and tapered-threaded connections?

Parallel-threaded systems, while requiring significant capital investment in reinforcement bar threading equipment, meet stringent performance standards for large infrastructure projects. Tapered-threaded systems, on the other hand, require less expensive processing equipment but involve larger, more costly couplers. These systems also need calibrated torque wrenches, which can be impractical on-site. When dealing with large, heavy bars, positional couplers are required, which can be more cost-effectively achieved with parallel-threaded systems than with tapered-threaded ones. C

TOP:
40mm-diameter Ancon MBT bolted couplers in bridge pile cap application.

INSET ABOVE:
Ancon Eazistrip reinforcement continuity system shown in a wall-to-slab application.

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LARGE-SCALE TEMPORARY WORKS FOR HS2'S CURZON VIADUCT

Cliff Shepherd of **Altrad RMD Kwikform** (**Altrad RMDK**) discusses the challenges of creating a bespoke temporary works solution to aid construction of HS2's Curzon Street railway station approach viaducts – one of the largest-scale projects in the company's history.

Birmingham Curzon Street Station is set to become a key destination and thriving departure point as part of Britain's new high-speed railway. The station will be the first brand new intercity terminus to be built in Britain since the 19th Century and will be net zero in operation.

Main contractor Balfour Beatty VINCI Joint Venture (BBV JV) sought the expertise of Altrad RMDK to create a large-scale bespoke temporary works solution to support the construction of the new 'Curzon Street No 3 Viaduct' – a key element of the Curzon Street railway station.

A bespoke formwork and falsework design was required to aid the construction of four viaduct decks, which exit the station and merge into one single bridge deck featuring three high-speed tracks, with a total length of 300m.

Construction has involved 11 concrete pours so far, using approximately 900m^3 of concrete in each pour. In total, that's nearly 10,000m^3 of concrete and with a total of approximately 5000m^2 surface area on the top of the deck. The sheer volume and complexity of co-ordinating these pours really highlighted the magnitude of the project.

The falsework configuration needed to be designed in a particular way to allow the transfer of the loads from the concrete deck and wind forces down into the foundations without overloading the structure, ensuring it could support itself at all stages of erection, in-situ concrete pouring and dismantling.

Engineers also made the provision to ensure that after the pouring of concrete, the site team could easily and safely move the falsework and formwork deck units to be reused elsewhere on the site.

VERSATILE AND CONNECTED EQUIPMENT

To help support the construction of a structure of this size, several interconnected products were specified, combining a falsework system with aluminium beams and composite steel soldier formwork beams to create the formwork cradles.

Heavy-duty propping, with clear span steel beams and further aluminium decking beams, was used to support the deck soffit over the 'V'-shaped void in the piers, with very heavy-duty walings to stabilise the side shutters.

A fully braced falsework system was the chosen method of support, with supports at 1.2m centres down the length of the viaduct. A fully braced method was required so that the structure would not move in any direction and was entirely restrained by its internal bracing.

ABOVE:
Pier formwork for the viaduct.

The deck profile was achieved with a system of aluminium walings and primary beams, which sat on top of the falsework and incorporated a cantilevered support to the wings of the deck. Again, this ensured the structure was then all internally supported – mitigating the need for the use of external props to the ground.

Due to the tight radius curves on the underside of the decks, a special formwork solution was designed to ensure the desired form and finish were met. Altrad RMDK worked closely with Cordek for this part of the project to precisely achieve the right shape and finish, devising a complete solution for the rounded corners, which proved to be rather complicated.

MAXIMUM EFFICIENCY AND SAFETY

To ensure the project was a success, the formwork solution had to be as efficient as possible. The safe working load for the Rapidshor legs is 8 tonnes and the engineering team took the design close to the limit at 7.85 tonnes. This allowed the project to be completed efficiently and safely without compromising the foundations and preventing overloading.

To minimise the dangers that arise when working at height, the falsework solution was designed so that it could largely be constructed horizontally and connected before being craned into a vertical position. By erecting horizontally as opposed to vertically, it meant that the time working at height was greatly reduced, improving safety conditions on-site.

Despite the large scale of the project, the innovative temporary works design improved the sustainability of the project as it allowed the whole temporary works structure to be lifted away and then be used elsewhere on-site, saving the customer time and money as the falsework and formwork did not need to be taken down and rebuilt.

This has been one of the largest projects that the author has worked on in a +33-year career and the entire Altrad RMDK team is extremely proud to be a part of this historic scheme. It not only showcases engineering excellence, but also demonstrates how inter-compatible and versatile the equipment is when working together to form very complex shapes.

