CM CONSTRUCTION MANAGER

Construction/Infrastructure Writer

Tom Ravenscroft writing for Construction Manager

My approach to feature writing for Construction Manager's print magazine and website has been to consider one key project as a catalyst to discuss wider themes and issues facing the built environment today. In the three selected articles I have focused on the detailed technical aspects of an individual project while also exploring the wider environments in which the project sits. Speaking to numerous sources at architecture practices, contractors and consultants provides a holistic understanding the reach of each scheme.


Technical Frame

HITTING NEW HEIGHTS?

The UK's tallest timber tower, in Hackney, is a hybrid of cross-laminated timber and steel. But are the gains balanced by sustainability trade-offs? Tom Ravenscroft reports

Twist in the strategy

Hitting new heights?

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The cost saving, environmental and schedule benefits of building with cross laminated timber (CLT) increasingly are being recognised by architects, contractors and clients.

An in-depth technical study of Hawkins\Brown's Wenlock Road housing scheme in Hackney (Europe's current tallest building that uses structural CLT) allows me to question the potential of CLT as a building material. This exemplar scheme is used as a springboard to juxtapose the architectural benefits of hybrid CLT structures against the more environmental credentials of pure CLT buildings, such as Waugh Thistleton's Dalston Lane scheme, also being built in Hackney.

A box outline the current timber highlights, and future projects, place this building within the development arc of CLT structures and acted as a shareable online article to draw people into the main feature.

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A super-material world

Building for research at atomic level presents particular challenges, as Tom Ravenscroft discovered at the National Graphene Institute. The result is a facility that will itself impact on the future of construction materials

Graphene, the world's first 2D material, was discovered by two scientists from the University of Manchester. To explore and develop commercial applications for the material the university has created the National Graphene Institute. Designed by architect Jestico and Whiles and built by contractor BAM Construct, the building contains some of the most controlled clean rooms in the world.

The research taking place in the building could impact the entire construction industry as the potential of new super materials is fully explored. This technical feature takes a detailed look at the precise nature of the design and construction processes needed to create spaces to undertake nanotechnology research and how the research could impact how buildings are created.

Speaking to a professor of nanotechnology allowed me to highlight six practical applications for Graphene in the construction industry. This provided another way into the article and a perfect, clickable web story to compliment the feature online.

Construction/Infrastructure Writer

Tom Ravenscroft writing for Construction Manager

Technical Infrastructure

Making waves

After leaving the helm of Balfour Beatty last year, Andrew McNaughton has a new project: the world's first power-generating tidal lagoon. **Tom Ravenscroft** reports

ON THE BEACHFRONT in Swansea Bay, Andrew McNaughton seems a world away from the profit warnings that forced him to resign as Balfour Beatty's chief executive just more than a year ago.

"After Balfour Beatty I decided to take some time off, which was a pleasant release," says McNaughton. "I took some time to think about what I'd do next." That period of reflection has led him to south Wales, where he has taken on the task of delivering the UK's first tidal lagoon into operational service.

The first of its kind in the world, Tidal Lagoon Power's Swansea power-generation project won planning consent last month. By 2019 it could be creating enough green energy to power more than 155,000 homes for at least 120 years.

The proposed £1bn scheme would have a 320 MW installed capacity and will generate electricity from the rising and falling of the tide in the Severn Estuary. It will involve constructing a 9.5 km breakwater in the bay to enclose a 11.5 sq km stretch of water. As the tide fills and drains this pool, 16 bi-directional hydro-generators will create electricity.

Track record

McNaughton had "many opportunities from all around the world", he says, but became involved with the project through Tidal Lagoon Power's chairman, Keith Clark, former chief executive of WS Atkins.

"I have known and worked with [Clark] over the years. He called and told me this is a project that I would enjoy, and that I'd get on with Mark [Shorrock – chief executive of energy company Tidal Lagoon Power]."

An experienced project manager, McNaughton project managed the construction of Terminals 2 and 5 at Heathrow, the widening of the M25, and in 2002, he won the ICE Civil Engineering Manager of the Year award for his work on the Channel Tunnel Rail Link.

As director of construction for Tidal Lagoon Swansea Bay since April, he is overseeing the technical development of this innovative piece of infrastructure and will be responsible for delivering it into operational service.

On taking the job McNaughton said: "I am thrilled to return to the industry's front line to oversee its delivery." But speaking to Construction Manager, he now makes clear he is thinking on a larger scale, and is focused on the long-term programme of coastal energy projects at parent company Tidal Lagoon Power.

"This is not a step back," he says. "I've joined because of the vision of Tidal Lagoon Power. We are building a new power company. Swansea Bay just happens to be the first [project]."

The UK has a commitment to deliver 15% of its energy from renewable sources by 2020, under the European Union's 2009 Renewable Energy Directive. McNaughton believes Tidal Lagoon Power's plans for a fleet of six UK lagoons could play a significant role in meeting this target, and satisfying the country's future energy needs.

"Tidal Lagoon Power is a concept that can make a radical change," he says. "I will look back in 10 years and not say that we created lagoons, but that we created a new industry. Every person in the organisation understands the future legacy. That is why I became a civil engineer in the first place, to build communities."

"Invigorated" by the role, McNaughton says he is enjoying working for the younger organisation: "This is something completely different to running a plc. The company is absolutely clear in its vision. It is so refreshing to have a series of investors and owners that really get the direction of the company." »

"We are asking funders to back something that will start generating income in four years' time"
Andrew McNaughton, Tidal Power Lagoon

The 9.5 km breakwater will encircle the new 11.5 sq km lagoon in Swansea Bay

Making waves

After leaving the helm of Balfour Beatty last year, Andrew McNaughton has a new project: the world's first power-generating tidal lagoon. Tom Ravenscroft reports

Generating energy from the Severn River huge tidal range, an idea that was first proposed more than 100 years ago, is finally looking like a realistic prospect as the Swansea Barrage has won planning permission.

As infrastructure projects can be hard to envisage, I used Andrew McNaughton, former chief executive of the UK's largest construction company Balfour Beatty, as a lens to personalise the project. Visiting Gloucester and Swansea allowed me to conduct the first in depth interview with McNaughton since his departure from Balfour Beatty, and his personal journey brought alive this infrastructure project. Alongside the interview a technical review of the barrage and discussions with the local public and politicians, provided a rounded viewpoint on the likelihood of world's first power-generating tidal lagoon being created in south Wales.

HITTING NEW HEIGHTS?

The UK's tallest timber tower, in Hackney, is a hybrid of cross-laminated timber and steel. But are the gains balanced by sustainability trade-offs? **Tom Ravenscroft** reports

Main picture and inset: Hawkins\Brown's Wenlock Road building continues the London Borough of Hackney's track record for innovating with timber

WHEN ARCHITECT HAWKINS\BROWN'S 10-storey 17-21 Wenlock Road residential scheme in the London Borough of Hackney topped out last November, it took the title of the UK's tallest cross-laminated timber building from a nearby nine-storey residential block by architect Waugh Thistleton on Murray Grove. But unlike its nearby rival, this latest timber tower is not a pure CLT structure. Instead, it's a hybrid of steel and CLT – a system the architect says allows for greater structural gymnastics, opening up more complex building forms that go "outside the box".

But introducing steel into the mix naturally adds embodied carbon and dilutes the sustainability credentials of a pure CLT project. Plus, it's pointed out that the airtightness benefits of CLT are dramatically reduced, while adding more materials and trades on site impacts on the programme benefits.

