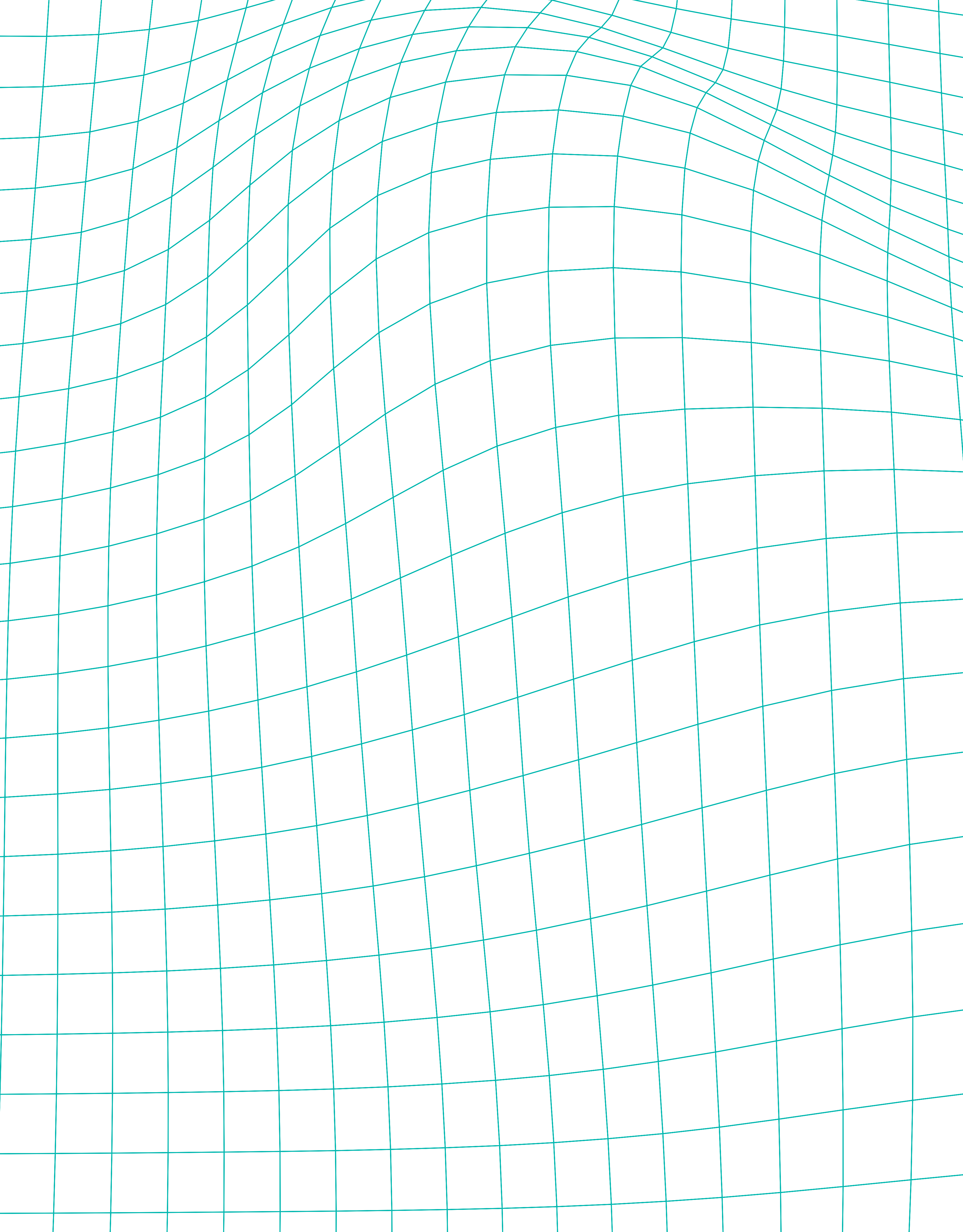
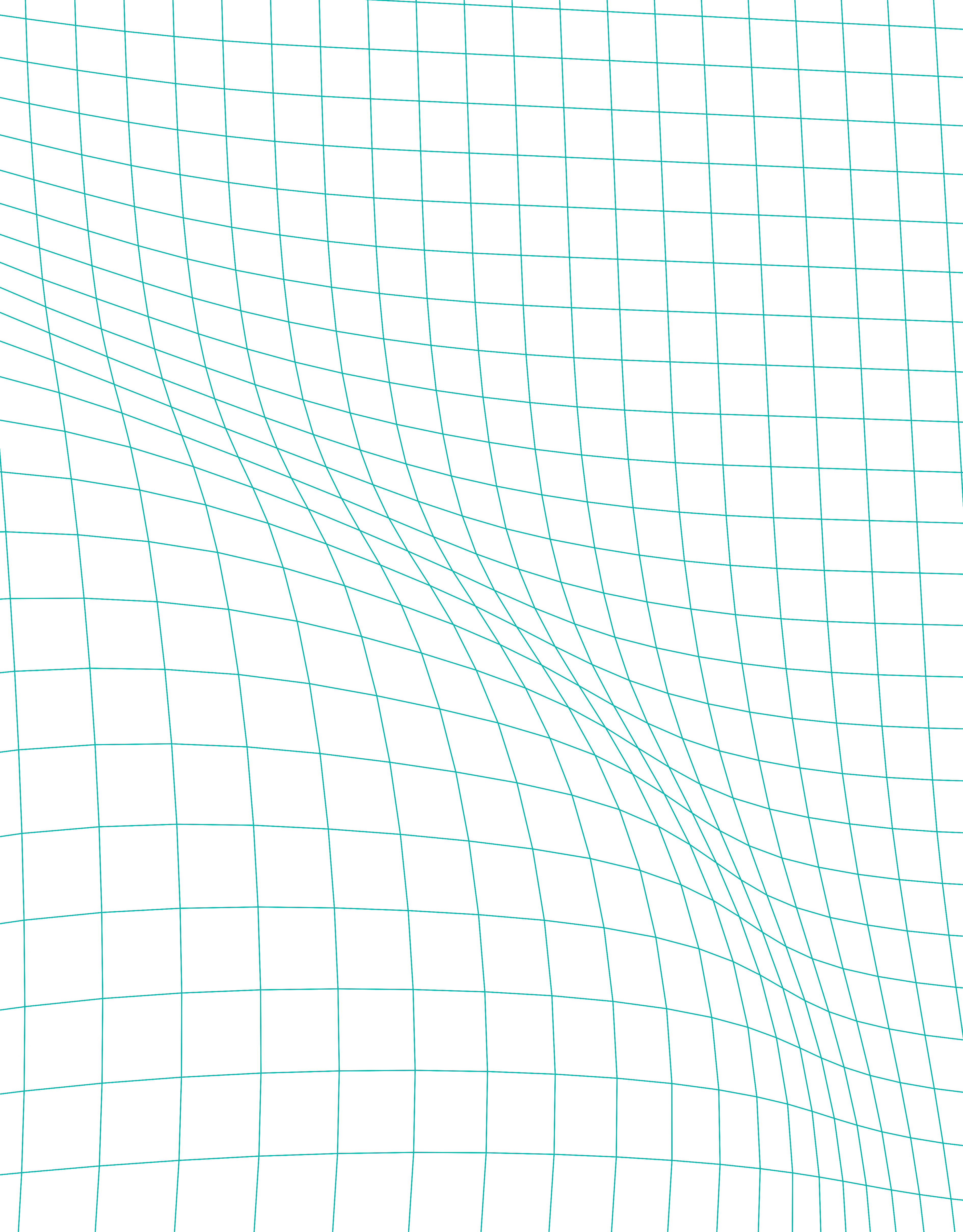
BFG

Moulding ideas into Shape

LANDMARKS BY BFG
CREATING DESTINATIONS WITH COMPOSITES
ISSUE 01





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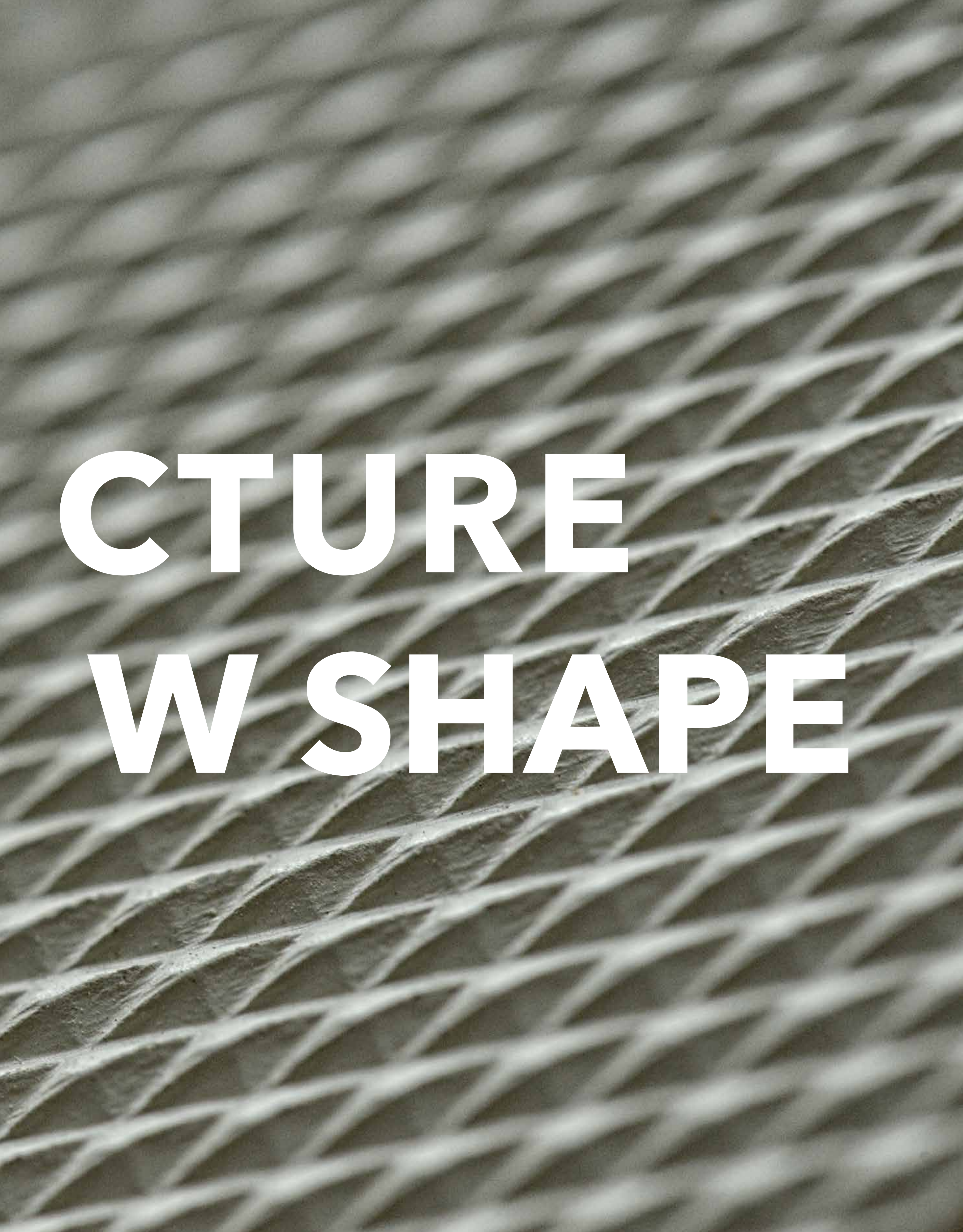

CTURE
W SHAPE

Explore

Welcome

"We can help you imagine tomorrow and pioneer new ways to make it happen, helping free your future structures from yesterday's conventional thinking."

Since ancient times, architects have been striving for futuristic ideas. For unseen, unheard of, unimagined yet functionally efficient structures and spaces. New buildings become part of the zeitgeist, embodying ambitions and technologies of the time.

In the modern era, it's hard to remember a time when architecture has been so ambitious or admired. Gone are the concrete boxes, and in their place, beautiful statements, flowing lines and gravity-defying creativity. It is as though the imagination of a generation is being set free.

Here at BFG, we can nurture your imagination for tomorrow and pioneer innovative approaches to make it happen, by adopting our ever-evolving composite engineering to liberate your future structures from yesterday's outmoded 'confined, conventional, material limited thinking'. So we invite you to create with us – and innovate with us – to transform structures and spaces and bring imaginative new landmarks to life.

With extensive experience spanning over four decades, BFG is the ideal partner to transform what was impossible yesterday into the award-winning reality of tomorrow. Our 15 plants worldwide and core design and engineering teams are dedicated to finding innovative ways to tackle the most challenging projects, on any continent. Yours should be next.

Please feel free to contact me and my teams directly to explore how we can work together. In the meantime, enjoy the journey as you discover some of the world's most advanced composite engineering excellence in our projects.

Dr Samer Aljishi
Group President, BFG

We are BFG

For over 40 years, BFG has been a global leader and pioneer in composite design, engineering and manufacturing, with over 2,000 people and 15 production facilities worldwide – and a total commitment to quality and innovation.

Sector focus

We currently cater to six sectors, each with unique performance requirements:
- Architecture and Infrastructure
- Transportation
- Corrosion Engineering and Process Equipment
- Wind and Renewable Energy
- Environmental Systems
- Leisure and Recreation.

Working in depth with sector leaders, we have world leading cross-functional knowledge and expertise in design methodology, materials composition and manufacturing processes – delivering significant advantages in performance, productivity and efficiency to each sector.

Landmark developments

Since 1975 we have worked in partnership with the world's leading architects, consultants, contractors, rail rolling stock builders, industrial process designers and renewable energy specialists – across both the public and private sectors – to create bespoke composites for a new generation of iconic buildings, industrial components and advanced transport networks: from the TGV in France to the KAFD World Trade Centre in Saudi Arabia.
Today, you'll find our advanced composites at work in the key landmarks and transport systems of many of the world's major cities, stretching all the way from Chicago to London to Sydney. Our structures include the world's largest composite dome, the world's largest composite roofing system, and composite claddings on landmark sports stadia, university facilities and supertall buildings. We consider every project as an opportunity to conceive, draw out our innovative ideas, learn and deliver the best.

Driven by innovation

Today's composites are designer materials, offering boundless possibilities. Driven by a vision to harness these possibilities, BFG invests heavily in research and development to lead the way in new design methodologies, high performance materials, manufacturing processes and product systems. Over the years, innovation has become our hallmark, leading to pioneering advances including the development of our own unique material systems, manufacturing processes and patented technologies. We have made significant investment in international ventures spanning areas as diverse as wind energy, anti-ballistic composites and advanced compact wastewater purification. Our dedicated R&D centre in Strasbourg is working in partnership with universities, laboratories and designers to develop revolutionary new wastewater treatment technologies.

Global footprint. International reach.

What makes us genuinely different is our presense in diverse sectors along with a global footprint – and our proximity to you. In recent years, it's taken us across five continents, serving major clients across six. BFG has fabrication facilities in Bahrain, France, Spain, USA, Brazil, China, India, the Philippines and South Africa, covering more than 100,000Sqm of manufacturing space and enabling us to offer global sourcing, regionalised manufacturing, localised delivery and installation of world class composites.

Serving the world's leading architects and contractors

We've worked in partnership with key players in architecture and infrastructure since we opened our doors in 1975. We've grown since then – in the scope and complexity of our services, and in the diversity of projects we inspire.

What makes us genuinely different is our presense in diverse sectors along with a global footprint – and our proximity to you. In recent years, it's taken us across five continents, serving major clients across six.


FLEXICAM
FLEXICAM
BFG
SHOP 21.01.2016

We work with leading architects, consultants, contractors and governments around the world, delivering bespoke composites for facades and claddings, structural roofing systems, domes and ceilings.

Over the last 40 years we've provided the very latest composite innovations to architects, with all the durability and versatility they need to create a new generation of structures – public buildings, sports arenas, hotels, transport hubs, malls and high-rise structures. Giving designers the freedom to build large scale, complex, lightweight structural shapes that would be too complex and high cost to achieve with conventional materials.

In fact, our role has been pioneering – from the development of long span composite primary structures to lightweight fire retardant materials. Today you'll see our advanced composites in structures designed or built by many of the world's leading creative architects and consultants.

Our team of over 100 talented and skilled engineers, backed by expert, hands-on leadership, roots its design and engineering methodology in a wealth of experience in materials and processes.

Conception to completion

At BFG, we deliver the full life cycle of services: conceptualisation, modelling, iterative design development, systems and process engineering, structural design, material and product development, testing, sampling, prototyping and product manufacture, all the way to delivery and installation.

Engineering excellence

Our team of over 100 talented and skilled engineers, backed by expert, hands-on leadership, roots its design and engineering methodology in a wealth of experience in materials and processes. With over 40 years of project records and an accumulated database of material properties and test results, our engineers have decades of technical data and insights to draw on. BFG's team is also in constant touch with world-leading universities and researchers to add state-of-the-art design expertise to its projects.

Many of our engineering leaders have had successful careers in manufacturing and installation prior to becoming lead designers. As a result, BFG's designs are created with manufacturing and installation in mind, helping reduce lead time and cut the number of design revisions and iterations needed to achieve project delivery.

Today, BFG deploys leading edge design tools, including CATIA and to interface with other architectural tools. Our world class structural engineering team uses NISA, HYPERMESH and other advanced analysis tools.

Over the last 25 years, BFG's composite structures have been subject to rigorous independent full scale load tests with strain capture. With hundreds of successful load deflection tests conducted over time, it enables extremely high levels of confidence in the structural performance of our composites.