Communication and collaboration with BBV and other companies involved in the project have been essential. To ensure that this worked effectively, there was a focus on maintaining regular face-to-face and weekly meetings. These meetings helped RMDK to stay aligned with all stakeholders, addressing challenges in real time and avoiding miscommunication.

Having a constant presence on-site allowed the firm to be proactive in identifying and solving issues as they arose. Being there physically not only helped prevent potential problems, but also strengthened relationships with BBV and other partners, which created a sense of teamwork and trust throughout the project.

SIGNIFICANT MOMENT

Lenka Vošvrdová, senior agent at Balfour Beatty VINCI's Curzon Street site, says, "We recently completed the first sections of our Curzon 3 Viaduct – a significant moment for everyone connected with this iconic structure in the middle of Birmingham city centre.

"This achievement was only possible thanks to the hard work, skill and expertise demonstrated on a daily basis by the Balfour Beatty VINCI site team and our supply chain partners."

LEFT:
Curzon Viaduct piers under construction.

INSET BELOW:
Completed piers after the formwork has been struck.

BELOW LEFT:
Formwork and falsework for the viaduct deck construction.

ARBROATH HARBOUR REPAIR

James Mount of **Natural Cement** looks at a repair project in Scotland undertaken in harsh marine conditions.

ABOVE:
Repointing using NATCEM 35 above the water line.

MIDDLE, TOP:
An alternative side of the Harbour entrance, with works completed.

Arbroath Harbour, situated on Scotland's north-east coast, serves a diverse range of users, including fishing boats, commercial vessels and leisure craft. Following an inspection by Angus Council, repairs were deemed necessary to maintain key areas of the harbour and outer breakwaters, which had deteriorated due to harsh marine conditions. Southbay Civil Engineering was appointed as the main contractor for the £380,000 project, carried out between August and September 2023. Throughout the works, the harbour remained operational, requiring careful co-ordination to minimise disruption.

The project aimed to restore the structural integrity of the harbour, using materials that could withstand wet conditions and be applied quickly to reduce downtime. NATCEM 35, a natural cement-based mortar, was chosen for specific underwater and tidal zone repairs due to its fast-setting and water-resistant properties.

The primary focus of the project was the repair of the north and south harbour entrances, as well as sections of the outer breakwaters. Initial work involved clearing debris and marine growth from the repair areas. To access the south entrance, a multi-cat vessel was used, while a workboat was employed for the north.

VOID FILLING

Sprayed concrete was used to fill voids in the harbour walls after surface cleaning. While the specific product was not identified, it was selected for its compatibility with the marine environment. At the north entrance, deep voids were filled in layers, with resin-fixed dowels securing the material in place for added stability.

For underwater sections within the tidal zone, NATCEM 35 was

applied. Divers were able to directly treat these submerged areas and the product's anti-washout properties ensured that it remained stable despite flowing water. This quick-setting mortar was key to reinforcing submerged parts of the harbour, allowing repairs to be completed efficiently without extended curing times.

RELIABLE MATERIALS

Given the harbour's exposure to extreme weather and tidal forces, the materials selected needed to perform reliably under challenging conditions. The mortar was particularly suited to this environment due to its ability to set underwater and resist chloride and sulfate attacks. Its fast-setting nature also allowed repairs to be completed rapidly, ensuring that harbour operations were minimally impacted.

The product's versatility was particularly useful in areas affected by tidal action, where the ability to set quickly and securely in wet conditions was essential. This was a key advantage in both the north and south entrances, where continuous public use necessitated a swift and efficient repair process.

Alongside the main structural repairs, the project included further works to enhance the harbour's overall infrastructure. The slipway at the boat repair yard was repointed and voids were filled to improve its stability. Stone blocks within the seawall were also repaired, ensuring the harbour retained its historical character while improving its durability.

Other improvements included replacing ladders and timber decking in a public viewing area, as well as conducting maintenance on the block paving. These upgrades enhanced both the functionality and aesthetic of the harbour, contributing to its long-term sustainability.

NATCEM 35's environmental credentials were another significant factor in its selection. Unlike traditional Portland cement, it has a 30% lower-carbon footprint owing to lower firing temperatures, thus making it a more sustainable choice for repairs in sensitive marine environments. Furthermore, its compliance with Drinking Water Inspectorate Regulation 31 ensured that the product was safe for use in areas where potable water might be present, protecting both marine life and the local ecosystem.