So are hybrid structures such as Wenlock Road an evolutionary cul-de-sac in the search for more sustainable construction methods? Or, for a city that is seeing a boom in high-rise construction, with 117 towers ready to start on site after winning planning in London, do hybrids offer a practical way to sustainably build tall?

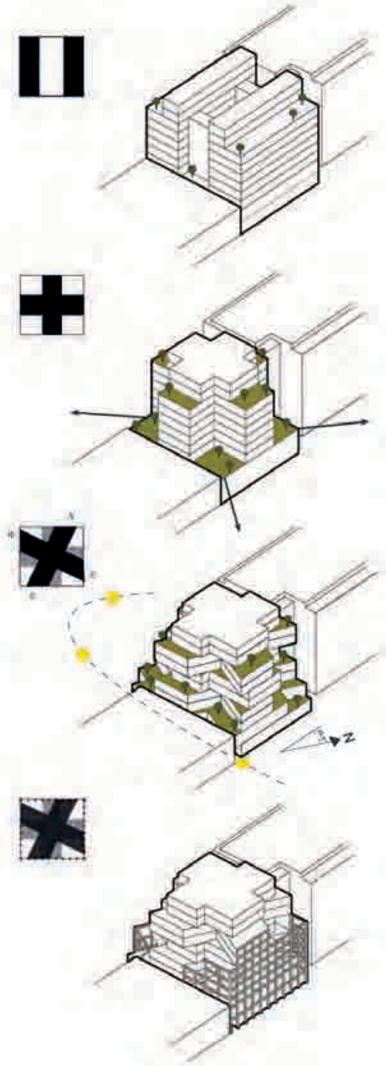
Hawkins\Brown's concept design for Wenlock Road was not initially designed as a timber project. The starting point was its unique form: a cruciform tower, with floor plates that twist every two floors, designed to achieve as many high-quality flats as possible on the site. Its twisted shape allows daylight, ventilation and views into the depth of the plan and means that all 50 residential units benefit from at least two or three aspects.

Aware that Hackney actively encouraged the use of timber, Hawkins\Brown mentioned in its design and access statement that it could potentially be developed in CLT. In fact, as the building progressed through the planning process

PHOTOS: TIM CROCKER

Twist in the strategy

A conventional plan has been replaced by a cross formation, creating more courtyards. The floorplate is then twisted every two storeys, to maximise light, and wrapped in a gridded screen to simplify the street frontage.



in 2012, Hackney mooted a "timber first" policy, although this was later watered down in the face of potential legal threats from the steel and concrete lobby. Nevertheless the decision was made by the developer, Regal Homes, that the tower should be constructed from CLT.

In collaboration with CLT contractor B&K Structures, several options were evaluated in terms of cost, efficiency and aesthetics, including a pure timber solution with all internal walls of the structure formed in CLT. However, due to the complex form and the extremely thick slabs that would have been needed to create the cantilevers, this option was abandoned as too heavy and too expensive.

After also considering a glulam hybrid, Hawkins\Brown settled on a hybrid of steel and CLT, wrapped around a reinforced concrete core, as the most efficient solution. The box section columns that make up the building's steel frame are either 200mm sq or 160mm sq, which are very thin for a 10-storey tower. This is due to the fact that the CLT, which by volume makes up 90% of the building, is still playing a major structural role.

"I don't see the benefit of cutting down more trees just to build a pure CLT building"
Alex Smith, Hawkins\Brown

"In its current design it wouldn't stand without the steel or without the CLT," explains project architect Alex Smith. "The building's twisting is a key part of its design. Introducing comparatively small amounts of steel to share the load in key locations allowed the complex form to be created in an efficient way."

Although a pure CLT would arguably be more sustainable, Smith is pragmatic about adopting a mixed approach to the frame. While appreciating the low carbon benefits of CLT, he says: "I don't see the benefit of cutting down more trees just >

> to build a pure CLT building. If you can stiffen something with steel, use less material and make a more efficient structure, that makes sense."

As a building material, CLT is becoming increasingly common in the UK, with its sustainable attributes as the main driver for its uptake. The renewable material, sometimes described as super-plywood, is formed from layers of spruce arranged crosswise and glued to create high-strength panels.

On site, there are substantial speed and cost benefits as CLT is a prefabricated material. The wood's compact layering also provides high levels of airtightness, substantially reducing the amount of energy needed to heat buildings compared to concrete-framed buildings.

These advantages were exploited heavily on the Building Schools for the Future (BSF) programme, with the material being ideally suited for low-rise construction with tight timescales and budgets. (Willmott Dixon's St Agnes primary in Manchester – based on Eurban's CLT system – is often cited as the UK's first "flat-pack" school). CLT construction is now established in the education sector: Hawkins\Brown won a 2014 RIBA Award for its exposed CLT project at Hilden Grange prep school in Kent, also designed by project architect Smith.

The London Borough of Hackney has in fact become a testbed for housing schemes made of timber, with Waugh Thistleton's Murray Grove block the tallest CLT building in the world when completed in 2009. It was followed by Karakusevic Carson Architects' 41-unit Bridport House in 2011 and now there are numerous CLT housing schemes on site in the borough. So, it is no surprise that Wenlock Road – the latest building to be pushing the boundaries of timber construction – is also to be found in Hackney.

Externally, the building is clad in western red cedar, with a dark brick grid used to define the street edge. Internally, because of Part B of the Building Regulations, which state that the building's structure must retain structural integrity for 90 minutes in the event of fire, the CLT elements have to be completely covered with fire-retardant dry-lining. With no visible CLT in the finished product and its unusual twisting form, Hawkins\Brown has created a complex design that does not have the look or feel of a standard timber building.

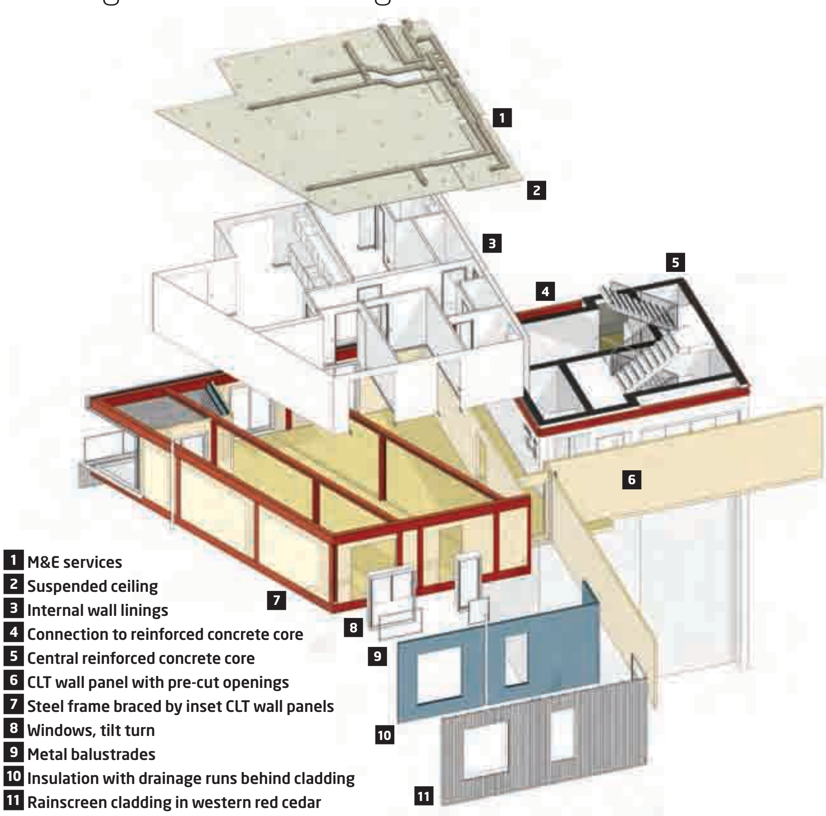
Non-typical CLT buildings

As Smith says, approvingly, "this is not a CLT-driven form". In his view, hybrid solutions allow for more non-typical CLT-shaped buildings to be created, maintaining a sustainable agenda while allowing the architects and structural engineers latitude to experiment structurally. "Sustainability should not be a restriction on ambitious design. In the future you will find that there will be more hybrid structures," he concludes.