Environmental impact

At BFG, we are committed to sustainable development. Our teams of architects, engineers and researchers are always searching for ways to minimise the environmental impact of FRP. In our Architecture and Infrastructure group, we are leading the way by helping our clients to achieve LEED certification for their buildings.

Quality assurance

BFG was awarded ISO 9001:2000 in March 2001 and upgraded to ISO 9001:2008 in February 2009. In September 2011, we achieved IRIS certification in the rail industry. We meet Class A1 of the German standard DIN 6701-2 for manufacturing adhesive bonds on rail vehicles and are certified to EN15085-2 for welding railway vehicles and components. External third party certification consistently places us in 'industry best' positions. We are also cerified for ISO 14001:2005 and OHSAS 18001:2007.

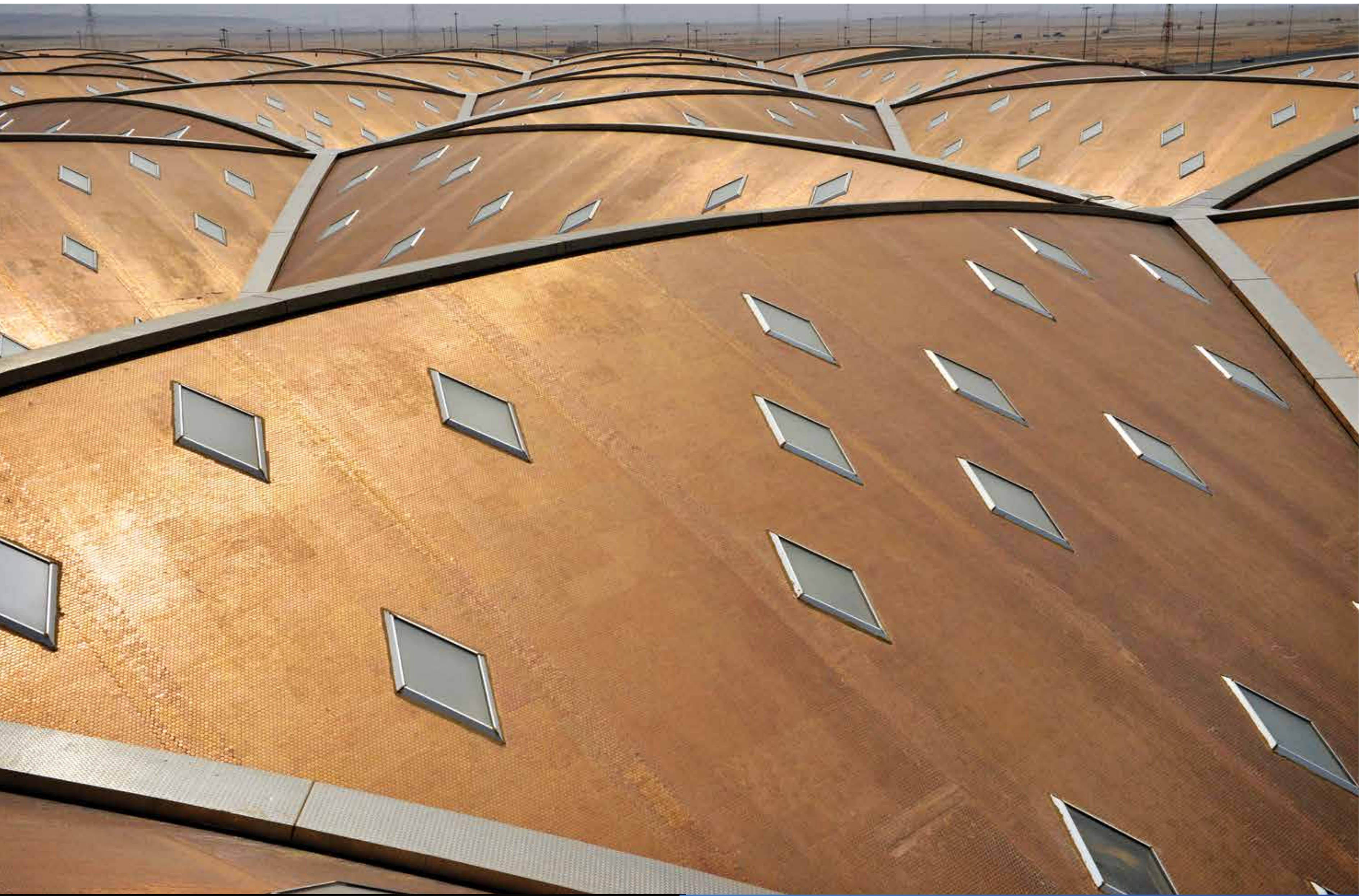
Manufacturing diversity

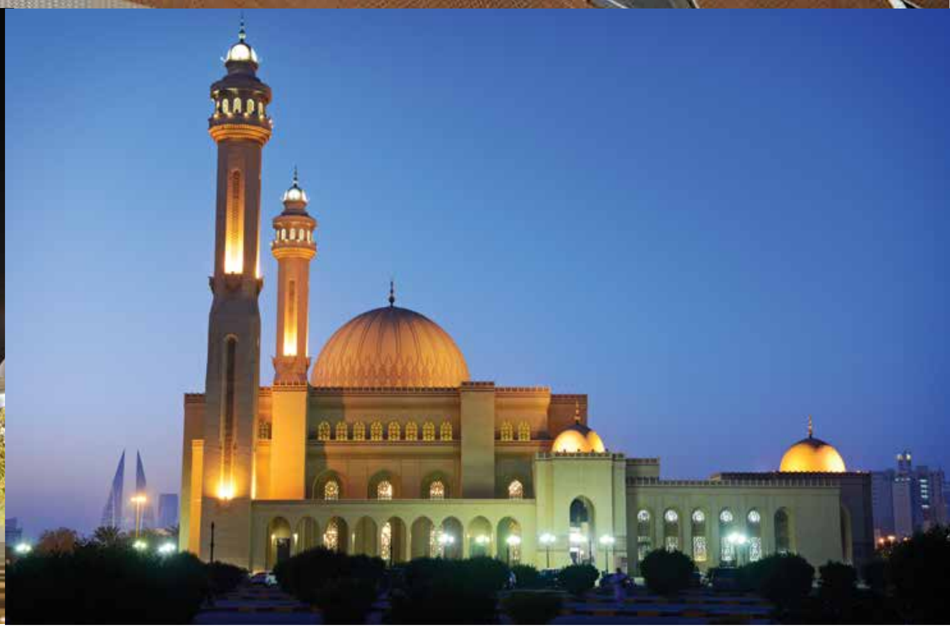
BFG specialises in composite manufacturing processes including:

- Open contact moulding
- Resin transfer moulding (RTM)
- Vacuum infusion
- Press moulding
- Painting
- Tool making
- Systems integration and assembly.

SPANNING SECTORS
BUILDING NEW MARKETS IN COMPOSITES

BFG is expert in composite design and engineering across the most diverse array of applications, from Europe’s latest high speed trains to critical components for the next generation of wind turbines.





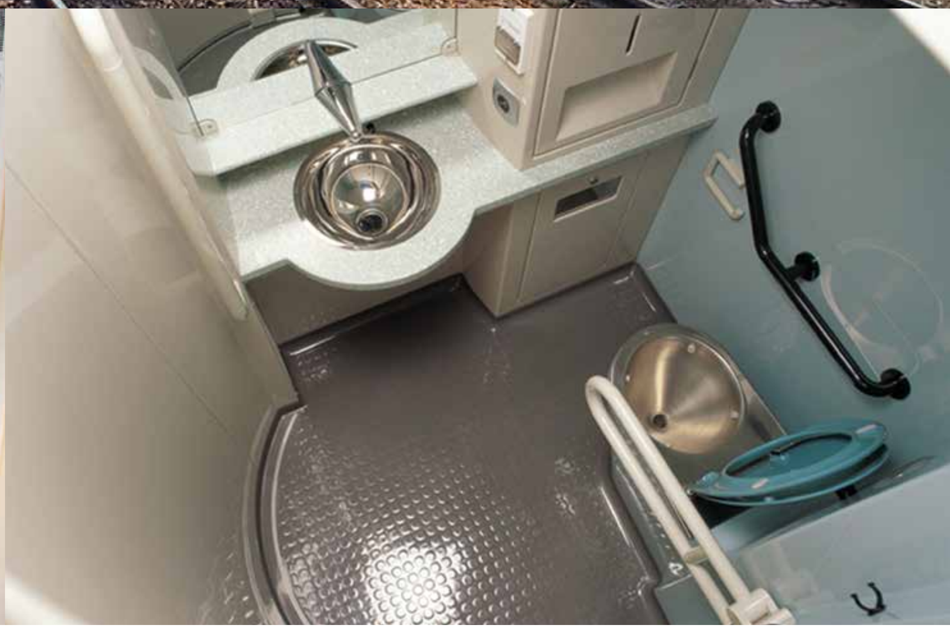
Architecture

FRP composites give the world's most ambitious architects the versatility and durability they need to create structures that go far beyond traditional limits. Over the last 40 years, composites have become an essential creative asset, giving a new generation of designers freedom to build complex shapes; reaching higher, spanning further and enabling an ever more imaginative built environment.

Since 1975, BFG has worked hand in hand with the world's leading architects, structural engineers and contractors to deliver turnkey composite solutions for external facades and claddings, complete structural roofing systems and domes, ceilings and shades. Our current portfolio of work includes major projects as diverse as the highrise KAFD World Trade Centre in Riyadh and the historic Holborn Station on the London Underground.

Transportation

Strong, lightweight composites are a key component in modern transport networks, from the high speed TGV in France to the latest local and regional trains in South Africa. As passenger numbers continue to grow worldwide, FRP components are proving robust, aerodynamic, fire-resistant and vandal-proof, with design flexibility that enables almost any design and shape.



For almost 20 years, BFG has been a market leading manufacturer of composites for the widest range of transport applications – from automotive to rolling stock. Our sector-leading FRP products cover interiors, exteriors, drivers' cabs and desks, front ends, sanitary modules and floors for buses, trucks and trains for clients including Alstom, Bombardier, Siemens, and Volvo.

Industrial

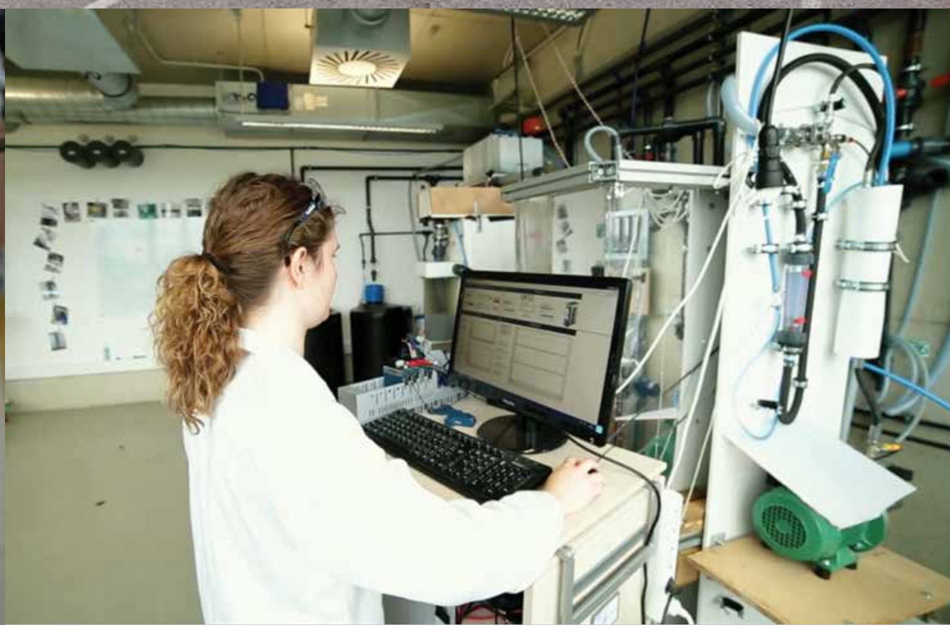
The latest FRP composites bring a host of advantages to industrial projects. Inherently corrosion and fire resistant, they can withstand heavy duty workloads with little or no maintenance over the long term. Structurally robust, they are capable of covering long spans with the minimum of joints.

For over 40 years, we have offered our industrial clients complete composite design solutions, from conception to production, including the industrial, engineering and structural design of everything from simple manhole covers and linings to complex long-span covers for water and waste water treatment plants.

Renewable Energy

BFG's composites are strong, safe and lightweight, making them perfect for highly specialised applications in renewable energy. In the wind sector, where long-term durability is key and maintenance is challenging – sometimes up to 100 metres above the sea – composites are required to protect wind turbines' most critical components.

As part of our commitment to sustainability, BFG fabricates high quality FRP composite components – including extremely durable spinners and nacelles – for the world's leading wind turbine manufacturers including GE, Hitachi, Gamesa, Acciona, Alstom and Leitwind.



Environmental

BFG is at the leading edge of design and engineering, most notably in areas demanding the highest environmental and safety standards. Our dedicated R&D hub in Strasbourg works closely with all BFG plants and partners with elite universities, laboratories and designers to develop new technologies that enhance sustainability and improve efficiency.

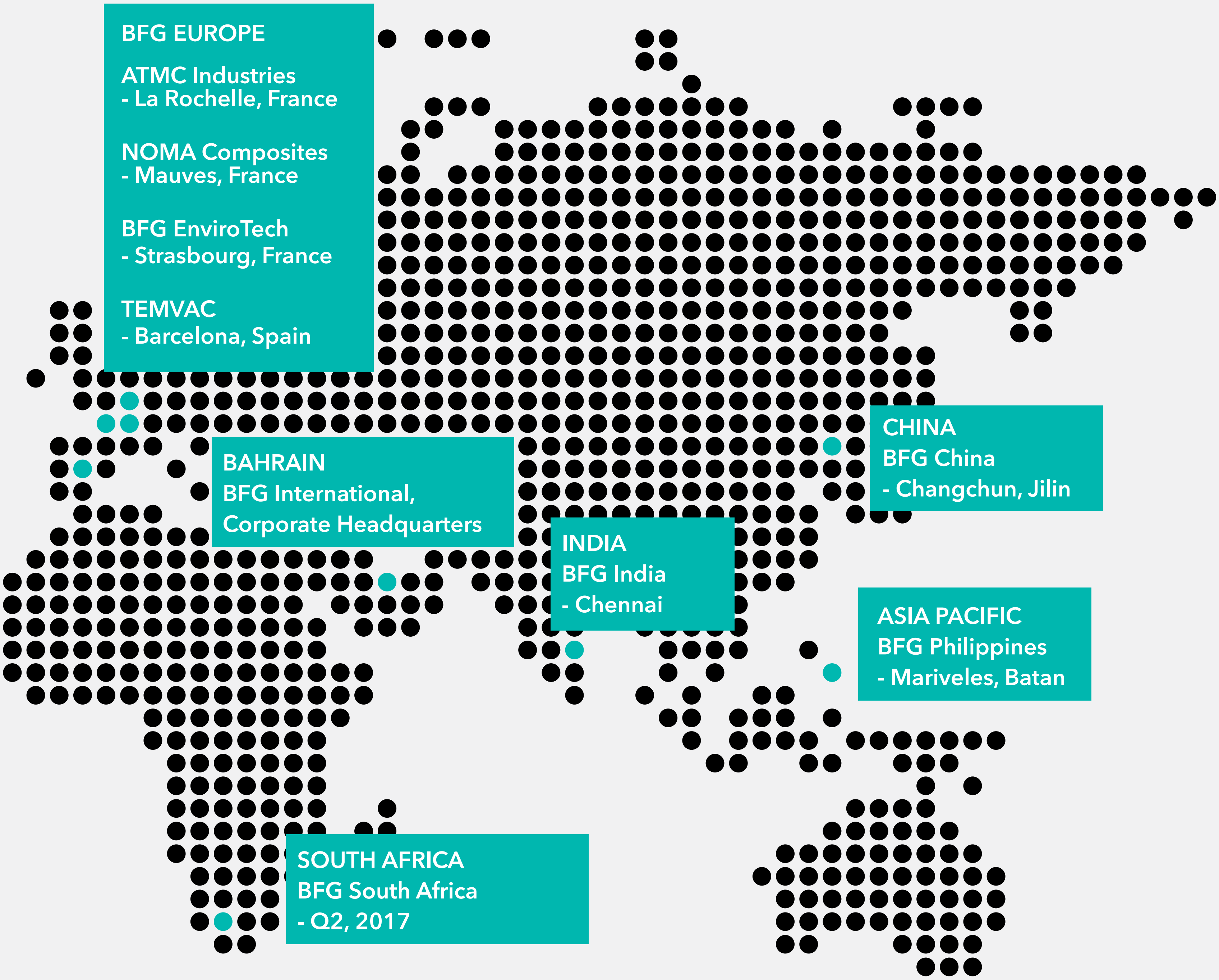
Our patented AcquaTrans system is an advanced, compact water remediation technology that boosts the efficiency and cuts the cost of recycling wastewater. Our system offers autonomous operation of up to 60 days.

Leisure and Recreation

Composites have significant applications in the leisure sector, where structural integrity and long term durability are critical performance factors. From marine craft and floating docks to water slides, BFG's advanced FRP can be shaped into a limitless array of forms.

Today, BFG is a long-standing partner to WhiteWater of Canada, producing high quality modular FRP components for the water parks designed and built by the company around the world.