Working in a public harbour presented several challenges, particularly in maintaining access for both vessels and pedestrians. Southbay Civil Engineering implemented a comprehensive traffic and pedestrian management plan to safely segregate work areas from the public. Close communication with the harbourmaster and local businesses, including an operational boatyard, ensured that work progressed smoothly with minimal disruption.

PLANNING AND EXECUTION

The project was completed on schedule and without any reportable incidents, thanks to careful planning and execution. The effective use of the correct materials helped ensure the long-term integrity of the repairs.

The Arbroath Harbour maintenance project successfully restored key sections of the harbour walls and breakwaters, ensuring the facility remains operational for years to come. Southbay Civil Engineering's ability to manage the complex logistics of the project, while keeping the harbour operational, underscores the effectiveness of the materials and methods used. C

MIDDLE, BOTTOM:
A wall reinforced further into the harbour for foot access and exit.

ABOVE:
Repointing of bottom of breakwater.

SUSTAINABILITY IN R&D – A NEW NORMAL?

Jon Potter of **Fosroc International** outlines what drives the R&D process and the things that should be taken into consideration along the way to manufacture products that the market needs and wants, with sustainability in mind.

Environmental Product Declarations (EPDs) provide a baseline to analyse a product's carbon intensity. From this analysis, hot spots of intensity can be identified. R&D then plays a major role in aiming to reduce carbon intensity. Both the raw materials used and the processes by which they are converted to end products can become in scope for development.

Throughout the supply chain, manufacturers are commencing such activities with the target of providing products with greater consideration of the environment. Science-based targets aligned with the overall requirements of the Paris 2015 agreement (limiting global warming to <1.5°C above pre-industrial levels) should be implemented; these can also be built into supply chain frameworks such as PAS 2080[1]. It is fast becoming the norm for the environmental credentials of a company's offer to be front and centre of any vendor selection programme. In the near future, vendors may be excluded from supply if they are not able to demonstrate progress.

MARKET REQUIREMENTS

Key to any product development is establishing market requirements. Where established specifications covering the product type exist (eg, a harmonised BS EN/ISO Standard or other industry Code), manufacturers should ensure compliance before introducing products to market. If no such Standards exist, manufacturers will work with their target customers and/or relevant trade association to establish a set of performance requirements to work towards.

Once an outline specification for the product is agreed with stakeholders (external and internal), development activities can commence. Raw material selection is the starting point of any potential new product development. Grades with higher levels of recycled, supplementary or bio-based constituents are becoming available. While some of these may be less commercially favourable at present, this may be a secondary consideration if supply depends on using these 'greener' constituents. In addition, as suppliers scale up production of these grades, economies of scale may result in prices becoming closer to their previous offerings.

MILESTONES

Key milestones along the development pathway include:

- Producing prototype formulations, usually using small-scale laboratory mixers. These will be tested for application properties as well as checks on whether performance targets are met. Stakeholder feedback may be sought on several different prototypes. A matrix of pros and cons against each prototype can be produced. Certain aspects of each of the prototypes may be desired to be combined. As such, many cycles of development may take place before arriving at a final formulation.
- Scale-up to production quantities. It is common for slight differences to be noted during scale up, due to the different machines used. Depending on the impact of these differences, revalidation of certain application or performance parameters may be needed. In addition, during scale up, various settings may be trialled to optimise throughput rates. If the EPD identified that existing manufacturing equipment is inefficient (eg, high power usage compared with best in class), new equipment may become in scope of the development project. Different packaging types may also be trialled; some of these may offer reduced environmental impact, eg, switching from plastic-based packaging to alternatives such as metal or paper.
- Large-scale trials of the products. Using the production batch and typically taking place on mock-ups of actual locations where the product is intended to be used, or alternatively on a live site with the client's permission, trials identify any residual application issues the end users may face when applying the product. For example, Fosroc has conducted product trials on such schemes as Hinkley Point C and more recently HS2 and National Highways. The importance of live site trials cannot be underestimated and cannot always be replicated by laboratory testing.
- Completion of relevant pre-launch formalities prior to official introduction. This might include a full suite of documentation such as technical and safety datasheets, obtaining required testing/certification (as outlined in the product specification initially agreed – see above), building of required stock level, briefings to internal staff on the new product and preparation of marketing

literature to support the new offering and promote its benefits.