Above and below: The high-strength spruce panels play a major structural role, allowing the use of comparatively thin steel columns

"To get the full benefits of CLT for mass housing, pure CLT is the only solution"
Andrew Waugh, Waugh Thistleton Architects

Slotting Wenlock Road together



But not everyone shares Smith's mix-and-match philosophy. Andrew Waugh, director at Waugh Thistleton Architects, a long time proponent of CLT, believes that only pure CLT-framed structures can realise the full benefits of the material. A pure CLT residential development, also for Regal Homes, designed by Waugh has started on site on Dalston Lane, again in Hackney. It has a world-beating 3,852cu m of CLT in its frame, and will also be the UK's tallest CLT structure when completed.

Waugh argues: "We should avoid using steel and concrete and use timber wherever it is feasible. It has a low carbon footprint, is replenishable and stores carbon." He also warns that hybrid structures can "undermine a number of other benefits of CLT, such as airtightness, and the lack of differential movement – timber is fast and straightforward, so introducing other materials and trades loses that advantage".

He accepts, however, that hybrids have a place – but sees it as a temporary one. "There are times when steel and concrete are useful and at the moment hybrids work within current regulations and knowledge bases," he says, viewing hybrids as only an intermediary step until the industry builds a fuller understanding of timber construction. "To get the full benefits of CLT for mass housing, pure CLT is the only solution," he says.

Meanwhile Craig Liddell, specification manager at B&K Structures, the specialist contractor that has designed and built both Wenlock Road's hybrid structure and Dalston Lane's pure CLT structure, certainly believes that both methods have merit. "When we design we are very pragmatic. We want to find the most appropriate, sustainable and economic solution. If that means introducing some steel, then we will look into that," he says.

Although a hybrid negatively impacts on some of the benefits of using CLT, in exchange you get more flexibility, variety, and the potential for timber buildings to go higher than ever before. "With the use of timber in hybrid form we could start to look at 20, 30 or even 40 storey structures," he says (see box, right).

New level of interest

Whether they opt for hybrid or pure, Liddell is certain that we will find major housebuilders looking more seriously at CLT in the near future. "The height and scale of these two projects in Hackney will generate a new level of interest in CLT, and I expect that 2015 will be a record year for the amount of CLT used in the UK," he says.

Outside its Hackney heartland, CLT is gaining ground in south London, with Lend Lease leading the way. The developer built the current world's tallest CLT building in Melbourne, Australia, in 2012 and is now working on several CLT schemes in London. In Battersea, at Cobalt Place, it is delivering 104 homes designed by AHMM, while 55 homes at Victoria Drive, also in the London Borough of Wandsworth, are also in the pipeline.

CLT is a major part of the £1.5bn development at Elephant & Castle, with Lend Lease seeking to use the material wherever it is appropriate. "Going forward we want to look to build more blocks from CLT, as we recognise the material provides great benefits," says Jon Kirkpatrick, head of sustainability at Lend Lease. "We consider CLT for all appropriate projects, as it is really important that we look at all types of technology, to get buildings up quicker and safer."

As CLT is more widely adopted, it looks set to become part of the industry's mainstream operations. And while a pure CLT building may be best suited to low to medium rise mass housing, we can look forward to hybrid structures pushing timber's geometric and height boundaries ever further. CM

Timber highlights so far...

Murray Grove, Hackney
Also known as the Stadthaus, this nine-storey tower in Hackney (right), designed by Waugh Thistleton Architects, was the tallest modern timber structure in the world when it was completed in 2008.

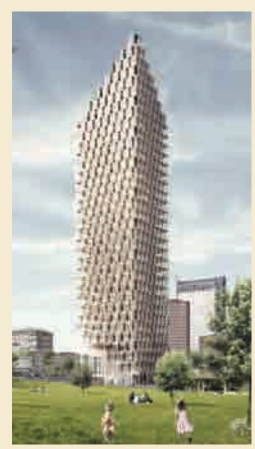
Forté, Melbourne
Designed and built by Lend Lease, the 10-storey apartment block in Melbourne, Australia, is currently the world's tallest pure CLT structure.

Wood Innovation and Design Center, British Columbia
Completed last year, the eight-storey hybrid of glulam columns and beams with CLT walls in Prince George, Canada, is currently North America's tallest timber building.

Bridport House, Hackney
This 41-unit, eight-storey social housing block designed by Karakusevic Carson Architects was the largest solid timber building in the UK when it completed in 2011.

G3 Shopping Resort, Vienna
One of Europe's largest timber buildings, the 500m long shopping centre (right), designed by Austrian architect ATP, is covered by a 20,000sq m contoured roof made from glulam beams and CLT.

...and six more to come



HSB Landmark Project, Stockholm
The proposed 34-storey timber skyscraper (right), with pillars and beams of solid wood, is to complete by 2023 to celebrate housing co-operative HSB's 100 anniversary.

Dalston Lane, Hackney
This 121-unit residential block will be the largest CLT building in the world when it completes next year.

The Tree, Bergen
A hybrid of glulam columns and CLT, this 14-storey apartment block is now on site in Bergen, Norway.

Tallwood tower, Vancouver
As part of a feasibility study titled The Case for Tall Wood Buildings, Michael Green Architects proposed a 30-storey timber tower.

HoHo, Vienna
Plans are mooted for a 25-storey wooden skyscraper in Vienna, Austria (right). Architect Rüdiger Lainer & Partner says the structure of the towers would be 70% timber.

Tall tower competition, US
Last October the US Department of Agriculture launched an ideas competition to design a tall wooden building with a $2 million prize. The winner will be announced this year.

A SUPER-MATERIAL WORLD

Building for research at atomic level presents particular challenges, as **Tom Ravenscroft** discovered at the National Graphene Institute. The result is a facility that will itself impact on the future of construction materials

GRAPHENE, THE WORLD'S FIRST 2D material, boasts an impressive list of superlatives: 200 times stronger than steel, the thinnest material on earth, the world's most conductive material, as well as being transparent, impermeable and flexible. It is no exaggeration to call graphene a super-material, which is why £61m, including £38m directly from government, has been spent on creating a dedicated research facility at the University of Manchester to investigate its potential.

Officially opened in March, the National Graphene Institute is a state-of-the-art research facility where graphene will be studied, and practical, patentable applications can be developed (see box, *p28*).

Designed by architect Jestico + Whiles, and built by BAM Construct, the intensively serviced 7,600 sq m building contains laboratories, offices and seminar rooms for 200 researchers, and two highly controlled clean rooms, where the most sensitive research will happen, and which defined the layout and specification of the entire project.