NORTH AMERICA
BFG USA
- NY / TN
SOUTH AMERICA
BFG Brazil
- Sao Paulo


BFG EUROPE
ATMC Industries
- La Rochelle, France
NOMA Composites
- Mauves, France
BFG EnviroTech
- Strasbourg, France
TEMVAC
- Barcelona, Spain
BAHRAIN
BFG International,
Corporate Headquarters
CHINA
BFG China
- Changchun, Jilin
INDIA
BFG India
- Chennai
ASIA PACIFIC
BFG Philippines
- Mariveles, Batan
SOUTH AFRICA
BFG South Africa
- Q2, 2017

Global network - connecting a world of innovative materials

Around the world, BFG enables its clients to become the inventors of their own products, with 15 advanced composite fabrication facilities across four continents, an expert, internationally mobile talent base and a truly connected global supply chain.

MIDDLE EAST

BAHRAIN

BFG Bahrain
Of the 500 people who make up the team at BFG Bahrain, over 330 are employed on our busy factory floors. Our Bahrain operation includes three advanced FRP production facilities capable of fabricating very large parts, as well as full CNC tooling, 3D CAD design and in-house production engineering and quality control teams. BFG Bahrain's teams produce composite elements for the widest range of applications – from roofing and cladding the next generation of skyscrapers in the Middle East to fabricating parts for Europe's high speed trains.

BFG Metal
BFG Metal is a leading supplier of custom-made components to clients across the GCC, Europe and the USA. BFG Metal also forms an in-house centre of excellence for designing and fabricating metal parts for BFG in Bahrain and its divisions around the globe. Established to enable BFG to integrate metal parts with FRP composites for transport, architecture and renewable energy, BFG Metal's expertise helps to reduce production lead time, increase reliability and enable smoother logistics.

Ilium Composites
Ilium Composites is a world leading innovator and manufacturer of fibreglass reinforcement. Created in 2010 and based in a custom-built 10,000Sqm facility in Bahrain, the company manufactures and distributes a range of ultra high quality fibreglass reinforcement products using a unique process technology protected by patent. Every year Ilium Composites produces over 15,000 tons of composite reinforcement for customers serving the transportation, construction, recreation and alternative energy sectors across the Middle East, Americas, Europe and Asia.

BFG Commercial Services
BFG Commercial Services offers the most comprehensive choice of interior and industrial design solutions – from furniture and flooring to lighting and fabrics – for clients including major housing developments, luxury hotels, museums and auditoriums. It sources products from an extensive list of leading international suppliers as well as providing its own custom-designed solutions.

EUROPE

FRANCE

ATMC Industrie
Based in La Rochelle, ATMC Industrie has in-depth engineering expertise in the design, tooling and fabrication of the most diverse array of composite products for rail, automotive and marine craft. Located on a dedicated 6,000Sqm facility with a 100-strong workforce – the company has its own specialist tooling workshop for manufacturing patterns and moulds, and two paint booths to apply advanced coatings.

BFG Environmental Technologies
BFG's R&D centre in Strasbourg is focused exclusively on scientific and technical research. In the area of waste management, working in close partnership with select universities, laboratories and designers, it is a hothouse for the development of innovative new technologies which help reduce costs and improve sustainability.


BFG

NOMA Composites
Acquired in 2013, NOMA Composites manufactures FRP panels, toilet modules and front ends for Europe's new generation of intercity and high speed trains. As a long-term supplier to Alstom, Bombardier, NOMA specialises in the production of front ends for the iconic SNCF TGV network. Based in a 34,000Sqm production facility in Normandy, NOMA's capabilities include Open Contact Moulding, Resin Transfer Moulding, vacuum infusion, press moulding, painting and systems integration and assembly.

SPAIN

TEMVAC
BFG's Spanish operation TEMVAC was formed in 2011 to specialise in the design and production of leading-edge vacuum sanitary systems, fully integrated toilet cabins and wastewater and fresh water tanks.

Turnkey service, designed to endure
Working closely with BFG's specialists around the globe, TEMVAC offers a complete turnkey service in-house, from design to testing, focusing on adaptability and cost effectiveness. Based in facility near Barcelona, the business has developed extensive test rigs for assessing vacuum sanitary systems and performing endurance and reliability tests to ensure the highest levels of performance.

ASIA

CHINA

Formed in 2006 to drive its expansion in the booming Chinese and Asian markets, BFG China has a workforce of 314 employees including 10 Quality Engineers and a dedicated design team 14 strong, based in a 23,000Sqm site in the Helong Economic Development Zone near Changchun City.

Today, the products fabricated by BFG in China include toilet modules and FRP interiors for China's High Speed Rail services as well as FRP interiors for Spanish and Australian railways, for clients including Alstom and Changchun Railway Vehicles. BFG China also produces bus shelters for clients in Germany and France and automotive components for trucks, buses and fire engines.

Committed to innovation
BFG China uses leading edge technology to continually enhance its quality standards and efficiency. As well as operating company-wide bilingual Enterprise Resource Management, it introduced an electronic archive system for knowledge management in 2011, and in 2015 pioneered use of a mobile app to optimise enterprise and project management.

INDIA

Since 2009, BFG India has been the region's foremost manufacturer of FRP composite products and structures, serving international rail and wind energy customers as well a range of leading domestic clients.

BFG India boasts a highly skilled workforce of 300 and a 6,000Sqm production facility with state-of-the-art equipment including a dedicated gel coat booth with extraction system; an extensive painting facility with a pressurised spray chamber, flash-off zones and curing chambers; an overhead crane and gantry for managing large parts and cold storage for phenolic resins.

Better connections
Based in a Special Economic Zone near the southern city of Chennai, BFG India is connected for business, with an extensive regional road network and an international seaport 60km away.

PHILIPPINES

Since 1991, when BFG established its first manufacturing facility in the Philippines – initially to serve Japanese demand for advanced FRP products – the business has grown rapidly. With three additional plants opened across the following 17 years, in 2000, 2005 and 2008 respectively, BFG Philippines now serves a diversity of sectors, with capacity for large-scale production for transportation projects as far afield as Canada and Australia.

Today, in the Phillipines hub, with factories covering a total area of 27,000Sqm, has a highly trained English-speaking workforce of 530 people from four nationalities, and supplies a wide range of world class composites, including wind generator nacelles and housings, auto parts, industrial products and railway interiors.

Export focus
BFG Philippines is based in Bataan's Freeport area, near the city of Mariveles – a strategic location with highly efficient international export connections. It is perfectly located to serve fast-growing markets across the Far East, China and Australasia.

AMERICAS

BRAZIL

Since 2012, BFG Brazil has grown in scope and scale, with over 150 people at its dedicated 5,000Sqm FRP production facility.

As well as producing key composite parts for the transport sector, BFG Brazil is fast becoming a leading supplier of composites to the Brazilian wind energy industry, including advanced components such as integrated nacelles and spinners.

Built for global trade
Today, BFG Brazil is open for business for clients worldwide. Based at an industrial site in Joinville, to the south of Curitiba in the state of Santa Catarina, it is ideally located close to three international airports and five seaports.

USA

Originally established as a joint venture company, BFG USA became a full subsidiary of BFG group in 2013. Today, the business is dedicated to providing a one-stop composite solution, from design and engineering through to environmentally-friendly manufacturing, using cutting-edge technology to achieve the highest standards of quality and precision.

Originally based in a 3500Sqm facility in the city of Plattsburg in upstate New York, the 10-strong team at BFG USA fabricate advanced composites for the transportation market in the Americas, including components for buses, train interiors and train front-ends. It also serves the leisure sector, producing complex parts for water parks.

Specialist processes
The production facility at BFG USA is fitted with specialist equipment for a comprehensive range of composite production processes, including glass cutting and kitting, moulding, curing, multi-colour gel coating, resin batching and blending and gelcoat colour blending. The factory will shift to Tennessee during 2017.

COMPOSITES DEFINED

What are composites?
Why choose composites for your next project?

Composites defined

What are composites?
Why choose composites for your next project?

Composites are engineered products made from two or more different materials, resulting in a new material that surpasses the qualities and performance of its components. While the construction industry draws heavily on the benefits of many different types of composites – such as plywood and reinforced concrete – the most common engineered commercial composite is Fibre Reinforced Polymer or Fibre Reinforced Plastic (FRP), a subgroup of which is also known as Glass Fibre Reinforced Plastic (GRP or GFRP). In this book we'll refer to the broader term of FRP.

At its simplest, FRP is a composite of glass fibre based fabric embedded in a polymeric resin body or matrix. The fibre provides strength and stiffness characteristics to the composite, while the polymeric matrix provides corrosion, weather resistance, and thermal and electrical insulation characteristics.

When the fibre fabric and resin are brought together in a mould (or 'tool'), which can be open or enclosed, and then resin is set (or 'cured'), the result is a lightweight, robust product capable of taking on a limitless variety of forms, depending on the shape of the mould.

There are several types of fibres available including glass, carbon, Kevlar (a type of nylon), natural fibres, basalt and even steel, all of which are used as reinforcements. These are combined with a range of different polymers including Epoxies, Polyester and Vinyl Ester, Polypropylene, Polyamide (nylon) and phenolics. It is important to note that unlike steel or aluminium, FRP composite is not a single material but a family of materials.

Design aesthetics

FRP structures can take on almost any surface form: flat, double curved, fluted, ribbed and contoured into a whole variety of shapes, with surfaces moulded to an extensive range of colours textures and finishes, from smooth to stone, glossy to matt, pebbly and even metallic like chrome and gold. At BFG, we achieve a variety of simulated finishes with uncanny similarity to natural finishes.

High strength-to-weight

Given the many possible permutations of different fibres and resins, FRP products can provide a range of strength and stiffness to cater to applications as diverse as planter boxes for use at home, all the way to fully composite aircraft. FRP structures achieve the required strength at much lower weight compared to concrete, steel or aluminium - as low as 25-30% of the weight of steel or 30-40% of RCC.

Durability and low maintenance

All the resins used in the production of FRP are corrosion-free materials, delivering significantly better performance than corrosion protected metals and concrete. Composite structures do not corrode or rust and have a long lifespan with little or no maintenance – early FRP pipes, boats and underground tanks are still in use after more than 50 years in service. Structures built by BFG are in excellent condition and performing as new after 35 years in service.

Parts consolidation

Monolothic composite parts can replace complex assemblies of multiple parts normally produced from traditional materials. As a result, there are fewer chances of joint failures and leakages, with lower maintenance, when complex shapes are moulded as monolithic panels rather than an assemblage of smaller panels. This is not possible with metallic or concrete materials without incurring high costs in tooling.

FRP structures can take on almost any surface form: flat, double curved, fluted, ribbed and contoured into a whole variety of shapes, with surfaces moulded to an extensive range of colours textures and finishes,

B F G

Light transmission

FRP can be moulded using resins that give translucence to skin surfaces; a unique property among structural materials.

Reproducibility of shapes

FRP components are moulded from durable tools, making the parts identical. When moulded to mimic an existing shape – such as from a historic building – FRP faithfully reproduces the original.

Dimensional stability

In common with other leading structural materials, properly designed composites can maintain their shape and functionality under designed structural and environmental loads.

High dielectric strength

FPR composite has excellent electrical insulation properties, making it ideal in applications where electric current can come in contact with part of the product, with FRP working as an insulator for user safety.

Heat insulation

FRP is a poor conductor of heat and excels in applications including window trims, door skins, roofing and exterior cladding.

Elevated temperature service

Composite parts with suitably blended polymer and additives deliver excellent performance in high temperature applications.

Fire resistance

BFG's FRP materials have been qualified to meet the world's highest flame, smoke and toxicity standards, even in high footfall locations including sports stadia and transport hubs. The IBC and NFPA building codes provide clear guidelines and performance information for FRP in construction applications.

Long term cost savings

Properly engineered composite solutions can enable facility owners to achieve real-world savings in total installed cost as a result of lower foundation costs and faster project installation, helping reduce equipment and management overheads. In addition to these upfront cost benefits, with virtually no maintenance costs over time, FRP solutions can substantially reduce total life cycle cost.

Ease of installation and removal

Lightweight composites delivered in pre-moulded kit form are smoother and quicker to install and require simpler and less complex structural supports than the traditional alternatives. As panelling size is limited only by transportation, the number of joints can be substantially reduced, enabling quicker and simpler assembly.

LEED credit contribution

Thanks to their special properties, FRP composites are friendly to the environment. They enable low maintenance, offer lightweight durability, use fewer materials, last longer and offer almost infinite flexibility in design. Composites help minimise overall energy consumption during construction and produce a lower carbon footprint and cumulative energy requirement compared with conventional building materials.

FRP materials can make a positive impact to securing LEED certification:

- **Low resource requirement.** Lightweight FRP materials have low ecological and carbon footprints. The overall materials and resource requirement in FRP production is significantly lower than for traditional building materials.

Thanks to their special properties, FRP composites are friendly to the environment. They enable low maintenance, offer lightweight durability, use fewer materials, last longer and offer almost infinite flexibility in design.


B F

- **Low energy.** FRP uses less energy in the production process - from the raw materials stage all the way to product delivery.

- **Long product life cycle.** FRP is a durable, low maintenance, long lasting material, with a long life cycle as determined by Life Cycle Assessment (LCA) studies. This reduces the need for replacement, repair and repainting over time.

- **Natural, non-depleting materials.** Glass, the main ingredient of the fibreglass reinforcement in FRP, is made from sand which is a natural, non-depleting resource.

- **Resistance to damage.** FRP materials are resistant to damage by moisture, weather conditions and salinity, as well as by termites and other insects, which reduces the need for toxic pesticides.

Architectural applications

Today, you'll find versatile FRP at work in a diversity of high profile applications worldwide, including:

- Structural long span roof systems and roof finishes
- Building facades and claddings
- Interior decorative panels and finishes
- Bridge structures and decks
- External shade structures
- Lightweight suspended ceilings and cowlings
- Structural domes
- Formwork and waffle moulds
- Statues and monuments
- Sculptures
- Shingles
- Furniture

Discover more about composites

To help you navigate the world of composites, we've included a more detailed information resource at the back of this book. You'll find more from page 153 onwards.


B F

Shaping the future

Look up and you'll see the future. For the world's greatest architects, it's ever higher. Ever more curvaceous, airy and light. More beautiful and reflective of natural forms. More human, intelligent and responsive. And much more challenging - embodying ever greater ambition.

Thinking without limits means overcoming technical barriers. So as we reach the limitations of traditional building materials, we need to ask not just 'what's next', but how to make it possible.

At BFG we see a world of infinite possibilities. And a future enabled with composites. Where buildings are made better, lighter, more efficient, more durable, more creative. A world where we use the expertise from four decades of composite innovation to design a brighter, more beautiful tomorrow.

In the years to come, we will continue to pioneer, leading the field in the development of new structures that add real value - and enabling powerful ideas to take shape.

Explore our world.

SURFACE
CREATING EXTRAORDINARY SHAPES AND SKINS IN THREE DIMENSIONS

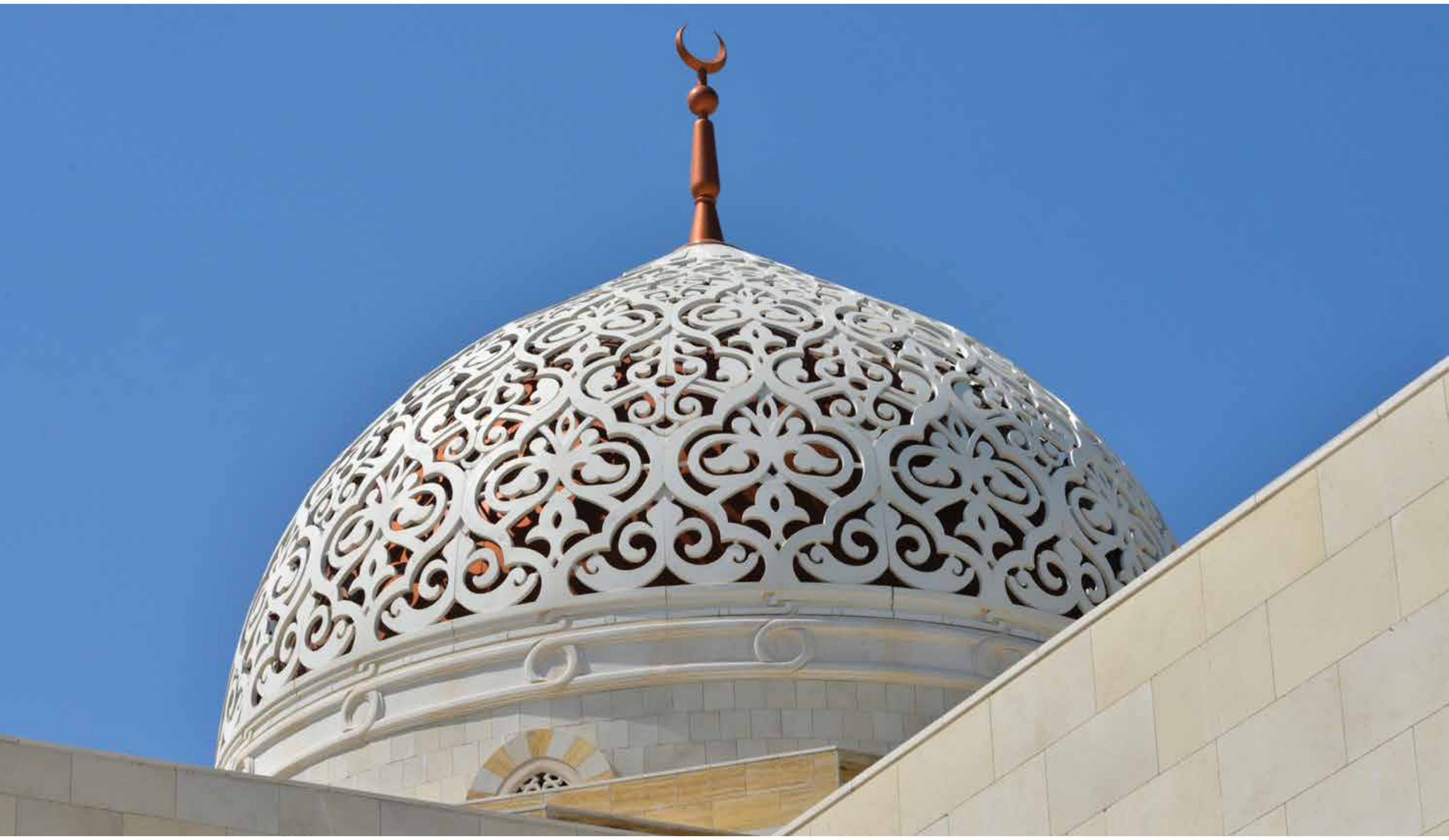
Why should the structures of the future be held back by the restrictions of old-fashioned building designs – and by outdated thinking limited by yesterday's materials? Instead, set your imagination free. With advanced composites from BFG, you can see the world in three dimensions. Touch new textures and finishes. And build or wrap your structure in audacious shapes, skins and claddings.