FINAL STEP

As a cyclic process, the final step of product development is to re-evaluate the key metric that you started with. Therefore, in the context of an introduction of a product where a key aim was for it to be more sustainable than its predecessor, the logical endpoint is the production of a new EPD, which hopefully identifies that a reduction in the carbon intensity of the new product has been achieved. End users may then compare the two products and quantify the reduction in the context of their potential use on a given project. For example, if a new product has a 2kg reduction in embodied CO_2 per bag compared with the previous, assuming 1000 bags are used on a particular scheme, then a 2-tonne reduction in CO_2 has been achieved.

While perhaps insignificant in isolation, when the combined efforts of the industry are brought to bear through a framework such as PAS 2080, the overall reduction in CO_2 generated will become significant. In this context, the next few years are set to be transformative in the way materials are selected for use. As such, development with these considerations in mind will become the new normal. C

Reference:

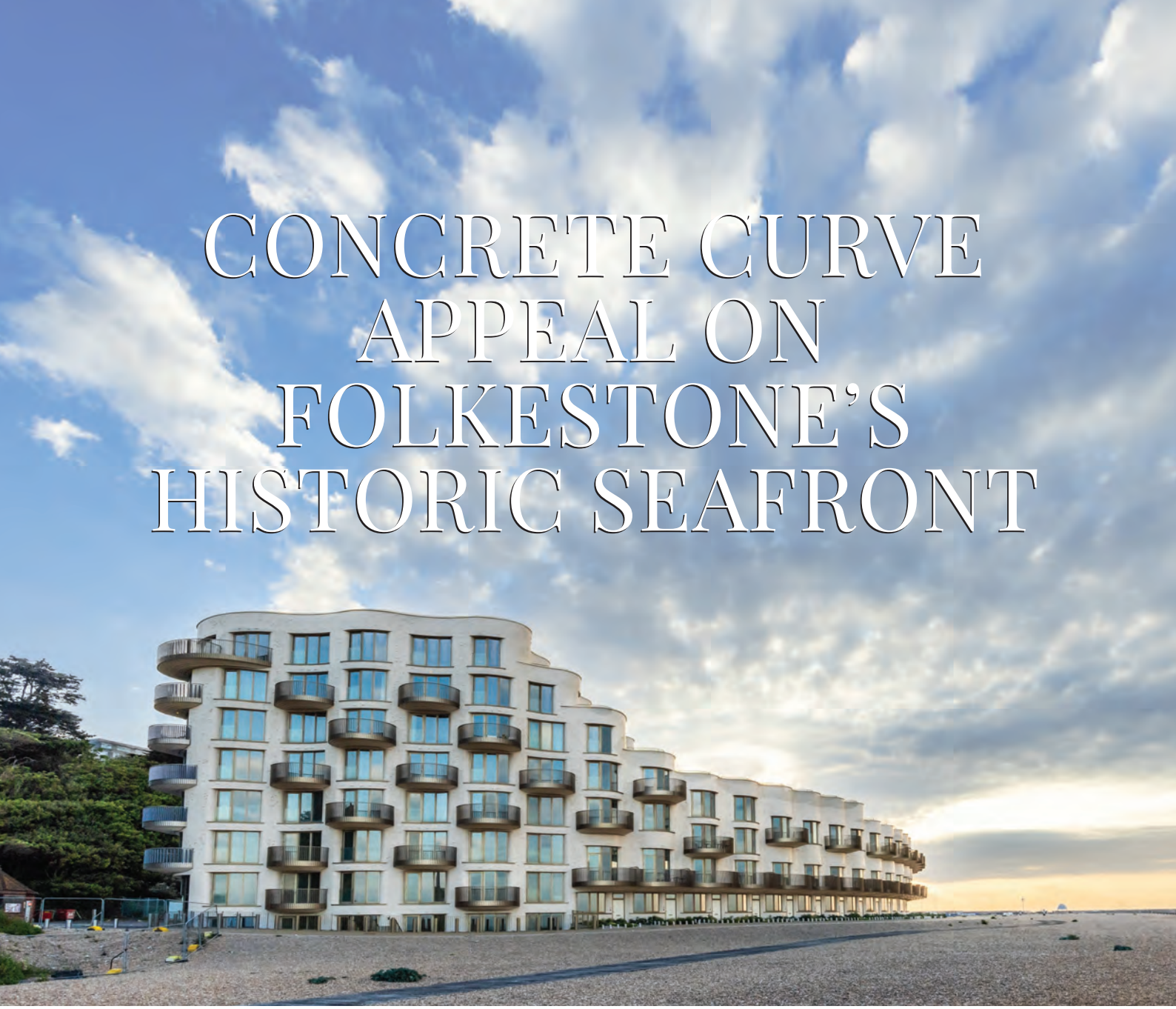
1. BRITISH STANDARDS INSTITUTION, PAS 2080. *Carbon management in buildings and infrastructure*. BSI, London, 2023.