The new material has scientists, governments and private companies clamouring to take advantage of its revolutionary characteristics, which will soon be making their way into construction products. Formed from graphite, graphene, a one-atom thick sheet of carbon arranged in a honeycomb lattice, is technically produced every time a pencil is used to write with.

However, it was not until 2004 that two researchers at the University of Manchester isolated the material by using Sellotape to painstakingly peel individual layers of carbon from a stick of graphite. The two professors – Andre Geim and Konstantin Novoselov – have subsequently been knighted and awarded the Nobel Prize in Physics, while Manchester has become the UK's home of graphene.

Although graphene was isolated in Manchester, other countries and technology companies have taken the lead in researching it. This facility will allow the university to reassert its position leading the race to develop practical applications for the material.

"Commercialisation of graphene was the key driver for the building," says Julian Dickens, associate director at Jestico + Whiles. "Some companies have taken a jump ahead in the application of graphene, so the primary purpose of the institute is to remedy this and create a bridge between the university and industry." >

"Commercialisation of graphene was the key driver for the building"
Julian Dickens, Jestico + Whiles

MANCHESTER UNIVERSITY

HUFTON + CROW

> The building is as high-tech as the research taking place inside it. Black steel cladding gives an overtly 21st century impression – a sleek stealth bomber set in the jumble of academic buildings that make up Manchester's university district. Up close, hexagonal – or graphene-shaped – perforations in the steel cladding that delineate Novoselov's breakthrough formula hint at the facility's purpose.

The scientific work taking place inside is on public display through a street-facing window that runs along the entire eastern wall, and gives views into the basement of the four-storey building, where the most critical research will take place. Above this clean room, a plenum level for services and access occupies most of the ground floor. A smaller clean room, laboratories and a huge amount of plant fill the three floors above. A seminar space that opens onto a roof garden tops the building.

Jestico + Whiles became aware of the project in 2012, shortly after completing the Mountbatten Building for the University of Southampton's School of Electronics and Computer Science – a facility dedicated to the research of nanotechnology and photonics.

"We won [the bid] based on the relevant experience we had designing clean rooms at Southampton," explains Dickens.

"It appears and acts as one building, but there are two entirely separate structures"
Philip London, BAM Construct

Graphene: six applications for the industry

"There is phenomenal potential for graphene to be used in construction," says Andrea Ferrari, professor of nanotechnology and director of the Cambridge Graphene Centre. "Walls, lighting, touch panels, sensors, generators, batteries and solar panels could all be impacted."

However, early research has focused on the electronics industry, where tiny amounts can be used to great effect.

Ferrari believes the next five to 10 years will determine which applications will make it into production. *Construction Manager* looks at six likely candidates.

Long-lasting LEDs

Set to go on sale this year, LEDs will be one of the first commercially available graphene products. Produced by Graphene Lighting, in which the University of Manchester owns a share, the lightbulb is claimed to have lower energy emissions and manufacturing costs, and a longer lifetime than traditional LED bulbs. The dimmable bulb's diode is coated in graphene, so it conducts more effectively.

Colin Bailey, deputy vice-chancellor of the University of Manchester, says: "Graphene products are becoming a reality a little more than a decade after it was first isolated – a short time in scientific terms."

One of only a few architects that has experience of producing high-tech research centres in the UK, Jestico & Whiles partnered with EC Harris to meet the requirements of the pre-qualification questionnaire, which demanded a project manager lead construction.

At Manchester the clean rooms are critical and the arrangement of the entire building follows from the need to meet the exacting specifications of these spaces. For its nanotechnology research the university required two clean rooms, one specified to ISO 6 (Class 1000) and a second, larger room to the higher ISO 5 (Class 100), where air is 10,000 times cleaner than that of the average office.

The clean rooms also had to meet stringent vibration standards: even the tiniest amount of movement can disrupt experiments that are being carried out at an atomic level. The university required the larger clean room to achieve a vibration criterion (VC) of D – the second-most stringent on the scale of A to E and 16 times more sensitive than the level of human perception. The smaller clean room had to achieve the lower rating of VC-B. The vibration specifications are the key determinant in both the organisation and construction of the entire institute.

"There is no point in building a beautiful car that doesn't work," says Dickens. "The primary design requirement was that the clean rooms meet the technical specifications set out by the client."

To meet the vibration criteria the primary clean room was located in the basement. Ramboll, the acoustic, fire, environmental, civil and structural engineer on the project, found bedrock 4 metres below ground, without which the site may not have even been feasible.

There were then both external and internal sources of vibration to contend with. Externally the main concern was the traffic to the north of the building on Booth Street. This was solved by fixing pot holes and locating the most sensitive equipment away from the road.

Shake shifter

The far bigger challenge was internal sources of vibration, particularly the extensive plant needed to service the clean rooms and other laboratories. To isolate the main sources of vibration from the sensitive laboratory spaces, a logical but radical solution was found. The main plant is housed over four floors in a central utility block (CUB), which has a structurally independent frame from the main building.

"It appears and acts as one building, but there are two entirely separate structures separated by a 50 mm isolation joint," explains Philip London, project manager at BAM Construct. The main building forms a "C" shape wrapped around the CUB, with access to the plant on all floors.

Achieving the vibration rating of VC-B for the second clean room was just as challenging. The smaller clean room was located on the first floor, where a building experiences substantially more lateral movement. To reduce movement to within the acceptable range an extremely stiff in situ concrete frame was designed.

"We used larger column sections and deeper floor slabs both with a higher >

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A street-level window runs the length of the "dirty" corridor, through which the public can view the research going on in the basement clean room

Impermeable paint

Graphene can be combined with oxygen to create graphene oxide for use in paints to give practically any material an ultra-strong and non-corrosive coating.

The material's exceptional barrier properties allow a thin layer of graphene paint to make a surface impermeable, providing protection from air, weather elements or corrosive chemicals.

For the construction industry there are obvious applications to protect any material on the exterior of a building.

"Paints are certainly a very interesting area of research," says Ferrari. "There are very real applications, such as coating bricks, that are being investigated."

Corrosion-proof steel

The fact that it is 200 times stronger than steel is one of graphene's most impressive characteristics, so it is no surprise that companies want to take advantage of it.

Ferrari says: "There are massive amounts of research being carried out on steel, with Tata Steel very interested." However, as a structural material, like concrete, it will have to undergo extensive testing before approval, so graphene's other properties are likely to be exploited before its strength.

Graphene-coated steels are being developed that could dramatically reduce damage caused by water and corrosive chemicals to increase their lifespan.

Interactive panels

Graphene's strength, flexibility and electric conductivity have attracted several mobile phone manufacturers, including Samsung, to invest heavily to bring the first graphene-based touchscreen to market.

Touchscreens could be integrated into a building and, as production costs come down, it may be possible to upscale this transparent technology to cover entire windows. The National Graphene Institute's architect investigated having an interactive panel on its street-side viewing window. >

> **"It puts the science on show, which was a key driver for this building, as research needs to be funded"**
> Julian Dickens, Jestico + Whiles

> percentage of reinforcement to create a rigid structure to ensure the clean rooms met the vibration standards," says London.

Between the two clean room spaces is a plenum space, which occupies the bulk of the ground floor, traditionally a building's most valuable space. The plenum space is occupied by ventilation and numerous filter units, allowing maintenance to take place without entering the clean spaces. It is one of many areas dedicated to servicing the building's specialist laboratories and clean rooms.