As we reach further and aim higher, there's no limit to how the composite surfaces of today and tomorrow – internal and external – can be moulded, shaped and finished on a grand scale. Enabling a bold new wave of expressive designs and aesthetics, BFG's surfaces make a powerful statement, create new focal points and transform buildings into landmarks.

DIYAR AL MUHARAQ MOSQUE, BAHRAIN

Ornamental dome
2013

Project: Ornamental dome **Location:** Diyar Al Muharaq, Bahrain
Client: Diyar Investment **Architect:** Gulf House Engineering **Engineering Consultant:** Gulf House Engineering
Main Contractor: MECC **Handover:** 2013



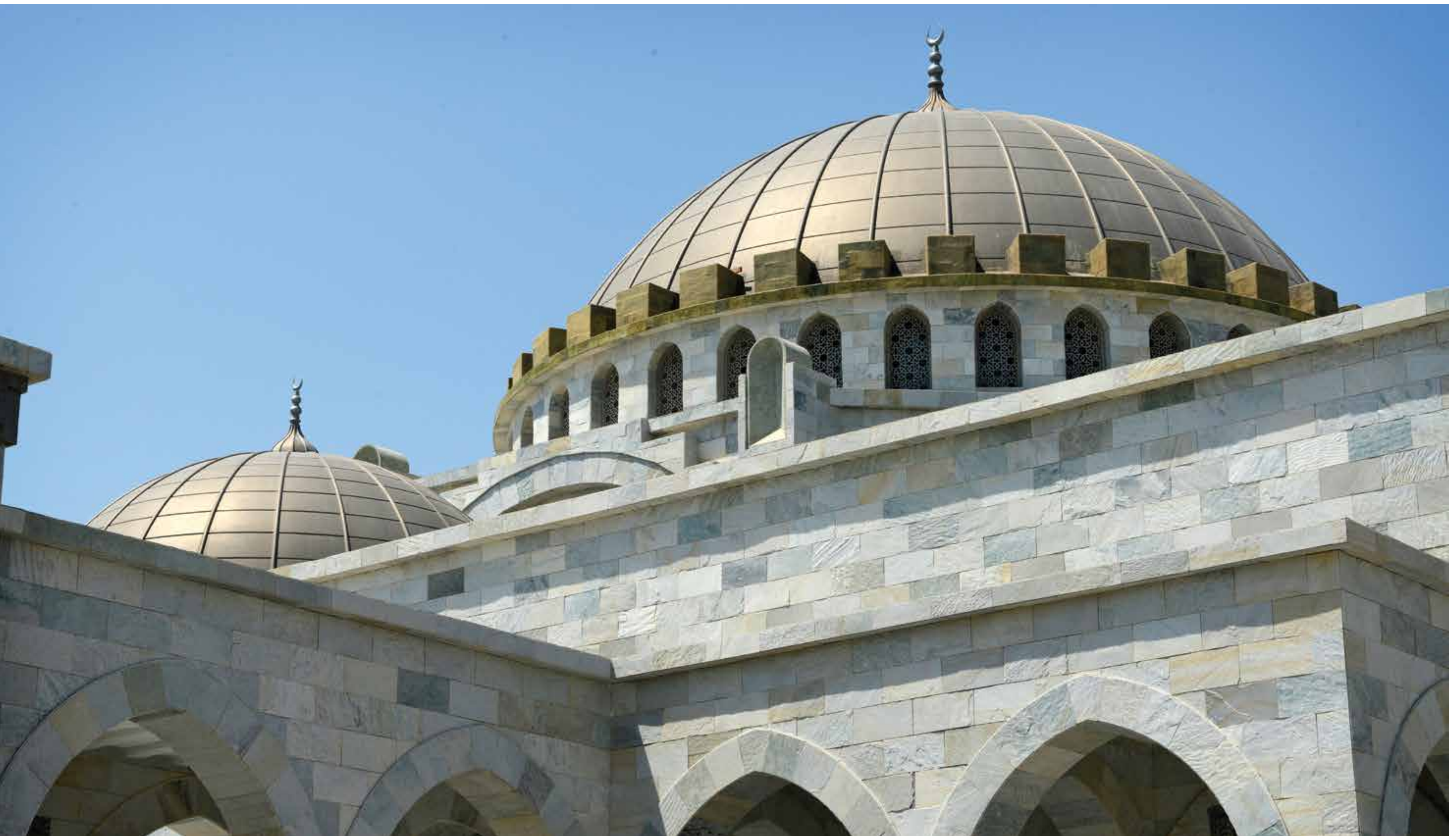
Envisioned as the unifying core of the community, Bahrain's new Grand Mosque is strategically located on a prominent 19,000m2 site on the island of Muharraq. Distinguished by its unique architecture and rich Arabian Islamic design, the mosque is regional architectural highlight, featuring a central three-layer composite dome illustrated with ornamental elements, and a stunning 45 metre minaret.

Designed to work together in a series of intricate layers, BFG built each of the three different FRP domes from 12 separate panels. The fabrication team at BFG in Bahrain used a traditional contact moulding process and rubber moulds to shape the domes' impressive 3D geometry. Installed in sequence on site by BFG, the inner dome was designed with a smooth gelcoat, the centre dome boasts a high gloss external finish, and the third dome, seen on the exterior, has a stunning see-through design with an inlaid Islamic pattern. Built to last for decades, the domes can withstand winds of up to 120km/h.

RASHID AL ZAYANI MOSQUE, BAHRAIN

Composite domes
2014

Project: Composite domes **Location:** Rashid Al Zayani Mosque, Qalali, Bahrain
Client: Al Zayani Investment **Architect:** Gulf House Engineering **Engineering Consultant:** Gulf House Engineering
Main Contractor: Skyline Contracting **Handover:** 2014



Bahrain's imposing new Rashid Al Zayani mosque takes a traditional form and applies it on a grand scale. Sitting on a 2810m2 site, the mosque has capacity for up to 1230 worshippers. Topped by a magnificent 16 metre diameter composite dome, beautifully finished in bronze, it also features a main prayer hall, prayer place for women, a courtyard, a Majlis for special occasions and six classrooms. The mosque is envisaged as a community hub with shops and apartments included in the masterplan.

BFG was selected to design, manufacture, and install a series of structural domes for the project – from the landmark 16 metre dome to a secondary eight metre dome and a suite of five eight metre diameter half domes arranged in sequence around the base of the main structure. Fabricated using a hand lamination process, the domes are gelcoated FRP with a double sided finish, the outer side painted with a lustrous, UV-resistant coating.

Able to withstand a wind load of up to 120km/h, the finished domes are extremely fire retardant and comply with ASTM84, Class A.

UNIVERSITY OF AMSTERDAM, NETHERLANDS

External and internal decorative facades
2007

Project: External and internal decorative cladding **Location:** University of Amsterdam, Amsterdam Science Park, Netherlands
Client: Sorba Projects, Amsterdam **Architect:** Architecture Studio HH, MVSA, Rudy Uytenhaak Architectenbureau
Engineering Consultants: Rudy Uytenhaak / MVSA Architects **Main Contractor:** Sorba **Handover:** 2007

To give the development of the University of Amsterdam's Faculty of Science (FNWI) on the new Amsterdam Science Park real stand-out quality, the architects devised a unique interior and exterior design concept. Thousands of FRP composite cladding panels would bear a 3D effect showing countless circles in relief, combining to form a pixelated pattern.

Realising the architect's vision, BFG engineered and delivered 4774m2 of moulded composite panels, each carrying a raised pattern of black burls which are an abstract representation of microscopic skin cells. In all, 2970 high gloss composite panels measuring 2 x 1.2m were created, each one light, weather resistant, easy to install - and delivering high levels fire retardance.

Fabricated using RTM moulding, the two colour pixel design was manufactured as an integral part of the cladding, with a special process of dual gelcoating on the pixelated areas, meaning that no additional painting was required.


12:06

Cultural fusion

KATARA PLAZA, QATAR

Structural domes
2015/16

Project: Structural domes **Location:** Katara Plaza, Katara, Doha, Qatar **Client:** Katara **Architect:** KEO **Engineering Consultants:** KEO **Main Contractor:** Imperial Trading and Contracting Company **Handover:** 2015/16

As a key component of the new Katara cultural quarter and leisure development in Doha, Katara Plaza is set to become one of the region's premier shopping destinations. Built on a coastal site overlooking The Pearl Qatar, it offers an 'open air mall' feel with high-end boutiques, departmental stores, office space, serviced apartments and a unique mall for children - built over two sprawling levels of secure underground parking.

The 35,000m2 Katara Plaza development promises its visitors a distinctly cultural experience as it fuses ultra-modern facilities with classical architectural influences and traditional Middle Eastern heritage. To reflect the coming together of ancient and modern, BFG was commissioned to engineer, build and supervise the installation of a pair of structural composite domes, each 14.5 metres in diameter.

Fabricated in 16 panels each using traditional tooling and a hand lamination process, the FRP domes were both finished in a translucent gelcoat ready for cladding in distinctive copper sheeting.
The Katara domes have a Class 1 fire rating and, to offer additional protection from coastal gales, are designed to withstand a wind load of up to 160km/h.

STRUCTURE

INNOVATIVE COMPOSITE FORMS THAT REACH FURTHER

Reach further and you'll discover that small is not always beautiful. 21st century structures call for light, space, scale and height, placing fresh demands on materials and fabrication. So it's no surprise that lighter, stronger, aesthetically pleasing composites are the heart and soul of the world's most imaginative new buildings.

BFG's innovative composite engineering creates 3D shapes on an impressive scale – enabling far larger parts capable of spanning greater distances with fewer joint lines, all with a choice of pioneering textures and finishes. Now, the only limitation is your creativity. Imagine it and we will create it.

THE BAHRAIN BAYAN SCHOOL, BAHRAIN

Exterior facade and domes
1982

Project: Exterior facade and domes **Location:** Bahrain Bayan School, Isa Town, Bahrain
Client: Al Bayan School **Architect:** Al Ansari Engineering
Engineering Consultants: Al Ansari Engineering **Handover:** 1982

The Bahrain Bayan School is the kingdom's first bilingual national school. Established in 1982 on a dedicated educational campus in Isa Town, it now boasts world class facilities including a theatre, running track and robotics lab. Over 30 years ago, BFG was tasked with transforming the school's ordinary concrete facade to reflect traditional Islamic architecture - and to top the building with a landmark dome. Over three decades later, the composite work remains in pristine condition.

To clad the exterior and build a new covered walkway for students – creating an external corridor around the building – BFG fabricated and installed a sequence of lightweight composite FRP sandwich panels in a Middle Eastern design, built using traditional hand tooling. Robust, fire retardant and impact resistant, the composite cladding was installed without disrupting the school schedule.

The self-supporting panels were fixed to concrete plinth with anchor bolts and connected to the building using single skin arched roof panels. No supporting steel was needed to complete the work. The panels were produced with a gelcoated finish which has required no refurbishment since installation, delivering maintenance-free performance for 34 years... and counting.

MANILA NINOY AQUINO INT. AIRPORT, PHILIPPINES

Entrance canopy
2002

Project: Entrance canopy **Location:** Manila Ninoy Aquino International Airport, Philippines
Client: Manila Airport **Architect:** Skidmore, Owings and Merrill (SOM)
Main Contractor: Tekenka Corporation **Handover:** 2002

Serving over 30 million passengers a year, Ninoy Aquino International Airport is the gateway to the Filipino capital. However, its location in the Pacific storm zone means it can face winds in excess of 150km/h, driven in across Manila Bay. When the airport needed a new canopy to cover the long passenger drop-off area outside the terminal, it turned to BFG for a weather-proof composite alternative to replace the previous aluminium structure which had been blown away.

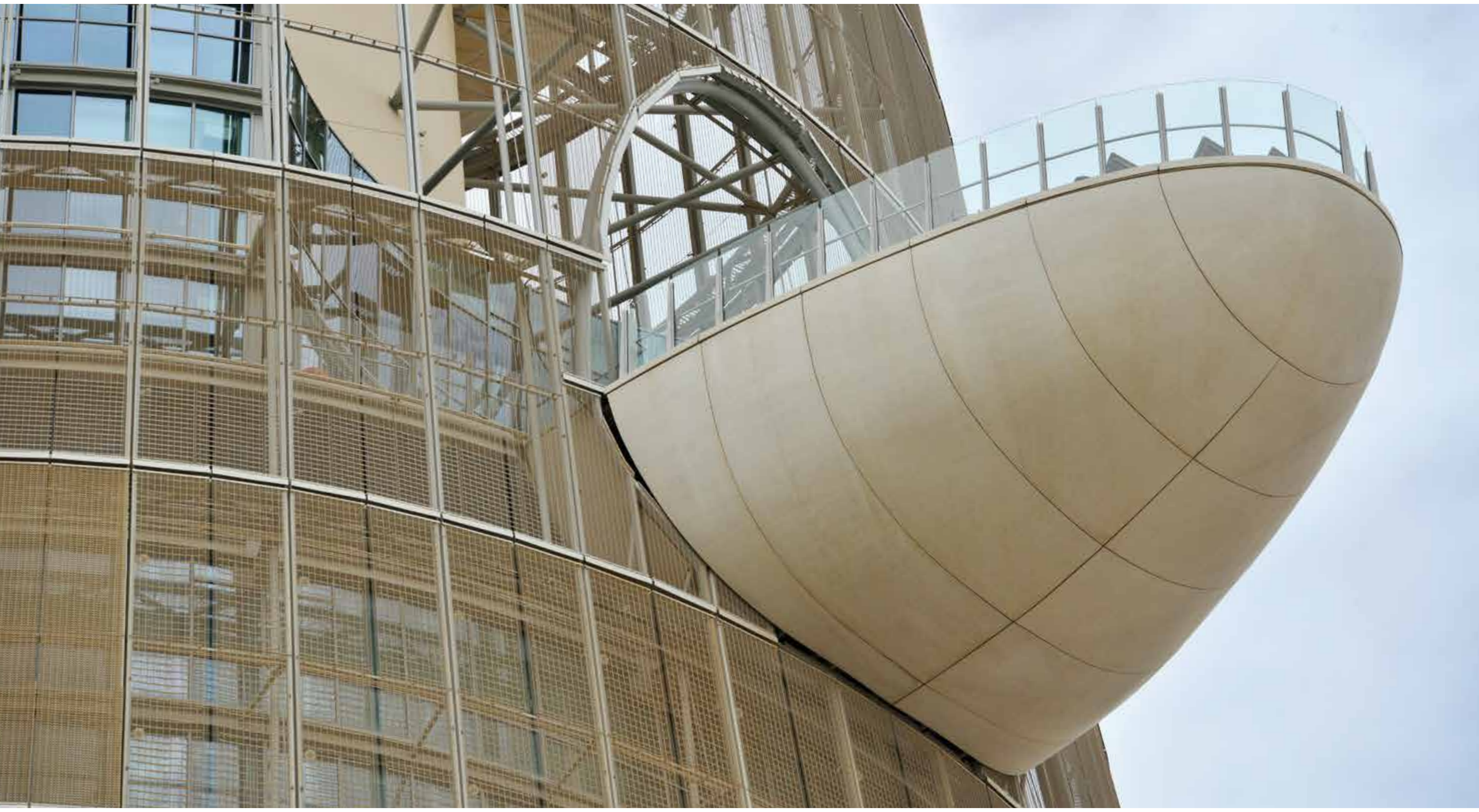
Delivering a sustainable, maintenance-free solution that would stand the test of time and cope with the elements, BFG designed, manufactured and installed a perfect sequence of arched FRP ceiling panels. To fit the existing steel frame – with only central structural support available on a sweeping parabolic arch – the project required a completely bespoke solution to account for variations in the shape of each panel.

To bear the brunt of future storms, the panels – each approximately 1.5m by 4m – were designed with a cantilevered overhang, resulting in very high uplift deflections. The new design, allied with robust composite engineering, has brought real dividends. So far, the canopy has withstood the effects of typhoons for 15 years.