ABOVE LEFT:
Adhesion testing.

ABOVE:
Colour matching concrete on HS2 project.

INSET:
Flow testing on a self-levelling product.

CONCRETE CURVE APPEAL ON FOLKESTONE'S HISTORIC SEAFRONT



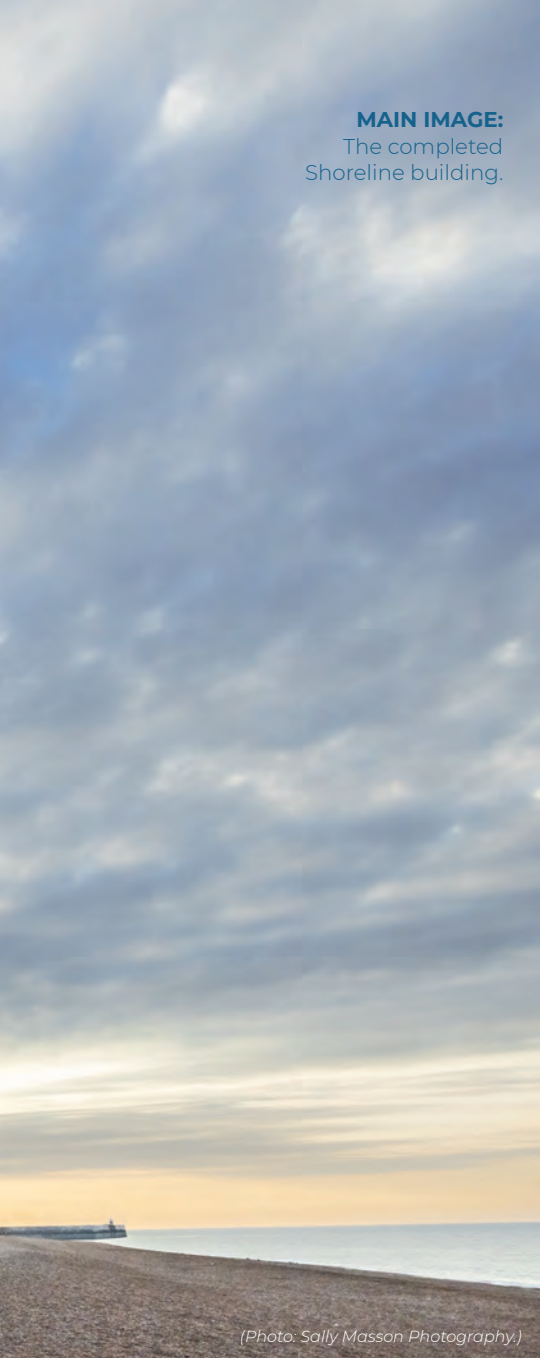
Shoreline is an architectural wonder. Comprising 84 homes as part of a stunning development designed to reflect its Folkestone beachfront location and Regency-era elements of the area's architectural heritage, this project serves further notice of the town's increasing reputation as a blue-chip south-east coastal resort. The building's sweeping curved, crescent-style form also offers an eye-catching example of how concrete is being used in ever-more imaginative ways to create residencies that marry the past with the present. Chris Page of Folkestone-based Jenner, contractor for the Shoreline development, explains the challenges involved in delivering the structure's complex customised concrete features.

Constructed by Jenner and designed by ACME architectural practice for the Folkestone Harbour & Seafront Development Company, Shoreline represents the first chapter of a masterplan that will transform Folkestone seafront. Up to 1000 new homes, as well as shops, bars, restaurants and attractive public and green spaces are earmarked, with Shoreline the jewel of the enterprising new hub.

Constructed using a reinforced concrete frame, Shoreline's manifold architectural curves are representative of coastline and pebbles, and the waves that roll in from the sea that is an uninterrupted stone's throw away. On a clear day, France's coastline is visible from Shoreline's semi-circular frontage, which bears white glazed bricks – sourced from Spain – to reflect the fluctuating colours of the surrounding natural environment according to the weather and time of day.

OVERCOMING PILING OBSTRUCTIONS

Jenner began work at the Shoreline site in January 2020. The country was in the grip of the Covid-19 pandemic and the contractor faced a swathe of initial challenges. The



MAIN IMAGE:
The completed Shoreline building.

(Photo: Sally Masson Photography.)

building was constructed using more than 200 continuous flight auger piles. These were driven to a 30m depth, creating foundations that are as deep as the building is high.