"It's not a large building but it is very heavily serviced," says London, who estimates that 40% of the construction budget was spent on services. In addition to standard water, electric and ventilation facilities, the building has three extraction systems to remove solvents, gases and general fumes, as well as piping for more than 10 types of gases supplied to the laboratory spaces.

HUFTON + CROW

Above: The plenum space allows the clean rooms above and below it to be serviced without maintenance staff having to enter them

Such complex building design was made easier though the use of BIM, which saved time and money on clash detection.

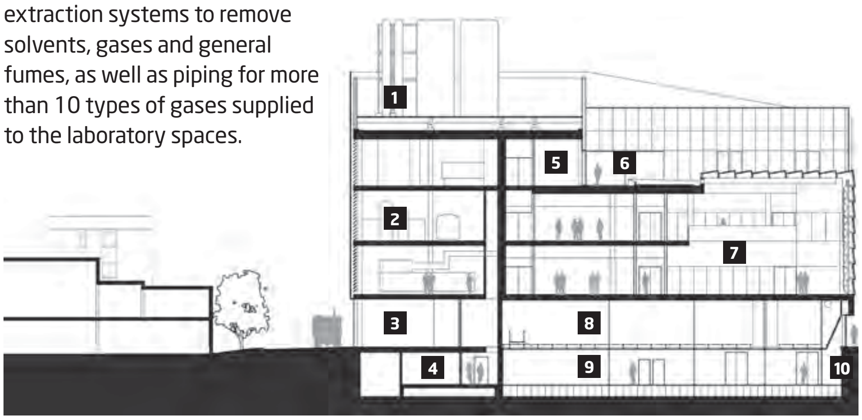
"Because of the intensity of the services, BIM was extremely beneficial to the project [see box, *p32*]," says London.

Although the design was driven by the extremely technical requirements of the laboratories, the architect has managed to introduce flourishes of interest. The main workspaces are broken up by an atrium, a roof garden accessible from the fourth floor and a *2001: A Space Odyssey*-inspired black wall for scientists to write on.

A top-lit corridor in the basement provides light into the clean room and a window for the public to view research taking place. This "dirty" corridor runs alongside the clean room to allow visitors to observe research in action without having to "gown up".

"It puts the science on show," Dickens says, "which was a key driver for this building, as research needs to be funded."

If it had been built five years into the future, this window could have been used to demonstrate the potential of graphene. The architect and Novoselov investigated covering it with a film that would transform it into an interactive screen for the public to learn about the material and the research. The facility came too soon for this innovation, but it could be a reality on buildings and sites in the future. >



1. Roof top plant zone
2. Plant
3. Loading bay
4. Comms room
5. Offices
6. Roof terrace
7. Breakout space
8. Plenum space
9. Clean room
10. Viewing corridor

Spray-on solar panels

In the future we may see "solar cells sprayed on a surface", says Ferrari. Photovoltaic cells made from layers of semiconducting material and graphene, which is transparent and highly conductive, have the potential to double the amount of energy converted in a panel. However, the material is not very good at collecting the electrical current produced inside a cell, so this is the area where research is currently being focused.

Graphene, made from abundant carbon, would replace the rare and expensive indium in photovoltaic cells, which could cut the price of panels. And spray-on panels could be feasible in the long term.

Self-cleaning concrete

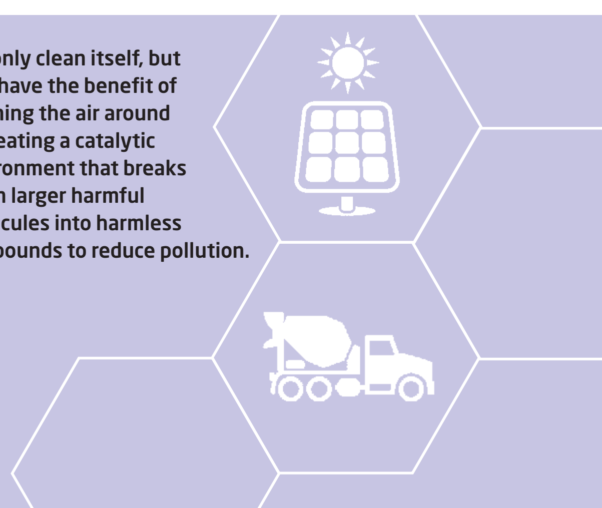
Introducing graphene into concrete could have the potential to increase the material's strength in the long term.

However, in the short term it is more likely that graphene will be used to improve the appearance and environmental performance of concrete.

"Research is being carried out into concrete that is self-cleaning or could benefit the environment," says Ferrari.

Graphene-injected concrete could make darkened and stained facades a thing of the past, as the nanomaterial's impermeable characteristics would prevent surfaces from collecting dirt.

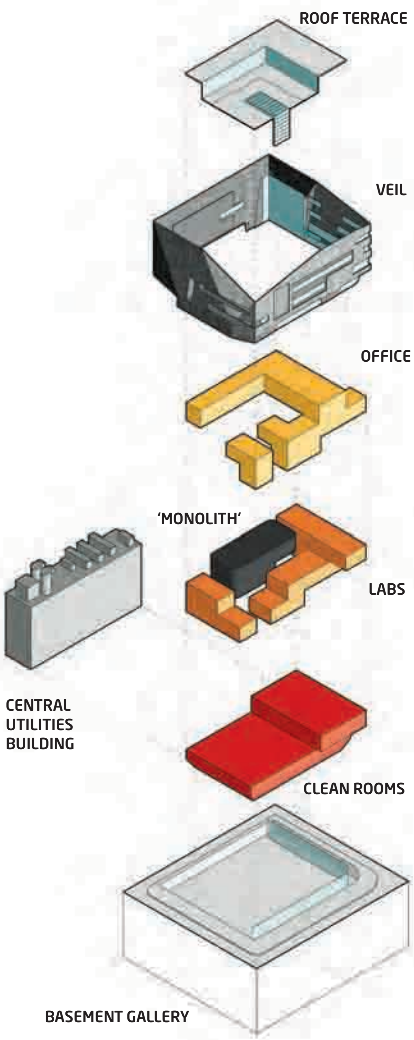
Concrete that contains graphene would not only clean itself, but also have the benefit of cleaning the air around it, creating a catalytic environment that breaks down larger harmful molecules into harmless compounds to reduce pollution.




The highly specified clean rooms, where the research takes place, have defined the layout and construction of the entire building

MANCHESTER UNIVERSITY

How the National Graphene Institute fits together



> However, the most obvious architectural flourish is the one that gives the building its black stealth bomber aesthetic. A skin wraps around the building, which Dickens describes as "quite lumpy", to create a unified appearance. This veil is detached from the building, over an inner Eurobond cladding system – this is relatively cheap and often used on industrial sheds – which hangs from the concrete frame and provides screening from the rain.

The cladding was chosen after the architect and representatives from the university visited several buildings in London. They considering a screen-printed glass box or a steel mesh cladding, but settled on using perforated black Rimex stainless steel. The hexagonal perforations match the form of graphene. A pixelated image of Geim and Novoselov's formula was by created by enlarging particular hexagons in the veil.

As Dickens says: "Often buildings are described as state of the art, but in this case it is true – they really are using the latest technology and the building really is cutting edge."

This facility has been built to meet exacting specifications and is where research into the future of construction materials may be born. The university has now turned its sights on a second building on the campus dedicated to graphene: the £60m Graphene Engineering Innovation Centre designed by Shard architect Rafael Vinoly. Due open in 2017, this facility will be dedicated to taking innovations from the institute into production. It should not be long before graphene products, and the material itself, is in use in construction. **CM**

Pushing BIM boundaries

The sheer complexity of the University of Manchester's National Graphene Institute, with its twin structural frames, highly controlled and precisely designed clean rooms, and dense levels of services, including multiple gas flows, extraction systems and ventilations units, made BIM invaluable on the project.