ASPIRE TOWER, QATAR

Composite panelling
2007

Project: Composite panelling **Location:** Aspire Tower, Al Waab, Doha, Qatar
Client: Khalifa Sport City Development Committee **Architect:** Hadi Simaan, AREP
Engineering Consultants: Arup **Facade Design:** Midmac / Six Construct **Handover:** 2007



To create a stunning centrepiece for the 15th Asian Games in 2006, architect Hadi Simaan envisaged a beautifully curvaceous 300 metre skyscraper in the shape of a torch, topped by a symbolic flame. Ten years later, Aspire Tower – also known as The Torch Doha – forms the hub of Doha Sports City and remains the tallest structure in Qatar. Among the tower's many features are health clubs, a five-star hotel across 17 floors, a three storey sports museum, a revolving restaurant and an observation deck, made possible with advanced, lightweight composite panelling from BFG.

Working in close partnership with the lead contractors, BFG developed high performance decorative panelling to clad three storeys of the tower's soffit, in addition to its elliptical swimming pool. Fabricated using conventional hand-tooling and contact moulded, the single skin gel coated FRP panels are fire retardant to Class 1 BS476 Part 7.

To enable the hotel's signature swimming pool to extend 12 metres out from the building, it cantilevers off the central core, as a 300 tonne concrete box. BFG's parabolic matt-finished panels were painstakingly attached to the pool's exterior structure at a height of 80 metres above ground level.

LIFESPAN

ENDURING SOLUTIONS
FOR EVEN THE HARSHEST OF CLIMATES

In structures designed to last generations, durability matters. Yet, over the years, a harsh environment always takes its toll and imposes its cost. Metals, wood and concrete all show the inevitable signs of environmental degradation, corrosion or wear-and-tear.

Extending a building's usable life with long lasting, hard wearing, good looking composites can make your investment go further, and keep maintenance time and costs to a minimum. Whether it's in the harsh and unforgiving climate of the Middle East, Asia's storm season, Europe's most unpredictable conditions or the wide temperature variations of the Americas, BFG's composite structures have proven resilient, whatever the weather.

Fusing ancient and modern

PORTO ARABIA, QATAR

Composite domes
2009

Project: Composite domes **Location:** Porto Arabia, The Pearl, Doha, Qatar
Client: CAT International Qatar **Architect:** CallisonRTKL **Engineering Consultant:** Dar Alhandasah
Main Contractor: Integra Doha **Handover:** 2009

Rising out of the warm waters of the Arabian Gulf, The Pearl - Qatar was conceived as MENA's latest luxury real estate destination, purpose built on an artificial island costing $2.5 billion. As the first phase of The Pearl, Porto Arabia is designed as the 'Riviera of the Middle East', fusing European and Arabian style cues and featuring a waterfront boardwalk, retail, restaurants, housing and entertainment.

BFG was tasked with delivering the architect's vision of an Arabian Riviera, by developing a huge variety of traditional domes which would help convey the project's authentic local roots.

In all, BFG designed, engineered and installed 37 FRP composite domes across the Porto Arabia site, each of a different design, and in a dazzling variety of surface finishes. The entrance dome alone is 19 metres in diameter and topped with a distinctive copper cladding.

Fabricated by hand at BFG in single skin structural FRP segments, the domes are textured and finished to maintain their pristine appearance for decades to come, without the need for maintenance – even with harsh summer sun and coastal winds.

Tropical centrepiece

AL ISTIGHFAR MOSQUE, SINGAPORE

Dome and skirting
1999

Project: Dome and skirting **Location:** Al-Istighfar Mosque, Pasir Ris, Singapore City
Client: Al-Istighfar Mosque, Singapore
Main Contractor: Pee Lee Construction **Handover:** 1999

Taking its inspiration from the legendary 'Blue Mosque' in Istanbul, Singapore's Al-Istighfar Mosque has been in daily use since the turn of the millennium. With room for a congregation of 3300, the 2500m2 mosque embodies design elements needed to cope with life in the tropics, including wide roof eaves, high ceilings with effective cross-ventilation and sun shade mouldings above the windows, fusing them with classic motifs from Islamic architecture.

To deliver on the architect's landmark vision, BFG fabricated and installed the mosque's centrepiece – a 12 metre diameter onion shaped composite dome, with window panels and composite skirting below.

Conventionally tooled and contact moulded in 12 segmented FRP panels using fire retardant resin and sealed with leak-proof joints, the dome was covered with a special UV coating to guarantee that its colour finish would last for over a decade.

AL FATEH GRAND MOSQUE, BAHRAIN

Composite dome
1986

Project: Composite dome **Location:** Al Fateh Grand Mosque, Manama, Bahrain
Client: Al Fateh Grand Mosque **Architect:** Dar Al Handasah
Engineering Consultants: Dar Al Handasah **Main Contractor:** Consolidated Contractors Company **Handover:** 1986

Al-Fateh Grand Mosque in Bahrain's capital Manama is one of the largest in the world, encompassing 6,500m2, with capacity for over 7,000 worshippers. In the mid 1980s, BFG was tasked with developing the mosque's signature dome on a scale that has yet to be matched. Thirty years on, it remains in pristine condition.

The mosque's sheer scale gave it immediate landmark status, with no fewer than four domes and two minarets. Its traditional centrepiece was awe-inspiring: the architect's vision called for a huge central dome with a 26 metre diameter.

Bahrain's Grand Mosque was not without its challenges. Built near the sea, the soft soil meant deep piles were needed. A heavy chandelier to be suspended below the main dome added to the structural complexity of the project. And technical solutions had to be fast-tracked in a short project window to meet the contractor's timeline.

BFG's lightweight composite dome structure totaled approximately 30 tonnes in weight – a fraction of the concrete alternative – eliminating the need for the heaviest foundations.
The dome was fabricated in 24 external segments, complete with insulation, and fixed to a lightweight aluminum space frame, which also secured a series of 293 internal decorative composite panels made in a range of colours with design elements in relief.

Below the internal dome, a beautiful ring of 3 metre high calligraphy covers the circumference of the ring beam, beneath which four stone arches reach down to the floor to form the main square.

Painstakingly hand made utilizing conventional plywood and MDF for the tooling, the dome's single skin FRP panels were produced locally in Bahrain, and designed to be fire retardant to Class 1 BS476 Part 6. BFG was able to achieve a simulated cement texture on the dome segments, designed perfectly to match the matt, sandy exterior of the main building below.

On site, our installation team worked to build the dome in less than a month, a real time saving over concrete. Three decades later, it remains in pristine condition – despite its coastal location, with high airborne salinity and high corrosion potential.

PROTECTION

PIONEERING ADVANCED MATERIALS TO SHIELD AND SAFEGUARD

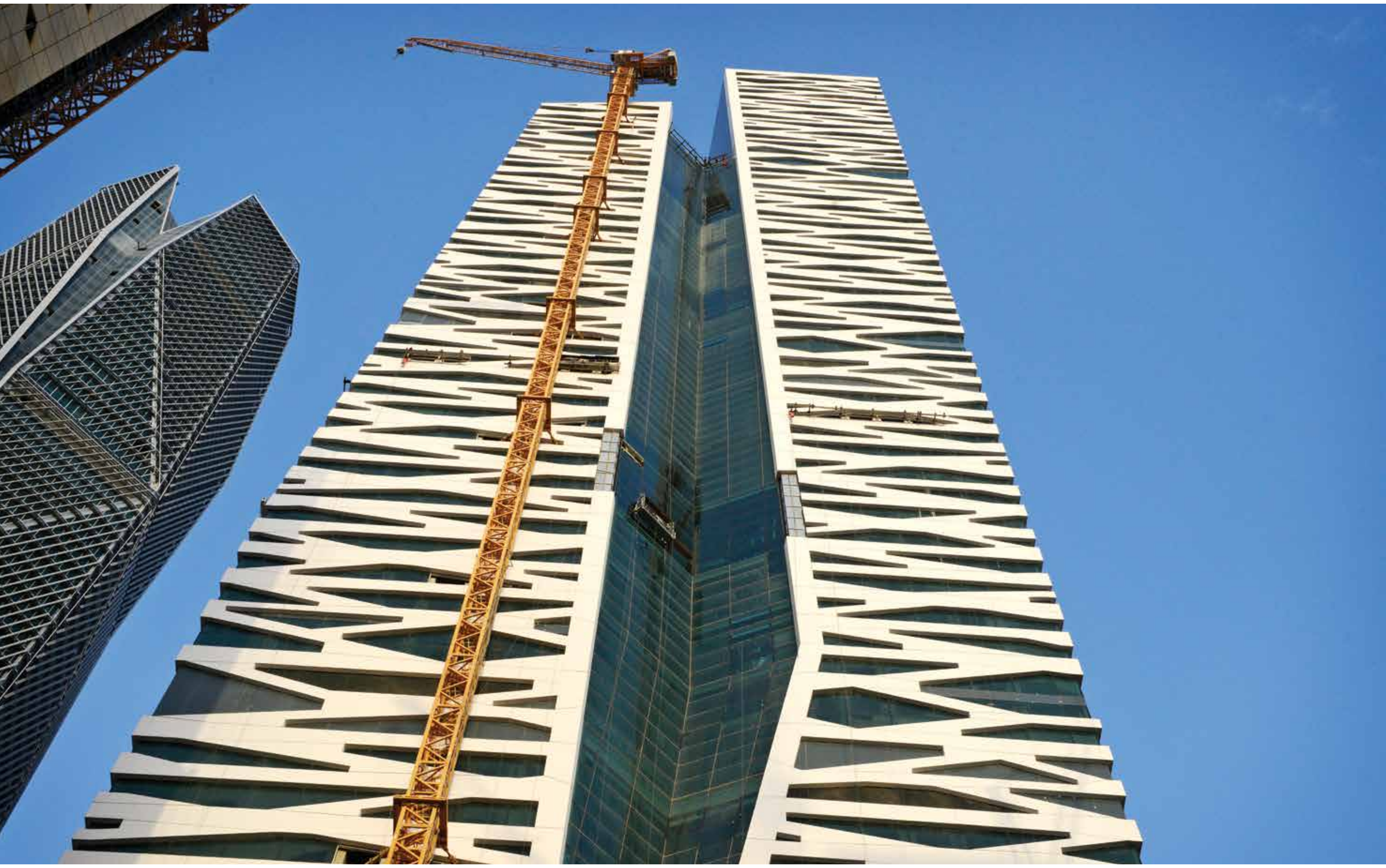
Advanced materials have a critical role to play in making the modern world safer. As safety becomes ever more important – from transport systems to large scale public events – regulation becomes ever tighter. FRP composites can be fabricated to be self-extinguishing and fire retardant from the very core, with glass fibre reinforcement material that not only adds strength and resilience, but has minimal flammability.

BFG has extensive experience in working in areas such as transportation, with the most demanding thresholds for fire and smoke compliance, and the most stringent public safety standards. Working hand in hand with customers and partners, our pioneering composite materials have been developed to specifically limit the source and spread of fire.

KAFD WORLD TRADE CENTRE, SAUDI ARABIA

External cladding
2015

Project: External cladding **Location:** World Trade Centre, King Abdullah Financial District, Riyadh, Saudi Arabia
Client: Al Ra'idah Investment Company **Architect:** Gensler **Engineering Consultants:** BuroHappold Engineering
Facade Design: Permasteelisa Gartner Middle East (PGME) **Main Contractor:** Saudi Binladin Group **Handover:** 2015

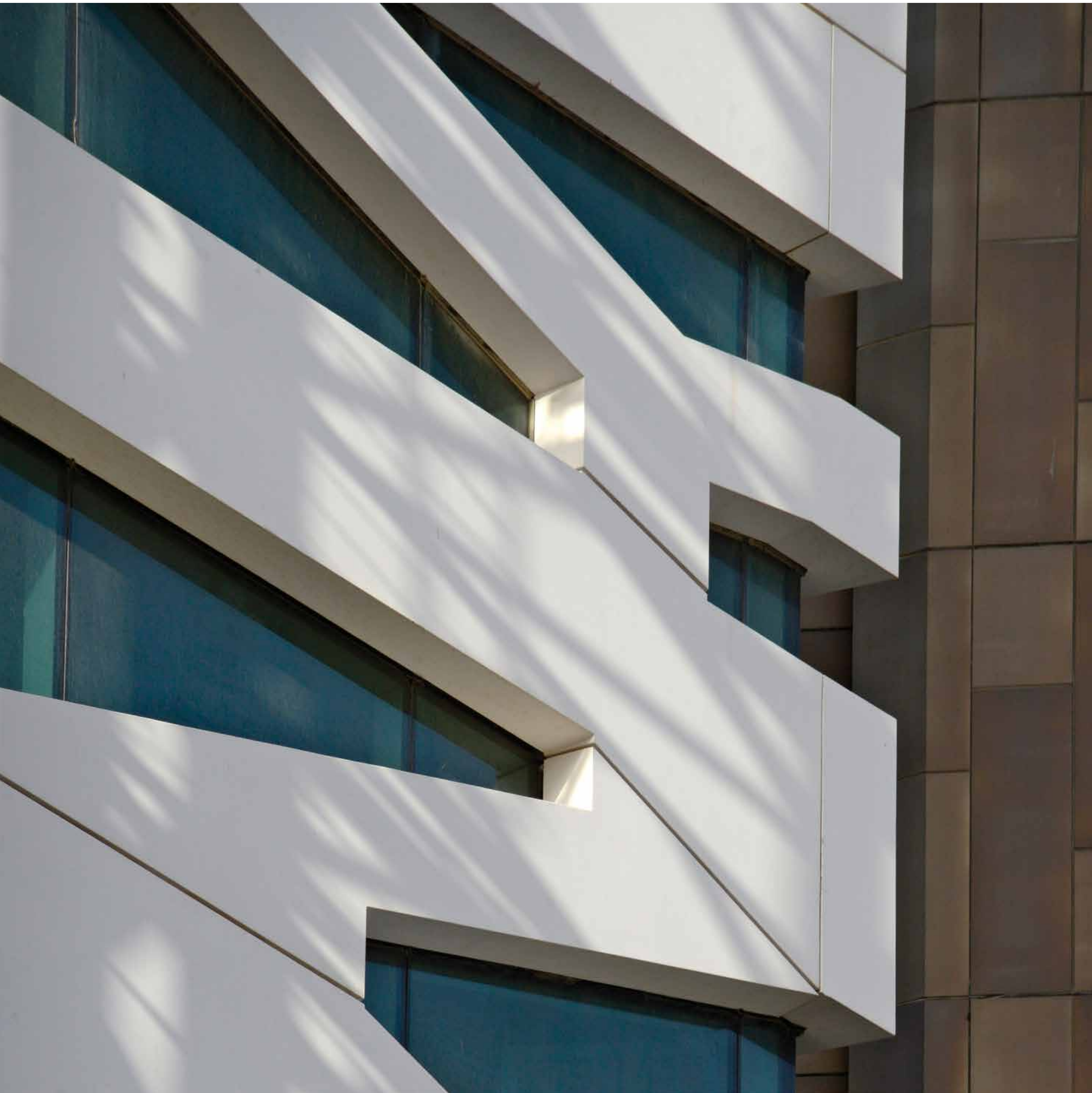


King Abdullah Financial District (KAFD) is Riyadh's state-of-the-art CBD. Future-focused, outward looking and bristling with high technology, the district will become home to the country's key financial institutions. Located on a prominent corner site, the new 303 metre World Trade Centre takes the form of a 'vertical wadi'. Visible from miles away, it is clad in a sequence of linear composite panels, to stunning effect. BFG's all-composite solution brought to life Gensler's vision of an intricate panel design, with all the benefits of robust, lightweight construction and faster installation.

Following comprehensive engineering analysis, structural design and performance testing based on the ASTM E330 standard – which measures wind load on exterior surface elements – BFG fabricated 3180 lightweight composite cladding panels capable of resisting sand-laden loads carried in high winds some 300 metres above ground level.

In all, BFG oversaw complete engineering, fabrication and delivery of 47,000m2 of decorative composite panelling for the exterior of the 63 floor tower. The panels were constructed from an FRP outer surface with a foam core, including aluminium structural struts, rockwool insulation and all the necessary components for an aluminium attachment system. The cladding met stringent fire and smoke criteria and is compliant with the International Building Code (IBC) to meet ASTM E 84 Class A and NFPA 285.

Producing the uniquely complex design – in which each panel was a different size and shape – required advanced tooling and manufacturing with the use of laser projection to construct the moulds, to help meet the client's stringent fabrication tolerances. These precise dimensional controls enabled perfect assembly when the panels were mounted at site.



Subterranean safety

LONDON UNDERGROUND, UNITED KINGDOM

Internal cladding
2008

Project: Internal CMS cladding **Location:** Holborn Station, London, UK
Client: London Underground Ltd / Transport for London **Engineering Consultants:** QinetiQ
Main Contractor: QinetiQ **Handover:** 2008

Holborn station in Central London is one of the British capital's key transport interchanges. Serving 36 million passengers a year, it connects the Central and Piccadilly lines on the London Underground network. At 110 years old, it is one of a number of deep level stations which require regular upgrade and maintenance to ensure the highest levels of safety.

To cover and protect the station's vital cable management system and upgrade the internal tunnel cladding along underground platforms and walkways, lead consultant QinetiQ tasked BFG to develop and fit a lightweight solution using a specially formulated fireproof composite material.