During the piling process, obstructions in the form of huge boulders were encountered before reaching the rock. To counter this, a huge rotary rig, which in ordinary times would not have been available, was hired to cut through tonnes of ragstone rock boulders. A steel casing, which was an innovation by contractor Van Elle, was installed as the rotary rig's drill bit went to work. This was crucial to preventing the ground from caving in as cutting progressed. Beach shingle was then used to fill the steel casing, with the CFA rig extracting the shingle and supplying the concrete as the casing was removed. As the

(Photo: Matt Rowe.)

ABOVE:
RC frame nearing completion with circular podium vents formed.

piling works neared completion, contractor O'Halloran & O'Brien constructed the groundworks and reinforced concrete frame on-site. The process continued over an 18-month period.

More than 3600m^3 of concrete was used in Shoreline's construction, along with 380 tonnes of reinforcement. For the building's curve provision, soffit shuttering, wide enough to accommodate the exterior wave-style contours, was used. It was supported by cantilever falsework, which also provided additional workspace for operatives during the formwork process.

Curves featuring a more acute radius were accommodated using curved-edged shuttering. This required a multi-layer plywood approach, with two layers of 12mm plywood being used in areas to fully reinforce the formwork. Shutters were notched at the back to serve the tighter radii. To ensure a uniform exterior aesthetic, the curved façades were hung from concrete frames.

A standard C50/60 strength-class concrete was used throughout the Shoreline development. Where additional protection was required for part-exposed columns and reinforced concrete walls in the building's undercroft, the cover to the reinforcement was increased to 50mm. Areas of fully exposed concrete were minimal. Where it was left without a finish on staircases, enhanced pre-concrete-pour quality assurance inspections were carried out. For fully exposed areas, new plywood was used to form a shutter face. This ensured a smooth, high-quality finish, with the plywood being recycled for multiple use on soffit shutters and columns at subsequent building stages.

Meticulous detail is writ large in every aspect of Shoreline's planning and construction. This is never more evident than in the gloriously curved façade, which was finished using a mix of more than 24 specially designed bricks. Practical, as well as aesthetic, considerations needed to be taken into account with the bricks' precise design, with

BELOW:
Looking west from the east block at completion.

(Photo: Sally Masson Photography.)

FAR RIGHT: Down stands with concrete soffits.

RIGHT: East block – stepped RC slabs to form the penthouse roof terraces sometimes referred to as 'the wedding cake tiers'

BELOW: Split floor levels within the townhouses.

(Photos: Matt Rowe.)

each one being carefully measured to ensure they were small enough to avoid becoming a perch for seagulls. Various mortars were also assessed to find a solution resistant to the coastal environment's harsher elements.

CUSTOMISED CONNECTIVE

Shoreline stands directly on a raised part of Folkestone beach at the foot of the town's historic Leas Lift and coastal park. The building comprises 20 five-storey luxury beach houses, four duplexes and two apartment blocks containing 30 apartments each. A mix of balconies, private and communal roof gardens, and roof terraces account for each property's outside space. Initial plans involved precasting the balconies off-site in white concrete. However, with the heaviest balcony weighing in at an astonishing 9 tonnes and the building's exposed seafront location making cranage a risky option, an alternative solution was sought.

Jenner, in collaboration with connection systems engineer Leviat and balcony manufacturer Blue Chyp, worked to deliver a system that effectively supported the balcony loads. With potentially corrosive airborne salts an ever-present risk in coastal environments, building materials used in the balconies' construction needed to display a high level of weather resistance. It led to the specification of steel-to-concrete (STC) bespoke balcony connectors. The STC connector is cast into the floor slab. Later a balcony stub is then bolted to the previously cast in STC. Once the façade (in this case brickwork) has been constructed, a pre-assembled steel balcony is lifted and attached to the previously installed stub.

The customised approach to the balcony connectors' design was essential to conforming with the structure's intricate angles and radii. Manufactured from corrosion-resistant grade 316 stainless steel, the connectors' non-standard aspect extended to the system's Ancon STC stud brackets. These were specifically devised to connect to the steel balconies and provide robust, long-term support. The balcony parts, created in multiple locations around the UK, were assembled on a specially designed rig on-site before being lifted into place. As proof of the project's myriad intricacies, it includes five different balcony designs that replicate the development's curved façade.

Post-tensioned balcony connectors drive efficiencies, as well as offer structural integrity. Formwork can be installed and subsequently removed – at the same time – and then reused on the next level or phase. Furthermore, greater sustainability can be achieved by allowing concrete to be poured simultaneously and tensioned in a single process.