Michaela Ellis, BIM co-ordinator at BAM Construct, says: "We try and use BIM on any and every feasible project, but we had never used BIM to such a degree before.

"People have been designing buildings for a long time, so of course it would have been possible to build this building without a BIM model, but not within the timeframe and budget we had."

BAM's use of BIM on such highly specified building was never in doubt, but the architect, Jestico + Whiles, provided more traditional 2D drawings. The contractor's in-house team, BAM Design, converted these into a 3D model, which was updated as the architects altered the design.

A fully federated model was co-ordinated with mechanical and electrical contractor Balfour Beatty, which had the task of fitting a huge amount of plant and pipework into a relatively small building. A detailed BIM model helped it to maximise the usable research space.

"Balfour Beatty told us that they could have a building twice the size and not fitted in all the M&E," recalls Ellis. BIM also reduced the project cost by improving co-ordination in the highly serviced building.

"We carried out live clash detection every two weeks," says Ellis. "Consultants and subcontractors would meet at Balfour Beatty's 'BIM cave' [a room in which the model was projected on to the walls], discuss 20 or 30 vital points, and resolve them."

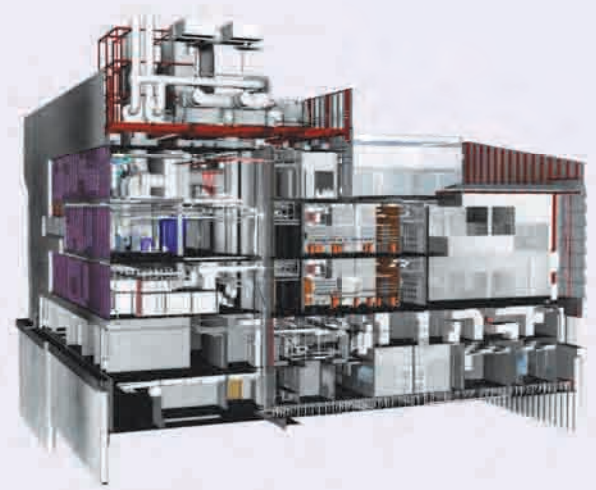
This process revealed around 500 clashes. A traditional process only picks up 90% of the clashes, so at an average cost to resolve an error £2,000, Ellis estimates a saving of £100,000. Indeed, she believes some issues would have cost much more.

"The foot of a 12 tonne extraction unit on the roof was overlapping the movement joint [between the two frames], which would have sent vibrations throughout the building. Rectifying this on site could have cost in excess of £30,000."

Now the project is complete the university will continue to use the BIM model to manage the building's complex services.

"We decided that, as it was such an exciting project, together with Balfour Beatty we would create a limited asset information model – a version of the model containing hyperlinks to the O&M [operations and maintenance] manuals of some of the plant assets," says Ellis.

For all the latest news on BIM, including case studies, project information and jobs, go to **www.bimplus.co.uk**



BAM CONSTRUCT

Making waves

After leaving the helm of Balfour Beatty last year, Andrew McNaughton has a new project: the world's first power-generating tidal lagoon. **Tom Ravenscroft** reports

ON THE BEACHFRONT in Swansea Bay, Andrew McNaughton seems a world away from the profit warnings that forced him to resign as Balfour Beatty's chief executive just more than a year ago.

"After Balfour Beatty I decided to take some time off, which was a pleasant release," says McNaughton. "I took some time to think about what I'd do next." That period of reflection has led him to south Wales, where he has taken on the task of delivering the UK's first tidal lagoon into operational service.

The first of its kind in the world, Tidal Lagoon Power's Swansea power-generation project won planning consent last month. By 2019 it could be creating enough green energy to power more than 155,000 homes for at least 120 years.

The proposed £1bn scheme would have a 320 MW installed capacity and will generate electricity from the rising and falling of the tide in the Severn Estuary. It will involve constructing a 9.5 km breakwater in the bay to enclose a 11.5 sq km stretch of water. As the tide fills and drains this pool, 16 bi-directional hydro-generators will create electricity.

Track record

McNaughton had "many opportunities from all around the world", he says, but became involved with the project through Tidal Lagoon Power's chairman, Keith Clark, former chief executive of WS Atkins.

"I have known and worked with [Clark] over the years. He called and told me this is a project that I would enjoy, and that I'd get on with Mark [Shorrock – chief executive of energy company Tidal Lagoon Power]."

An experienced project manager, McNaughton project managed the construction of Terminals 2 and 5 at Heathrow, the widening of the M25, and in 2002, he won the ICE Civil Engineering Manager of the Year award for his work on the Channel Tunnel Rail Link.

As director of construction for Tidal Lagoon Swansea Bay since April, he is overseeing the technical development of this innovative piece of infrastructure, and will be responsible for delivering it into operational service.

On taking the job McNaughton said: "I am thrilled to return to the industry's front line to oversee its delivery." But speaking to *Construction Manager*, he now makes clear he is thinking on a larger scale, and is focused on the long-term programme of coastal energy projects at parent company Tidal Lagoon Power.

"This is not a step back," he says. "I've joined because of the vision of Tidal Lagoon Power. We are building a new power company. Swansea Bay just happens to be the first [project]."

The UK has a commitment to deliver 15% of its energy from renewable sources by 2020, under the European Union's 2009 Renewable Energy Directive. McNaughton believes Tidal Lagoon Power's plans for a fleet of six UK lagoons could play a significant role in meeting this target, and satisfying the country's future energy needs.

"Tidal Lagoon Power is a concept that can make a radical change," he says. "I will look back in 10 years and not say that we created lagoons, but that we created a new industry. Every person in the organisation understands the future legacy. That is why I became a civil engineer in the first place, to build communities."

"Invigorated" by the role, McNaughton says he is enjoying working for the younger organisation: "This is something completely different to running a plc. The company is absolutely clear in its vision. It is so refreshing to have a series of investors and owners that really get the direction of the company." >

"We are asking funders to back something that will start generating income in four years' time"
Andrew McNaughton, Tidal Power Lagoon

The 9.5 km breakwater will encircle the new 11.5 sq km lagoon in Swansea Bay

> Unsurprisingly he is confident this lagoon and its larger siblings will come to fruition. However, the first project, in Swansea, still has to pass several hurdles before it becomes a reality.

The Severn Estuary has a very large tidal range – second in the world only to the Bay of Fundy in eastern Canada – which has led to numerous proposals to use it to generate electricity. The first came in 1925, and many have followed. All have been brought down by economic and environmental concerns.

But McNaughton believes that, just as the railways expanded in the Victorian age, now is a time when private investment and innovation are key to new infrastructure: "We are now in an age where the government is seeking private investment into infrastructure." In addition, he points out that the lagoon would have less of an environmental impact than the proposed barrage across the Severn.

"The lagoon is not impounding water," he says. "The lagoon remains tidal, and a large extent of the foreshore will be pretty much as it was before."