In addition to being graffiti resistant, BFG's FRP composite panels were required to meet the world's most stringent flammability, flame spread, smoke toxicity and smoke density standards, complying with London Underground's specifications – Section 12 of the UK's Fire Precautions Regulations – and tested to BS 6853 standard.

CNC tooled to achieve high degree of profile accuracy, then contact moulded and gel coated to match the colour and texture of the existing surroundings, the composite panels are also RF transparent, unlike metal cladding which would have interfered with the station's communications system.


British Museum
BORN
Way out
HOLBORN
NO EXIT
Way out
Central line
1 Heathrow Terminals 123&5 1 min
2 Heathrow Terminals 4&123 3 mins
3 Northfields 5 mins
17:11:02
EXPOSURE
THE MUSICAL
Exit only in emergency

LOAD

BEAUTIFUL STRUCTURES WITH BUILT-IN STRENGTH

Achieving world class strength-to-weight performance once meant achieving a trade-off or following the path of least resistance. No longer. Today's FRP is one of the world's most robust commercial building materials. Operating at a much higher strength-to-weight ratio than concrete, steel or aluminium, it places lighter loads on substructures and foundations, providing strength without substantial increases in weight.

Modern composites can be custom designed to provide your choice of mechanical properties, including tensile, flexural, impact and compressive strengths, under the most demanding of load conditions. Which is why you'll find BFG's revolutionary lightweight FRP long span roofs, claddings, domes, formwork and structures all over the world – enhancing structural performance and lowering the cost of foundations.

SHEIKH ISA LIBRARY AND CONFERENCE CENTRE, BAHRAIN

Structural roof
2003

Project: Structural roof **Location:** Sheikh Isa Library, Manama, Bahrain
Client: MOWA **Architect:** Arcade Consultants, Dr. Omar El Farouk & Associates
Engineering Consultants: Hosney Consulting Engineers **Main Contractor:** Cybarco **Handover:** 2003

The impressive Sheikh Isa Library, which sits next to the Grand Mosque on reclaimed land in the Bahraini capital Manama, houses over 250,000 titles and audio visual items. Conceived as one of the island's signature cultural spaces, it has evolved into a multi-use venue featuring conference facilities.

While the building's design aesthetic draws on Islamic influences, five huge shell vaults on the roof – designed and fabricated by BFG from a special composite – truly catch the eye. At 50 metres long, over 10 metres in height, with 16 metre span, and installed on light and simple steel supports, the 4000m2 FRP roof comprises 30 vast structural sandwich panels, each assembled on site to exacting performance standards.

Rising to the challenge of building near the sea with high salinity in the air and soil, BFG was able to deliver considerable savings in weight – and therefore foundation costs – while delivering a monolithic solution that minimised joints, and promised next to no maintenance over time.

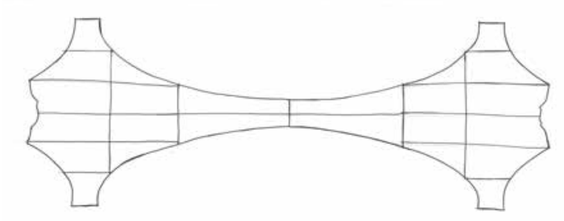
The hallmark of this project was innovation at every step. Dedicated CNC cut tooling templates were developed for the fabrication of very large moulds at site. Laser projection was deployed to help shape the fluted parabolic surfaces, while a highly controlled polymerisation process was pioneered to ensure a uniform cure across large format composites.

To enable the fabrication of huge panels, larger than anything that could be carried by road, BFG built a temporary factory on site, replicating its quality systems to ensure the panels achieved the same standards as those made in BFG's plants.

Reflective beauty

THE AVENUES MALL, KUWAIT

Ceiling cowlings
2016/17



Project: Decorative ceiling cowlings **Location:** The Avenues Mall, Kuwait
Client: Al Rai Real Estate Co **Architect:** Gensler **Engineering Consultant:** Pace
Main Contractor: Ahmadiah Contracting **Handover:** 2016/2017

With more than 800 stores spread over seven districts, The Avenues Mall in Kuwait is one of the Middle East's largest retail destinations. To support the ambitious expansion plans in place, architects Gensler envisaged acres of new internal space, with a glazed canopy, and beautifully reflective cowlings suspended from the roof.

To realise the architect's vision of a perfectly mirrored ceiling, BFG is custom fabricating a set of 192 composite internal panels, designed to be fixed to the main trusses of the roof structure. Manufactured as FRP PET foam sandwich panels using CNC tooling and an open mould hand lay-up process, BFG is to deliver 14 full size cowlings measuring 26 x 12 metres each, and four half size units, totalling 5,120m2. Each unit comprises a perfect jigsaw of 12 smaller panels.

BFG's key challenge was to achieve a mirrored finish to the cowlings' large doubly curved surfaces. Using a metal solution would have been astronomically costly, time consuming – and very heavy to suspend. BFG rose to the challenge of applying a specialised mirrored surface to FRP panels on a scale never attempted before, then transporting and installing the panels without the slightest surface damage.

To make it happen, BFG's process development team worked closely with a specialist coating technology provider from the US and transferred the technology for a patented spray coating system to our plant at Bahrain, mastering a pioneering process that turned FRP sandwich into sculpted chrome finished panels which are fire resistant to BS 476 Part 7 Class 2.

HHR KAEC STATION, SAUDI ARABIA

Structural primary roofing system
2015

Project: Structural primary roofing system **Location:** HHR KAEC Station, King Abdullah Economic City, Saudi Arabia
Client: Saudi Railways Organisation **Architect:** Foster+Partners **Engineering Consultants:** Dar Al Handasah
Main Contractor: El Seif Engineering Contracting Co Ltd **Handover:** May 2015

The Haramain High Speed Railway (HHR) is a visionary infrastructure project in the heart of the Saudi Arabia, linking the ancient cities of Makkah, Medina and Jeddah and the ambitious new King Abdullah Economic City (KAEC). Imagined as gateways to each city, the network's four landmark stations are destinations in themselves: rich in places to connect, meet and shop.

In 2011, BFG was awarded the contract to build and install 34,000m2 of complete structural roofing for the HHR terminal in KAEC, having worked on design and engineering with the contractors, project architects and engineers for two years prior to the award.

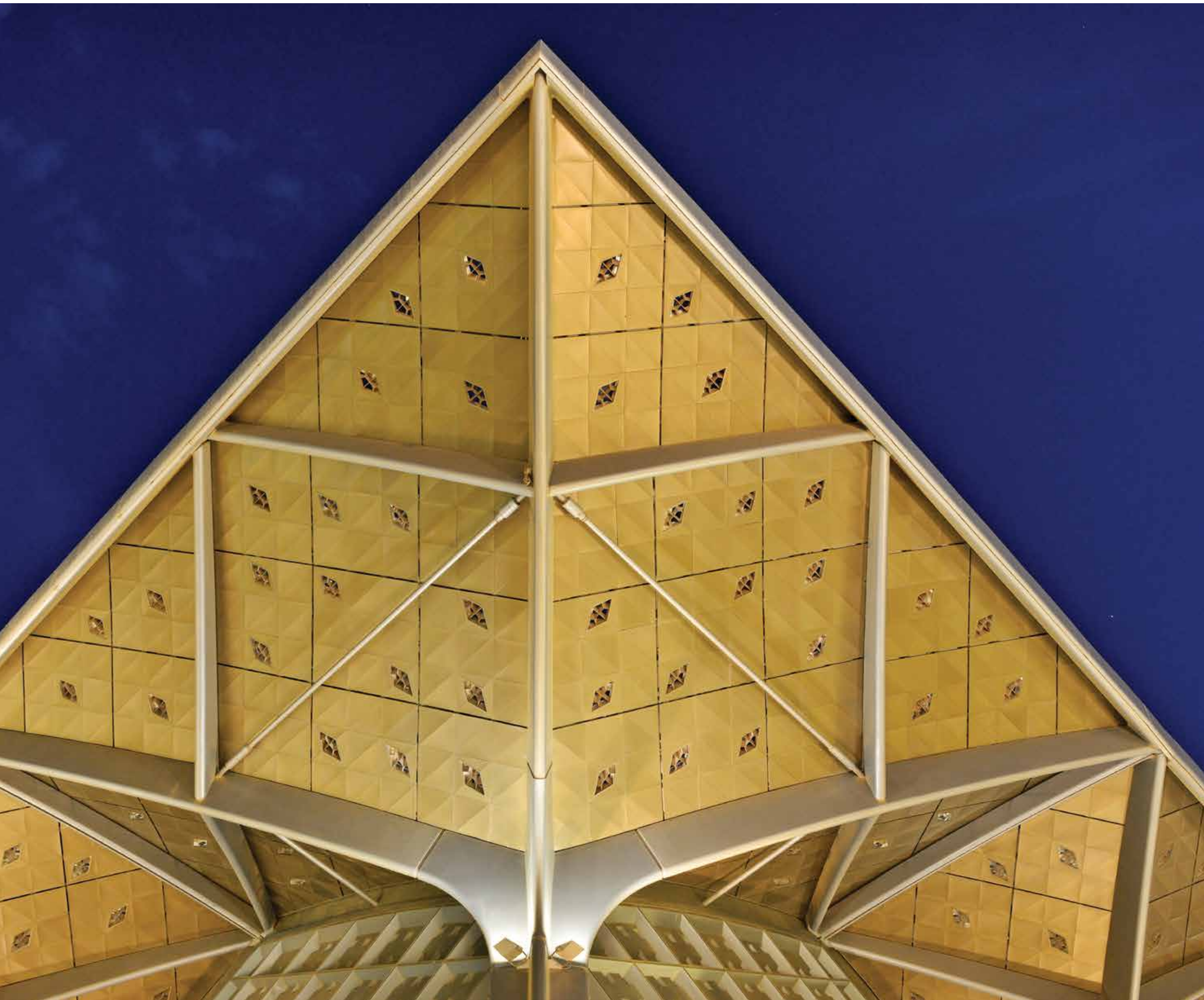
Making it happen

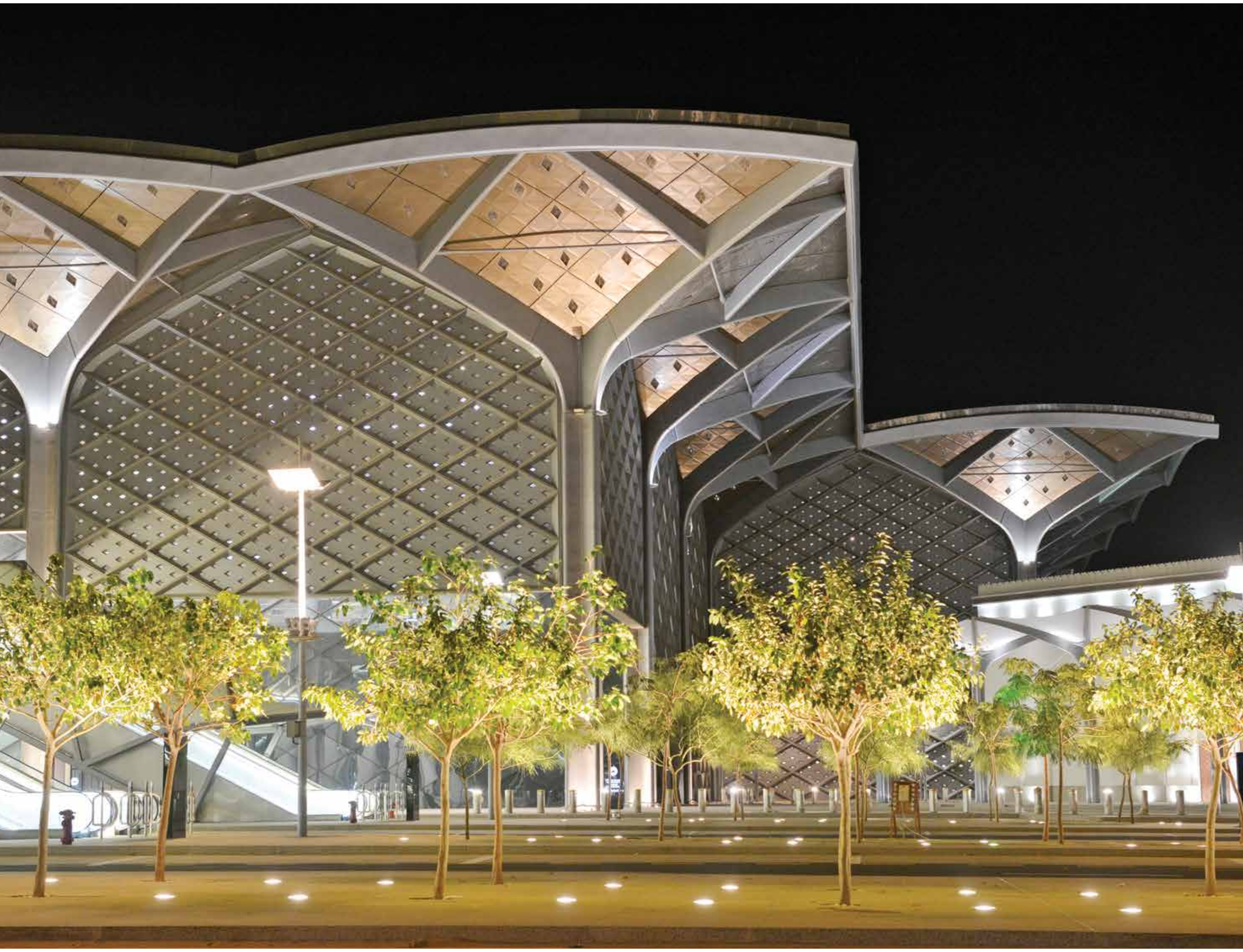
To transform the architect's vision into reality, BFG designed, built and installed a composite roof system including a suspended aluminium soft ceiling and an anti-glare natural light system – all at a height of 30 metres above ground level. Given its location, and bearing in mind the effects of the harsh Saudi summer, the maximum unsupported span of 14.8 metres was designed to withstand intense temperature variations, high winds and heavy sand-laden loads.

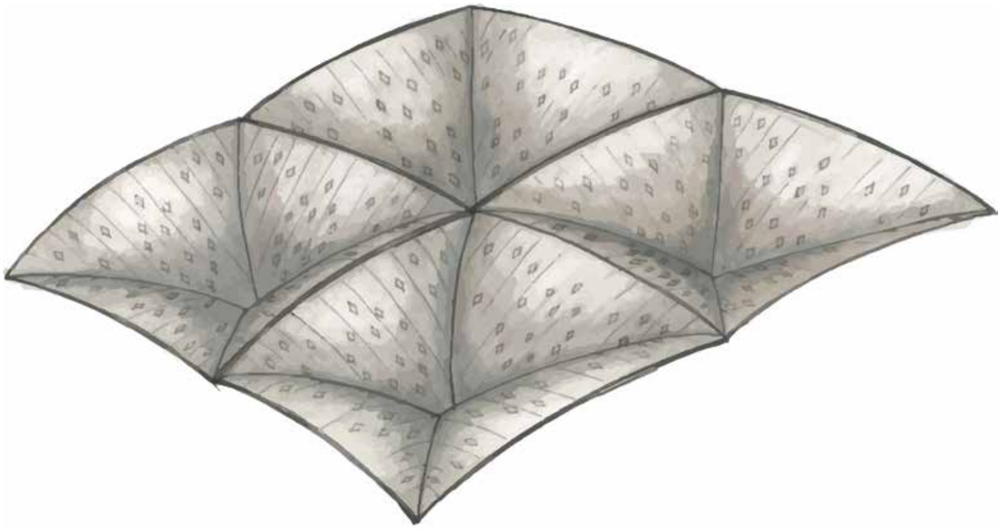
The project involved the creation of 42 large-scale FRP composite roof modules in grids 27 metres square. The manufacturing process featured state-of-the-art vacuum-based moulding with continuous impregnation technology; a unique and proprietary high productivity process developed by BFG.

BFG's work on the project included:

- **Fabrication and installation of 1848 individual FRP roof panels** covering 34,000 m2 of roof, with additional panels for walkways, edge coping and joint caps with provision to accommodate structural movement. Each panel has spherical curvature, and is a self-standing structural Sandwich FRP composite construction with a structural and thermal insulating core.
- **The panels are covered with a complex mosaic of hexagonal stainless steel faced ceramic tiles** with a distinctive bronze metallic finish – all fixed in place with non-shrinking grout. The entire roof system was designed to meet fire specifications to comply with ASTM E84 Class 1 (FSI<25, SDI<450).
- **Design, supply and installation of all upper and lower support brackets** made from quality high tensile stainless steel.
- **Manufacturing and installation of a custom-designed aluminium suspended ceiling**, coated in a bronze anodised finish.
- **Production and installation of skylights and glazing**, using a unique anti-glare system fabricated in Italy. The combination of a high reflected antiglare system and glazing was designed to maximise the use of natural daylight to achieve a remarkable >300 lux internally in the areas of highest footfall without any additional electric light support.







IMAGINATION

DISCOVER NEW FREEDOM TO CREATE WITHOUT BOUNDARIES

Free your imagination and liberate your thinking. Imagine that anything is possible – and that much of what you were taught has been superseded. Every generation has the chance to forge a brighter, more creative built environment. But few have had the tools to make it real.

At BFG, our pioneering composites give the world’s architects, contractors and interior designers the freedom to innovate and create beyond traditional boundaries. And to achieve tomorrow what would be unthinkable only yesterday. Composites can transport you and your next structure beyond the natural limitations and outdated mindsets of old-fashioned materials. Enabling the fantastic. The awe-inspiring. The beautiful.