Shoreline is a remarkable achievement; a sum of constituent parts comprising architectural imagination, technical innovation and the collaborative efforts of committed, skilled and experienced building stakeholders. Its brilliant white contours are a sight to behold, bringing breathtaking new curve appeal to Folkestone's historic seafront. C

Sustainable precast walls: achieving aesthetic excellence and durability with structural steel fibres

As the construction industry evolves, sustainability and efficiency are increasingly prioritised. Precast concrete, a vital component of modern architecture, is no exception. Steel fibres are a viable alternative to traditional reinforcement methods, offering advantages in performance, cost-efficiency and environmental impact. Kadir Aktas of Bekaert explores the applications, benefits and key performance features of steel fibres as concrete reinforcement, with a focus on precast wall panels.

Steel fibres have gained significant traction in the construction industry over the past decades. Initially, they were predominantly used in industrial floors, slabs, tunnel segments and mining applications. Recent advancements in structural fibres have expanded their usage into more complex areas, such as precast elements. As an efficient and sustainable concrete reinforcement solution, steel fibres are used in both civil engineering precast applications (pipes, utility vaults and switchgear cabins) and building applications (modular housing, façade elements and sandwich panels).

The growing recognition of steel fibres' ability to reduce the total amount of reinforcement material, lower labour intensity and boost productivity has positioned them as an efficient and sustainable primary reinforcement solution.

FIBRES IN WALL PANELS

Wall panel manufacturers are increasingly adopting steel fibre reinforcement, blending aesthetic appeal with structural efficiency, while reducing the environmental impact.

To meet the increasing demand for sustainable and efficient construction solutions, Bekaert recently worked on a precast wall project for a large-scale factory in France.

The project required precast panels with high structural performance and aesthetic quality. The design parameters included a focus on reducing the construction time and total cost of the panels while maintaining structural integrity.

The wall measured 8m in length, 3m in height with a thickness of 150mm (Figure 1). The original design incorporated a double-layer fabric reinforcement, which is a time-consuming process for a precaster. The design team optimised the structural design according to *fib* Model Code 2010[1], taking into account several combinations of permanent and variable load conditions, including wind.

Finite-element analysis confirmed that the load conditions allowed for the replacement of double-layer fabric with steel fibres. Galvanised Dramix 5D 65/60 GG fibre was selected for its high tensile strength, enabling post-crack hardening in flexural performance, while the glued fibres ensured ideal consistence and homogeneous distribution in the concrete.

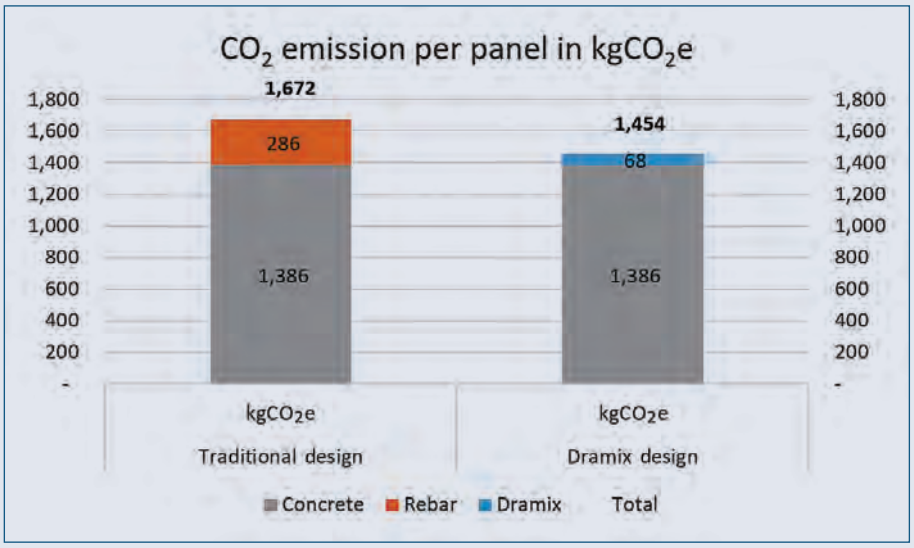
This steel-fibre solution not only met the precast panels' structural requirements by providing improved durability and performance but also offered a corrosion-free smooth surface, making it the ideal fit for both structural integrity and an efficient production process (Figure 2).

The lifting was done with a tilt-up table and panels were loaded vertically on the truck to be transported to the jobsite. With the help of a crane panels were placed in the grooves between columns and positioned with less than a 4mm gap (Figure 3). Some 80 panels were assembled in three days, saving substantial time during the construction phase.