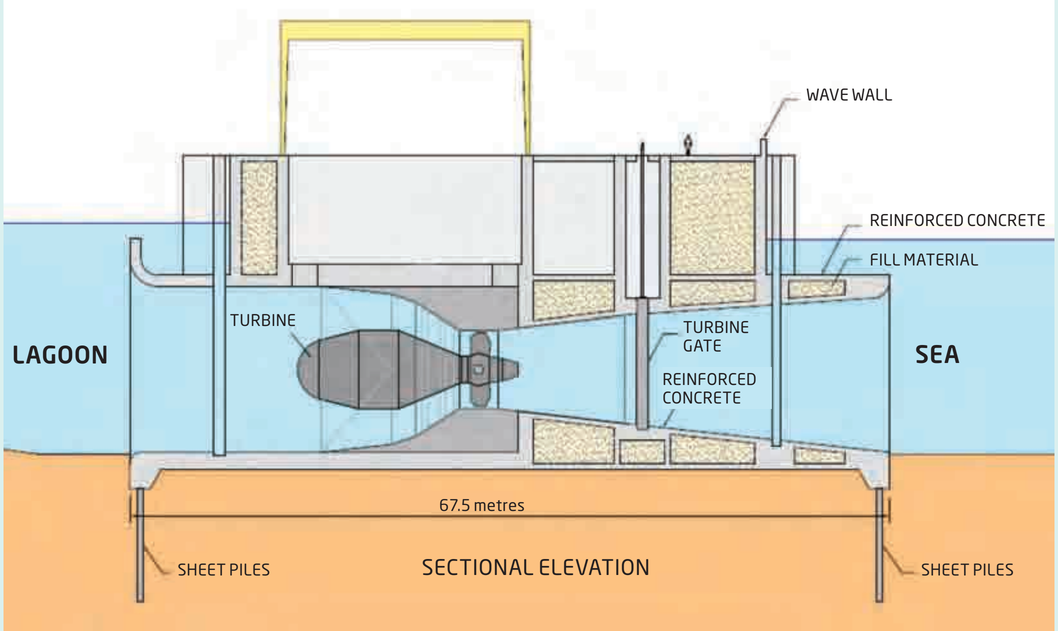
McNaughton believes the public's attitudes to sustainable energy and tidal power have become more positive: "There is a public awareness that a change is needed in the way we produce energy. If you see green energy as a good thing for the future, then you know that there have to be trade-offs. There is now a more mature attitude to looking at the impact, both ecological and for the community."

Eco friends

Environmental groups have given the project qualified support.

Gareth Clubb, director of Friends of the Earth Cymru, says: "Tidal lagoons are a much better bet than a barrage >

The highs and lows of building at sea



Tidal Lagoon Power's Swansea Bay project would be the first man-made, energy-generating lagoon in the world. But creating power from the tide is not a new concept: mills driven by ebb tides, known as tide mills, have existed for more than 1,000 years in the UK. In more recent times a barrage at La Rance, northern France, has been generating electricity since 1966 (box, *overleaf*) and in South Korea the Sihwa Lake Tidal Power Station came into operation in 2011.

The key concepts for a tidal lagoon are well understood, and the turbine technology is tried and tested. The 9.5 km U-shaped breakwater will run from a point next to the mouth of the River Tawe, by the port of Swansea, and then rejoin land next to Swansea University's new Bay Campus.

A concrete structure at a midpoint in the breakwater – to be built by Laing O'Rourke – will house 16 low-head bulb turbines that will generate electricity as the tide flows in and out of the lagoon. In a similar manner to run-of-river hydropower schemes, flow is created by gravity through the difference in head – or water height – inside and outside the lagoon walls.

Atkins is the client's engineer. Costain, which is also an investor, will provide project management support to Tidal Lagoon Power.

The Swansea proposal differs from the often-mooted Severn and existing barrages elsewhere (box, *overleaf*): unlike these schemes, it does not straddle the estuary and fully obstruct flow. Construction of the £1bn project has been divided into three main contracts: the turbines, the concrete turbine house and sluice gate structure – together known as "the civils package" – and the marine wall. There are also separate contracts for ancillary works, such as the breakwater surface, roads, slipways, utilities

"It is actually possible to take advantage of the tides and increase production"
Ton Van der Plas, Tidal Lagoon Power

and landscaping, building the visitor centre and the turbine assembly plant. The largest contract by value is the £300m marine works package to construct the 9.5 km wall, for which China Harbour Engineering Company has been named as preferred bidder.

The wall will rise from 5 metres at the shore, where construction will begin, to 20 metres out in the bay. At high tide 3.5 metres of the wall will be visible and at low tide up to 12 metres. It will be constructed over three summer seasons (March to October). The wall will act as a breakwater, protecting an area of water against waves and the project itself from being washed away, but it will also act like a dam, retaining a water-level difference between the open sea and the enclosed bay area.

"We need to create a big swimming pool at sea," says Ton Van der Plas, senior marine engineer at Tidal Lagoon Power. "It is a dam structure, built offshore, which is designed to withstand alternating head differences four times a day. At the same time, it needs to be stable during storms and wave attack. So it is more than a typical breakwater or a typical dam, and combines the function of those two structures."

The construction sequence for the breakwater wall is as follows. First, 2 metre-high barrier walls of "quarry run" – randomly shaped stone – are laid parallel under water with the space between them filled with sand.

Further progressively narrower layers of rock and sand are placed on top of the construction until a barrier with a triangle-shaped section is formed (see diagram, *right*). Larger "rock armour" is then positioned on top of the structure to protect it from the sea.

The fast-flowing water in the estuary means the construction process throughout has to be carefully managed, explains Van der Plas: "A large tidal range [the difference between the high and low tide] comes with tidal flows, which will tend to erode the newly placed material. It is key that any sand placed is protected as quickly as possible by rock or other means to prevent erosion and loss of progress." The marine contract also include sourcing and transporting the 5 million tonnes of rock to Swansea Bay. To promote the project's green credentials, Tidal Lagoon Power intends to use as few trucks as possible, and instead transport the rock by sea.

One plan being explored is to move the rock from a quarry on the Lizard Peninsula in Cornwall, by sea. Tidal lagoon Power's plans to re-open a disused quarry in Cornwall have come up against local opposition, although the final decision on sourcing the quarry run will lie with China Harbour Engineering Company. The 7 million tonnes of sand required will be dredged from Swansea Bay. Around 80% of the material for the sea wall will be placed using marine equipment rather than manpower.

Although the structure is not technically demanding – Van der Plas describes it as "everyday" – the large tidal range that makes the site ideal for generating power creates complications, as it makes for an extremely variable construction environment.

The bund wall will be constructed with a combination of marine plant, such as barge- and pontoon-mounted equipment, and land-based equipment, with the tide determining what equipment can be used when. This will change throughout each day, explains Van der Plas.

"With low tide, the land-based plant has a maximum work area, but six hours later most of the site will be flooded. With high tide, there will be sufficient water depth for most of the site for marine plant access, but six hours later one-third of the site will be dry or have only limited water depth, prohibiting most vessels from working there." However, by working on several fronts at the same time, vessels and land-based equipment can move between locations depending on the tide to continue working.

In fact Van der Plas points out that the tides in the estuary can be advantageous for construction: "With planning and the right equipment, it is actually possible to take advantage of the tides and increase production. For instance, inspection of completed work can for a part be done in dry conditions as opposed to underwater surveys or even through diver work."