Composites shape the future now.

Encasing a stadium

BASRA SPORTS CITY, IRAQ

External cladding
2012

Project: External cladding **Location:** Main Stadium, Basra Sports City, Southern Iraq
Client: Ministry of Youth and Sport **Architect:** HOK (360 Architecture)
Engineering Consultants: Thornton Tomasetti and others **Main Contractor:** Abdullah Al-Jiburi **Handover:** 2012

To promote growth and development in Iraq's second city, a new 65,000 seat stadium – one of the largest in the region – was built as the hub of a world class multi-venue, mixed use sports complex on the fringes of Basra. The project's ambition was boldly expressed on its exterior. The main stadium was enveloped with a stunning curtain wall of multidirectional curved composites – a vast 'sculptural skin' – that saw the architect's vision transformed into reality with the help of BFG's advanced engineering.

Designing the stadium in the shape of fronds from the trunk of the date palm, architects HOK wrapped it in a facade of 288 interwoven FRP panels, giving the oval-shaped structure a basket-like appearance. Echoing the patterned facades of traditional Iraqi homes, the textured skin also copes with the effects of the local climate.
In all, more than 48,000m2 of BFG's advanced synthetic structural cladding was needed to encase the stadium, forming large double curvature panels each 32 x 6 metres and stacked five levels high, to interweave with steel support columns.

Constructed from an FRP outer surface with a Phenolic Impregnated Paper Honeycomb core and gelcoat finish, the panels met rigorous performance criteria to withstand the harsh local environment – in addition to high levels of fire resistance to BS476 Part 7.

Futuristic façade

ESIEE, FRANCE

Composite roof panels
2008

Project: Composite roof panels **Location:** ESIEE, Cité Descartes, Noisy-le-Grand, France
Client: AXIMA **Architect:** Dominique Perrault Architecture **Engineering Consultants:** [INSERT HERE]
Facade Design: [INSERT HERE] **Handover:** 2008

Rising like a beautiful angular slab in the horizon at Cité Descartes, a higher education and technology hub outside Paris, the ESIEE graduate engineering school has a highly futuristic feel. There is no traditional façade. Instead, a stunning inclined plane reminiscent of a computer keyboard rises from the ground and runs the entire length of the building, covering the common areas of the institute: library, lecture halls and restaurant.

To enable the architect's ambitions of a unitary exterior – and create the first large-scale structure in France with a fully composite roof – BFG subsidiary NOMA Composites worked to fabricate 2402 FRP roof panels covering a total area of over 9000m2.

With an average thickness of just 3mm, the infusion-moulded panels deliver UV resistance and are fire retardant to the French NFF 16101 standard, with a fire rating of M2 - high performance structural characteristics despite an average weight of just 12kg/m2. Above all, the pure white panels proved essential in communicating the future-focused intent of the building, shaping a new structure at the leading edge of science.

Creating a cultural icon

SHEIKH ABDULLAH AL SALEM CULTURAL CENTRE, KUWAIT

Composite Canopy
2016

Project: Composite canopy **Location:** Sheikh Abdullah Al Salem Cultural Centre, Kuwait City
Client: Amiri Diwan **Architect:** SSH **Engineering Consultant:** SSH
Main Contractor: Al Ghanim International **Handover:** 2016

At the heart of Kuwait's new national cultural district, The Sheikh Abdullah Al Salem Cultural Centre is a world class museum zone – a celebration of diverse scientific and cultural achievement – in buildings designed to inspire wonder and awe. Architects SSH reflected traditional Kuwaiti forms in the main 'street' which echoes the traditional Ferej to create exciting spaces, Islamic patterns, corners and walkways – set beneath a brilliant and playful composite canopy.

To cover the vast space below, BFG produced 3300 individual decorative shingles, each 2.5 metres square, from advanced FRP composite. These fire retardant structural sandwich panels were manufactured using the Resin Transfer Moulding (RTM) process, enabling a double-sided finish, which was an aesthetic and functional requirement of the brief.

The shingles are arranged to form an awe-inspiring canopy that runs the length of the district's central spine, providing shade from the intense desert sun and creating elegant curved forms overhead. Designed to accommodate LED lighting, the canopy comes alive at night, helping ensure that the new Cultural Centre becomes an instant icon in its own right.

GALLERY

GROUND-BREAKING PROJECTS IN ARCHITECTURE AND INFRASTRUCTURE

Since 1975, BFG's architectural projects have been as diverse as they have been inspirational. Here is just a flavour of our extensive portfolio of work - docks, mosques, hotels, military installations, palaces and tunnels.

QATIF SPORTS CENTRE, SAUDI ARABIA
CLADDING PANELS, 1998

Project: Vault and Cladding for Qatif Sports Center
Location: Qatif, KSA
Client: Shinsung Corporation
Handover: 1998

PRIVATE PALACE DOME, BAHRAIN
BRONZE DOME, 2012

Project: Convention center 12m GRP Dome
Location: Bahrain
Client: Private
Engineering Consultants: Gulf House Engineering
Main Contractor: NASS Contracting
Handover: 2012

PRINCE MOHAMED BIN ABDULAZIZ INTERNATIONAL AIRPORT, SAUDI ARABIA
MEDINA MOSQUE, 2015

Project: GRP 20m diameter structural golden dome, GRP palm design claddings, GRP mishrabiya panels, GRC minaret.
Location: Medina, KSA
Client: Civil Aviation, KSA
Handover: 2015

MECCA MOSQUE, SAUDI ARABIA
DOME, 2014

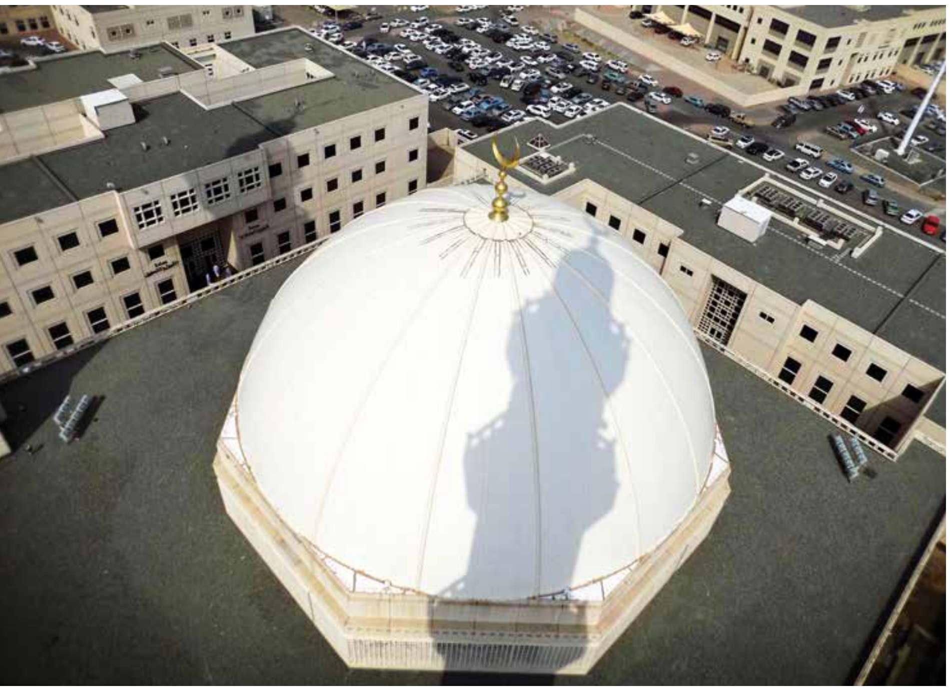
Project: 28m Diameter Mosque Dome for Umm Al Qura University
Location: Mecca, KSA
Client: Saudi Arabia Ministry Of Higher Education
Engineering Consultants: Perkins and Will
Main Contractor: Rabya Construction Company, Riyadh
Handover: 2014

BANK OF BAHRAIN & KUWAIT (BBK), BAHRAIN
SUFFIT PANELS,1984

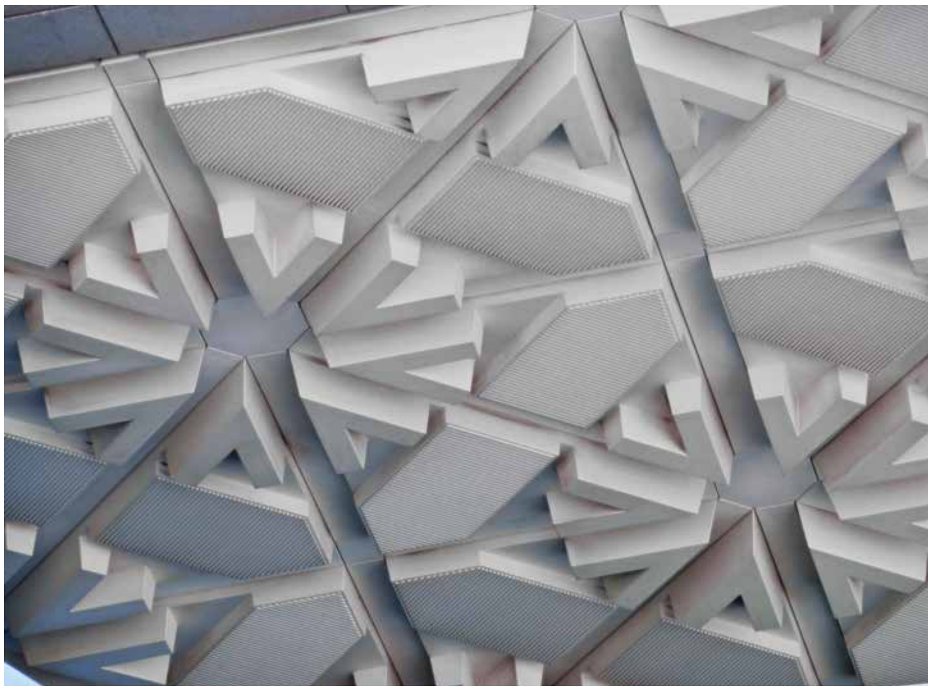
Project: 5x5x7m Triangular GRP suffit panels and internal architectural planters
Location: Headquarters building, Bahrain
Client: Bank of Bahrain & Kuwait
Handover: 1984

GULF HOTEL CONVESNTION CENTRE, BAHRAIN
SUFFIT PANELS AND FACADE, 1997

Project: Suffit panels over the entrance and decorative facade panels around the exterior of the building
Location: Bahrain
Client: Gulf Hotel
Engineering Consultants: IG Design
Main Contractor: Nass Contracting
Handover: 1997




ARABIA



FERRARI CENTRE, BAHRAIN

GRP PANELS, 1990

Project: Decorative GRP panels

Location: Bahrain

Handover: 1990

SAKHIR CONVENTION CENTRE, BAHRAIN

DOME, 2016

Project: Convention center GRP Dome

Location: Bahrain

Client: Confidential

Engineering Consultants: Gulf House Engineering

Main Contractor: G P Zachariades

Handover: 2016

PYRAMIDS FOR TOYTOWN, SAUDI ARABIA

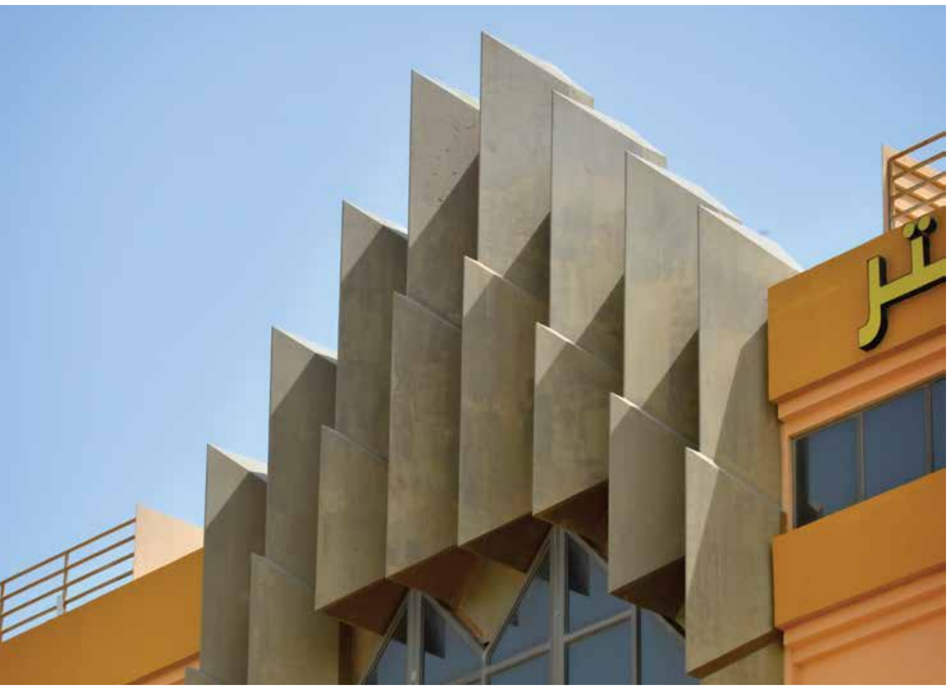
PYRAMID, 1998

Project: 10mx10m Pyramids in multiple colours, structurally self supported

Location: Alkhubar, KSA

Client: Abdulla Fouad

Handover: 1998




INGOT

SAKHIR PALACE DOME, BAHRAIN
DOME, 2011

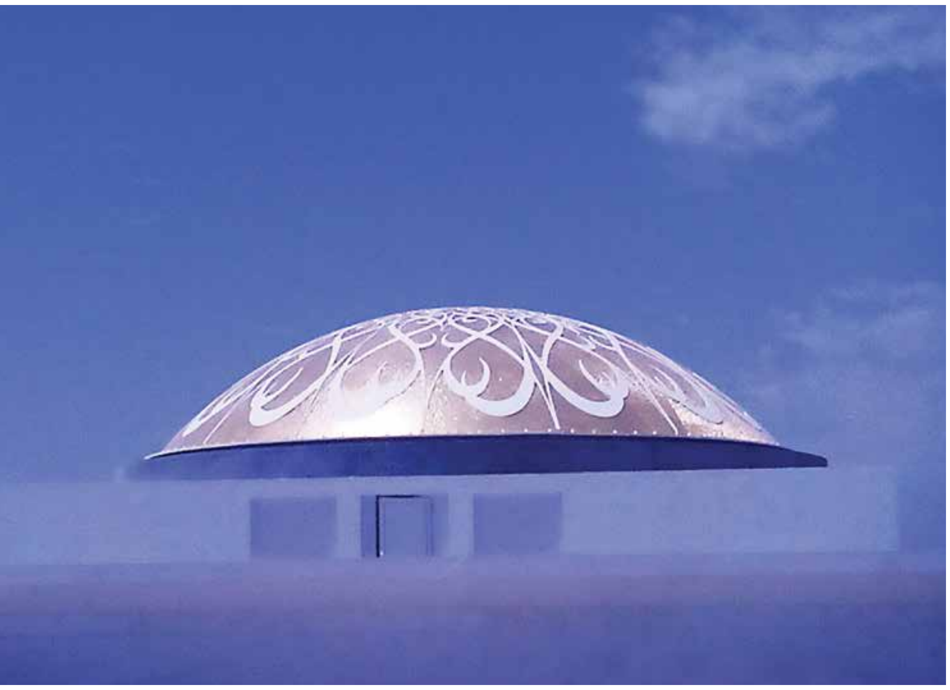
Project: GRP Structural dome bonded with 18k gold-plated tiles and GRP Calligraphy
Location: Bahrain
Client: Royal Court
Engineering Consultants: Gulf House Engineering
Main Contractor: NASS Contracting, Bahrain
Handover: 2011

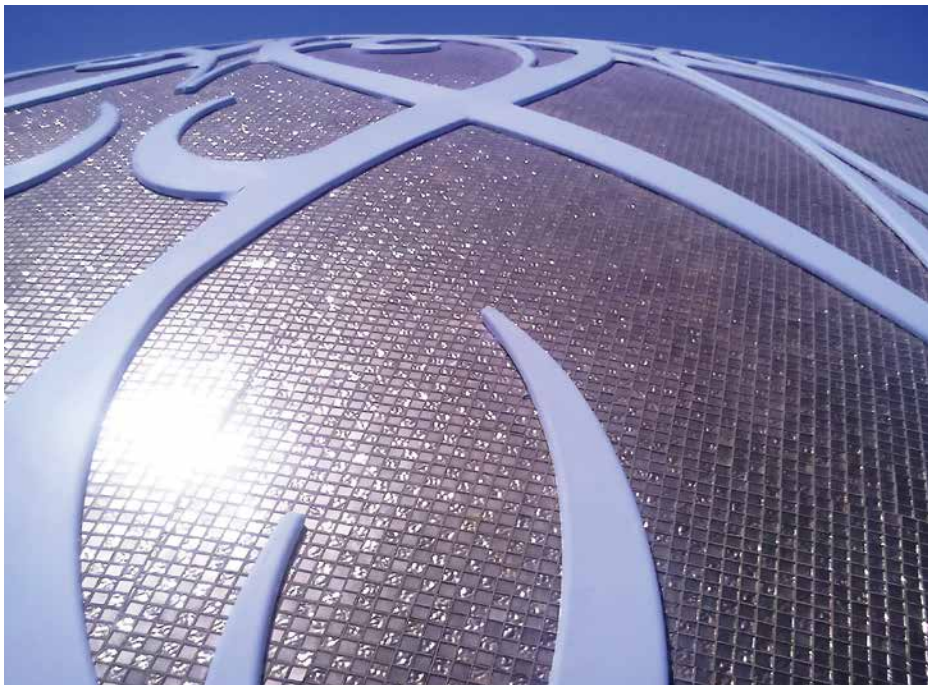
WORLD TRADE CENTRE, BAHRAIN
GRP COWLING, 2010