TOP:
Figure 1 – precast wall elements.

ABOVE:
Figure 2 – pouring fibre concrete into a mould for precast manufacture.

Figure 3 – fibre-reinforced precast wall installation process.



ABOVE:
Figure 4 – wall panel CO_2 calculations.

Adopting Dramix solutions not only gave technical and economic benefits but also led to a significant reduction in carbon emissions. Through a life-cycle assessment (LCA), carbon emission results have been obtained using One Click LCA calculations tools in accordance with the current EN 15978[2].
The impact on global warming potentials of both solutions is calculated at product and process level from cradle to gate (A1–A3).

Figure 4 illustrates the CO_2 emissions for traditional and Dramix solution per material. The design optimisation resulted in a 35% reduction in steel usage and a 13% overall reduction in the wall panel's carbon footprint. The use of steel fibres allowed the project to meet the sustainability targets set by the end customer.

CONCLUDING REMARKS

As precasters are looking for methods to reduce the amount of material used, while increasing the production speed, steel fibres come out as the preferred solution for these elements.

By eliminating the need for traditional fabric reinforcement, steel fibres provide significant design flexibility and allow substantial production time savings as reinforcement preparation time has been eliminated. Thanks to galvanised steel fibres, the durability of the structure is improved without compromising its aesthetic appeal.

Steel fibres provide a practical and sustainable solution to many challenges precasters face. By offering efficient reinforcement with lower material consumption, steel fibres contribute to both cost savings and a reduced environmental footprint. The successful application of steel fibres requires careful selection of fibre type, proper design optimisation and adherence to performance standards.

Moving forward, steel fibres are set to become an integral component of modern construction, particularly in applications where sustainability, efficiency and durability are key. By embracing this technology, precasters can meet the evolving demands of their clients and contribute to a more sustainable built environment. C

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1. FÉDÉRATION INTERNATIONALE DU BÉTON. fib *Model Code for Concrete Structures 2010. fib*, Lausanne, Switzerland, 2013.
2. BRITISH STANDARDS INSTITUTION, BS EN 15978. *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method*. BSI, London, 2011.

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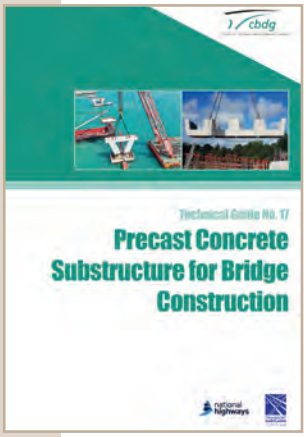

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Incorporation of precast concrete is well-established at deck level. However, there are increasing trends worldwide towards incorporating precast elements in bridge substructures. This guide presents a summary of the common applications of precast concrete in bridge substructures globally, with commentary on key issues.

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A slipformed finish is extruded from the formwork and cannot be considered to be 'formed' in the traditional sense. Typically, the extruded finish is hand-floated while still 'soft' in order to close the surface; it is more akin to a worked surface rather than a formed surface in this respect. Advice Sheets are based on the knowledge and experience of The Concrete Society's technical staff.

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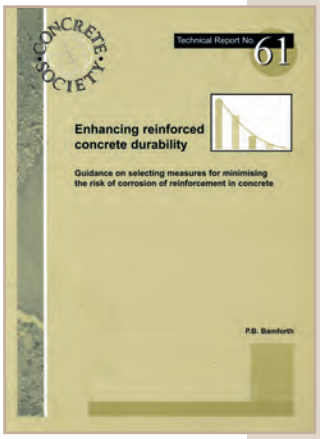

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Enhancing reinforced concrete durability

Report detailing current technologies to combat premature deterioration of reinforced concrete structures. The materials and systems available for improving performance are separated into those that improve the resistance of the concrete cover, those that improve near surface resistance, those that increase tolerance of the steel to chlorides and carbonation, and those that avoid corrosion.

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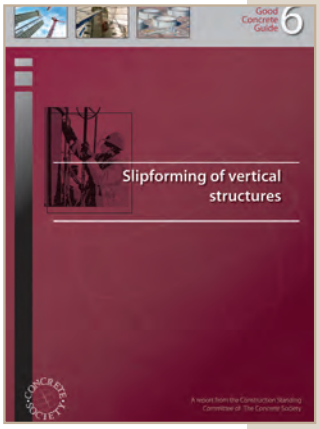

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