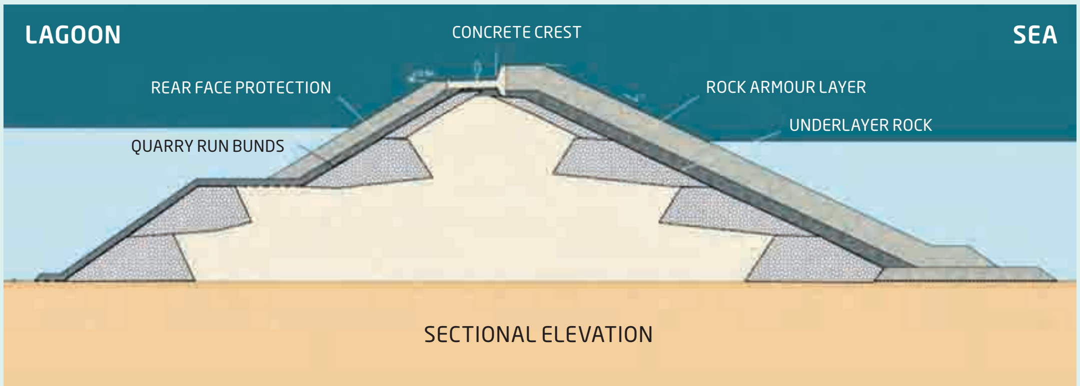
Connected to the sea wall, an oval 2 km coffer dam will create a dry environment to allow the turbine structure to be constructed, as the final element of the marine contract. Laing O'Rourke was named in May as preferred bidder for the £200m contract to deliver 410 metre concrete turbine house and sluice structure block.

At the south-west of the lagoon the reinforced concrete structure comprises 16 turbine housings and eight sluice gate housings with a 137 metre-wide dividing structure between them. Each housing unit for the 16 bi-directional turbines – supplied by General Electric and Andritz Hydro at a cost £300m – will be 15 metres wide. Set to be assembled in a plant to be built in Swansea, these 7 metre-diameter bi-directional turbines generate electricity from tidal water both entering and leaving the lagoon.

The sluice gate units will each be 16 metres wide. The steel vertical lift sluice gates will act as an additional mechanism to control the water entering and leaving the lagoon.

The structure will also contain operations and maintenance rooms, some below the road level and some above in the "offshore building".

The wall is structured to withstand alternating differences in the height of the tide four times a day



YVES JALABERT

Rising tide: five marine energy projects

Rance Tidal Barrage (above)
When it opened in 1966, this barrage across the Rance River in Brittany, northern France, was the largest tidal power station in the world, with an installed capacity of 240 MW.

Sihwa Lake Tidal Power Station
Currently the world's largest tidal power station, with an installed capacity of 254 MW, this barrage in South Korea opened in 2011. It was constructed from a seawall built as a flood defence.

Annapolis Royal Generating Station
The 20 MW facility on the Bay of Fundy in Canada, the only tidal power station in North America, was opened in 1984.

Tidal Lagoon Power (planned)
Along with the proposal for Swansea Bay, Tidal Lagoon Power wants to create a fleet of lagoons around the UK and has applied for planning for a site in Cardiff. Further projects are earmarked at Newport and Colwyn Bay in Wales, Bridgwater in Somerset, and West Cumbria (see map, right).

Incheon Tidal Power Station
Currently under construction in South Korea this barrage with 44 turbines will have a capacity of 1,320 MW when it opens in 2017, making it the largest tidal power station in the world by some distance.

SeaGen
The world's first large-scale commercial tidal stream generator was placed in the Strangford Narrows off the coast of Northern Ireland in 2008. The 1.2 MW generator was built to demonstrate the potential of the technology.

MeyGen (planned, below)
The first stage of this proposed scheme would place four 1.5 MW turbines on the seabed in Scotland's Pentland Firth that will take advantage of fast-flowing current to generate electricity.

MEYGEN

> across the Severn. That scheme was universally opposed by the environmental sector because of the catastrophic damage it would have caused to wildlife and habitats."

The charity is "broadly supportive of the scheme", if "environmental impacts can be mitigated and managed". Two areas of concern are the impact on migratory fish and the source of the rock for the lagoon wall. No decisions have been taken on rock supply, but reports that Tidal Lagoon Power is to reopen a quarry on the Lizard Peninsula in Cornwall to extract 3 million tonnes of stone have provoked fierce opposition from locals.

Swansea, however, seems to embrace the project – it is expected to attract 100,000 tourists a year and a visitor centre is planned as part of the scheme. Jonathan Roberts, editor of the Swansea-based *South Wales Evening Post*, says the "general mood in Swansea is largely positive."

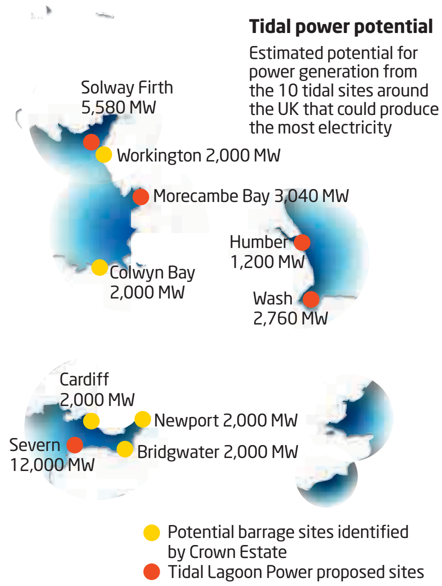
"The economic benefits, in terms of significant investment, job creation and increased visitor numbers, will be most welcome," he says. "And there is a strong sense of pride in being chosen to lead the development of this technology."

The scheme also has political support. Labour's Mike Hedges, Welsh Assembly member for Swansea East, says the "vast majority of my constituents are in favour [of the lagoon]". In addition to 1,850 construction jobs, the project would create 110 roles in operations, maintenance and at the visitor facilities. A new 9,300 sq m assembly plant for the 16 turbines to be used at Swansea is expected to employ a further 100 people.

Short order

But even if all the environmental boxes are ticked, the remaining barrier is financial. However, McNaughton believes the project's size and speed of delivery, will help: "There was a huge economic problem [with the Severn barrage], as it was too big to finance. There was a lot of time before you see a return on investment. Trying to raise £20bn in capital for a project with a 10-year build time [for the Severn barrage] is a big ask."

He argues the Swansea project is more realistic: "We will begin commercial operation in 2019, so we are asking funders to back something that will start generating income in four years' time."



Tidal power potential
Estimated potential for power generation from the 10 tidal sites around the UK that could produce the most electricity

Tidal Lagoon Power has investment commitments from Prudential and InfraRed Capital Partners for the scheme. However, this is predicated on achieving a "contract for difference" from the government. This sets out a price over a fixed period that will be paid for electricity to a power generator. It is being negotiated with the Department for Energy and Climate Change, so McNaughton will not comment on the "strike price" the company is seeking. However, the reported figure of £168/MWh for 35 years is much higher than the £92.50 strike price for the nuclear reactor at Hinkley Point.

Tidal Lagoon Power explains this by saying its five future lagoons will be larger, and so will benefit from economies of scale to produce cheaper power. It commissioned a report that states that lower strike prices of £130/MWh and £92/MWh would be needed for the second and third lagoons respectively.

"You can't look at Swansea in isolation", says McNaughton. "You have to look at the fleet. We believe that when you take a view of the fleet performance over the long term, there is an obvious economic benefit." There is also potential to export the technology: "We have had interest from several other countries," he reports.

McNaughton is in no doubt that the Swansea lagoon will succeed where the Severn barrage failed. "Tidal Lagoon Power has the single aim of building lagoons," he says. "It's just a fantastic way of generating power." **CM**