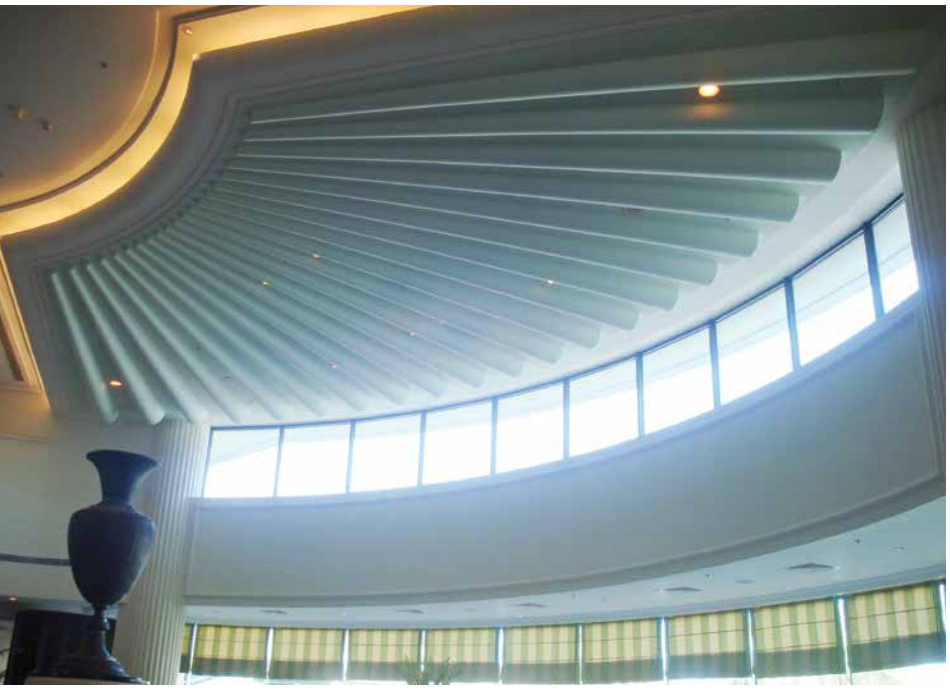
Project: GRP cowling under link bridge
Location: Bahrain
Client: World Trade Centre
Engineering Consultants: Atkins
Main Contractor: AMA Bahrain
Handover: 2010

RITZ CARLTON, BAHRAIN
DOME AND SUSPENDED CEILING, 1994

Project: Dome and suspended ceiling
Location: Bahrain
Client: G P Zachariades
Handover: 1994







MINA SALMAN INTERCHANGE - BAHRAIN
GRC CLADDINGS, 2011

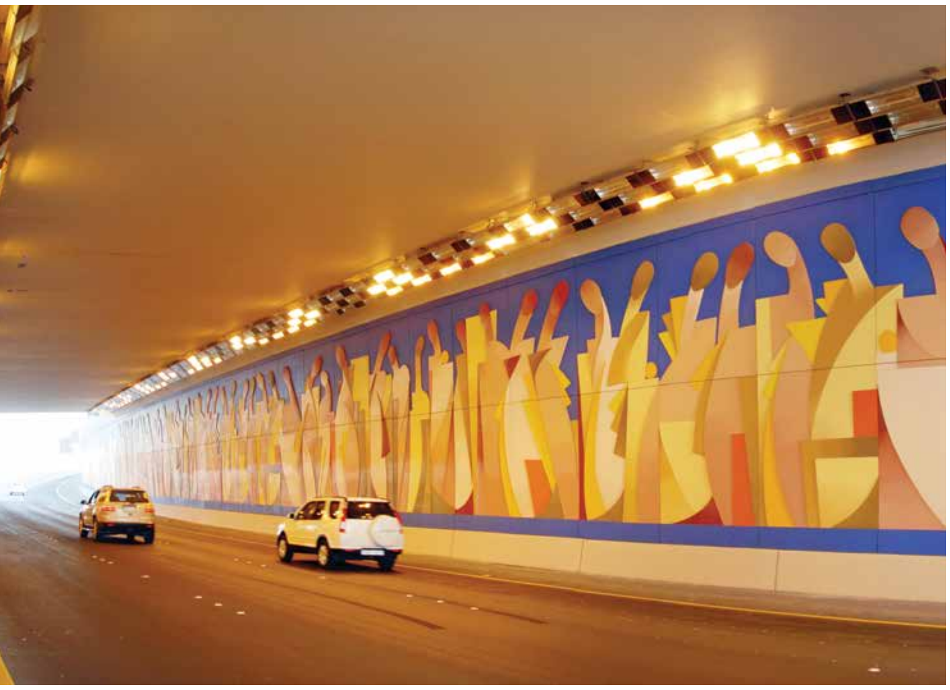
Project: GRC Cladding moulded in architectural design panels
Location: Mina Salman Interchange, Bahrain
Client: Ministry of Works, Bahrain
Engineering Consultants: Parsons
Main Contractor: AFCONS
Handover: 2011

MERSEY QUEENSWAY TUNNEL, UNITED KINGDOM
CLADDING PANELS, 2012

Project: Cladding panels
Location: Queensway Tunnel, Merseyside, UK
Client: Merseytravel
Engineering Consultants: Merseytravel
Main Contractor: BFG UK Ltd
Handover: 2012

MANILA YACHT CLUB ADVANCED COMPOSITE FLOATING DOCK MARINA, PHILIPPINES
COMPOSITE FLOATING DOCK , 1999

Project: Floating dock at Manila Yacht Club. Size ranging from 1.5, to 3m width and 12m length. FRP access ramp to boating docks
Location: Manila, Philippines
Client: Manila Yatch Cub
Engineering Consultants: BFG International
Main Contractor: BFG International
Handover: 1999



AUTORAIL Á GRANDE CAPACITÉ (AGC)

Location: France
Train Builder: BOMBARDIER
Country of Train builder: France
End client (Operator): SNCF
Country of operation: France
Line/ cities served: ALL FRENCH CITIES
Year of Supply: 2007
Year of End of contract: 2012
Type of Product: Front ends, Interior, door pillar, bogie box, Toilets, Floors driver cab, and ceiling covers.

X61 REGIONAL TRAINS

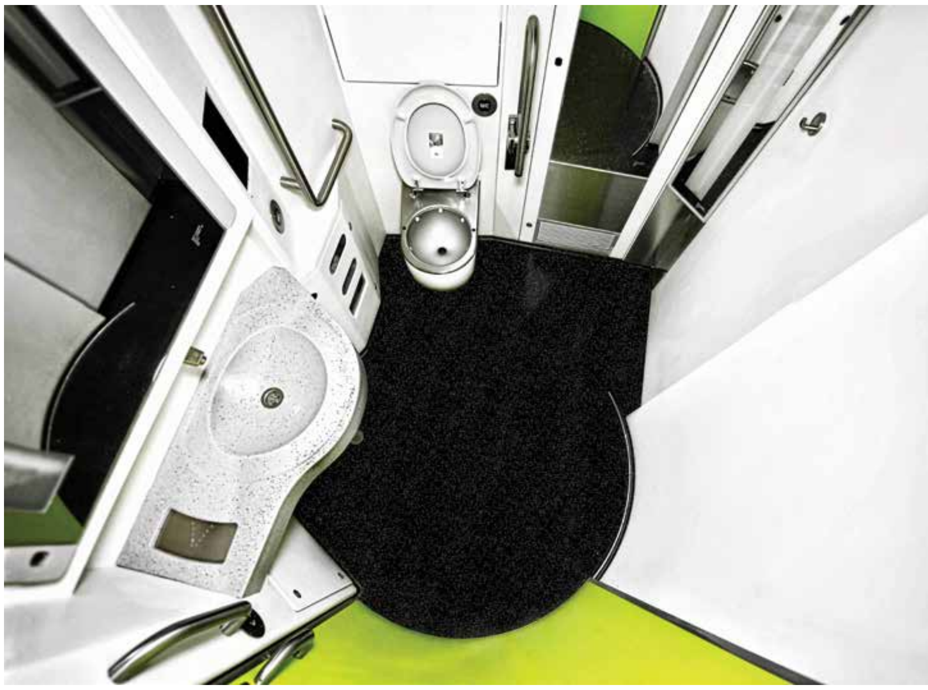
Location: Sweden
Train Builder: Alstom
Country of Train builder: Alstom - Germany
End client (Operator): Skånetrafiken – Skane, Sweden
Country of operation: Sweden
Line/ cities served: Across Sweden
Year of Supply: 2009
Year of End of contract: 2011
Type of Product: Toilet Cabin

DOUBLE DECK TRAINS - DD 2010

Location: Gorlitz, Germany
Train Builder: BOMBARDIER
Country of Train builder: Germany
End client (Operator): : Deutsche Bahn
Country of operation: Germany
Line/ cities served: : Across Germany.
Year of Supply: From 2013 to 2021
Year of End of contract: 2021
Type of Product: Toilet Cabins


ORES
2


WC
SOS



PRASA TRAINS

Train Builder: Alstom, GIBELA
Country of Train builder: France, South Africa
End client (Operator): PRASA (South Africa)
Country of operation: South Africa
Line/ cities served: South Africa
Year of Supply: 2016-2027
Type of Product: Interiors, Front Ends and Driver Cabs

QUEENSLAND NEW GENERATION RAIL

Client: Bombardier Transportation India
End Client: Queensland Rail
Project start date Q1 2015
Anticipated end date: Q2 2018
Technology: Phenolic panels in vacuum bagging process
Fully assembled and painted- plug and play solution for our clients
Bonding done as per A1 Bonding standards
Fire and smoke requirements as per BS6853 CAT 1B
Fully FRP range of Interior panels, Driver desk and Front ends

INNOVIA MONORAIL 300

Location: Sao Paulo, Brazil
Train Builder: Bombardier
Country of Train builder: Brazil
End client (Operator): Metró (Metropoltano de sao Paulo)
Country of operation: Brazil
Line/ cities served: Sao Paulo, will run between Vila Prudente and Cidade Tiradente
Year of Supply: 2013
Year of End of contract: 2017
Type of Product: Front Ends


PRASA
prasa


CENTRAL STN
TRANSLink


CENTRAL STN
QueenslandRail


KAFD

Nouvelle Automotrice Transilien (NAT)

Location: BFG Bahrain
Train Builder: Bombardier Transportation
Country of Train builder: France & Belgium
End client (Operator): SNCF
Country of operation: France
Line/ cities served: From Paris (Line H, J, L & P)
Year of Supply: 2006 - 2019
Year of End of contract: 2019
Type of Product: Interiors & Driver Cabs

CITADIS TRAMS

Location: BFG Philippines / Bahrain / ATMC LaRochelle
Train Builder: Alstom Transport
Country of Train builder: France
End client (Operator): SNCF and other Countries
Country of operation: Global
Line/ cities served: Global
Year of Supply: 2008 – 2018
Year of End of contract: 2018
Type of Product: Interiors and Front Ends

G97 and G114 GAMESA WIND TURBINES

Nacelle and Spinner - Vacuum Infusion and VARTM
Production in India started in 2015, patterns and mold made by BFG India

HITACHI CHEMICAL WIND TURBINES

2.5 MW Nacelle and Spinner - Hand layup
Produced in the Philippines since 2009, over 300 delivered to date
Nacelle Covers for the Hitachi – Subaru 80/2.0 Wind Turbines deployed in Japan

GE WIND TURBINES

GE 1.6 MW Spinner – VARTM
Produced in Bahrain 392 delivered to date GE interior Components –VARTM
Produced in Bahrain 4,000, Dust covers, Grease pans Catch boxes and coupling covers and Dynamo Shrouds produced.


Gamesa


Gamesa


Hitachi Chemical


Hitachi Chemical

SINGAPORE BEDOK
GRP STRUCTURAL COVERS, 2000

Location: Singapore
End client (Operator): Mininstry of Environment , Signapore
Country of operation: Singapore
Main contractor: SEMPCORP
Year of End of contract: 2000
Type of Product: GRP structural odor control covers

JABAL ALI STP PHASE 1
GRP STRUCTURAL COVERS, 2006

Location: Dubai, UAE
End client (Operator): Dubai Municipallity
Country of operation: Dubai, UAE
Engineering consultant: MWH
Main contractor: AAAJV
Handover: 2009/2010
Type of Product: GRP structural odor control covers

Fresh Water Reservoir Tanks
Long-span Tank Covers, 2003

Client : Ministry of Works, Bahrain
Location: Hamala, Bahrain
End client: Ministry of Works, Bahrain
Handover: 2003
Type of Product: Fresh Water Reservoir Tanks

TECHNICAL INFORMATION

GUIDELINES FOR
ARCHITECTS AND ENGINEERS

FRP: Properties

Mechanical Properties

FRP composites are anisotropic materials, meaning that their properties vary as a function of direction. The mechanical properties and stiffness are dependent on composite design parameters such as reinforcement orientation and volume, as well as the thickness and number of layers of reinforcement.

This engineering versatility allows the designer to optimise performance based directly on the structural requirements. Reinforcements can be provided in only the required direction, and in each such direction the type and amount of reinforcement can be varied as per the stress and stiffness requirements in that direction.

The primary FRP composite mechanical properties reviewed within an initial structural design include, but are not limited to strength and modulus in tension, shear and compression, in each of X, Y, Z directions. For thin laminates under bending conditions, flexural strength and modulus are also examined.

As in all structural design, two limit-state conditions should be satisfied in pursuit of a safe and functional structure: strength and serviceability.

Strength design assures that the loads imposed on the structure do not exceed the allowable strength (or resistance) limits of the individual members.

Serviceability design seeks to ensure that the structure complies with durability and human comfort limits while remaining within the elastic regime, such as deformation, vibration, and crack-control limits. One of the codes of practice commonly referred to set such allowable Strength and Serviceability limits states is the EUROCOMP code for the design of composite structures.

The mechanical properties of FRP composites are governed by:

- Material type (such as Glass, Kevlar or Carbon fibre)
- Form of reinforcements (including random chopped fibres, woven, unidirectional or multi directional stitched mats)
- Quantity of reinforcements (the aerial density of the chosen form in grammes per m2) and
- The combination of reinforcements with different types of matrix resins (Polyester, Vinyl Ester, Epoxy, Phenolic etc).

For an FRP product required to withstand flexural loads (loads perpendicular to the plane of the laminate), the design is often governed by deflection requirements. In the event that additional stiffness is required, a lightweight structural core material can be introduced to separate the laminate plies, similar to the web separating the flanges in an I-shape steel beam. This transformation to a sandwich core composite provides a much stiffer response without excessive weight gain. The use of structural core materials may produce a damage-tolerant system when loaded perpendicular to the surface.

Shear stresses may be described as in plane, transverse to the plane (through thickness), or between individual layers of reinforcement or at the skin to core interface. In-plane shear properties are controlled by fibre orientation and laminate stacking sequence. Transverse, or punching, shear strength is highly dependent on reinforcement type and volume. Inter-laminar shear strength is primarily dependent on the matrix and matrix/fibre interface properties. Sandwich core laminates loaded in bending will impose a shear load on the core which will often be the deciding factor in the type and density of core chosen, and will also tend to govern the design of the bonded interface between core and laminate skins.

Global (Euler) or local buckling will often control the compression capacity of a laminate, although sandwich core laminates are often designed with sufficient panel stability to allow the compressive strength of the laminate skins to control strength and stiffness. This can be true when loaded either longitudinally or transversely. In sandwich core laminates, compression perpendicular to the surface should be taken into account when selecting fibre type and/or core density.

The modulus of elasticity of structural FRP materials in building components is relatively lower than that of steel hence often this is compensated by increasing section modulus by way of using cores and profiled or fluted forms. Carbon fibre reinforced FRP materials can be designed to provide comparable stiffness properties in line with those of steel or aluminium, if required. Individual fibre modulus, fibre orientation within layers, fibre volume (as compared to resin), and relative layer thickness will affect modulus values and become critical considerations in material selection for deflection-driven designs.

FRP: Properties

Physical properties

Fibre Volume Fraction

The ratio of fibre reinforcement to resin matrix material is typically described by the fibre volume fraction (Vf), which is the fraction (or percentage) of the fibre in the total laminate volume. An alternative to Vf and commonly used property is fibre weight fraction or content, Wf. This specifies the weight percentage of reinforcement in a laminate. The fibre fraction is an important parameter, required to properly engineer FRP products, as the designer seeks to employ the optimal quantity of fibre to achieve strength and stiffness requirements.

Density

The density of FRP composites is calculated by the Rule of Mixtures (EUROCOMP, 2005). The typical density range for an FRP laminate is 1300 to 2000 kg/m3. The density of sandwich laminates can be considerably less depending on the thickness and density of the core chosen as well as the thickness of the laminate skins.

Shrinkage

Thermosetting or Thermoplastic resins shrink volumetrically upon curing as a function of resin chemistry, cure temperature profiles, material volume and quantity of fillers. The dimensional changes caused by shrinkage are usually relatively small and can be accounted for in the design of the mould or tooling. Improper consideration for shrinkage can result in cracked or warped parts that exceed allowable tolerances.

Coefficient of Thermal Expansion

As is common with most materials, FRP composites expand as temperatures increase. The coefficient of thermal expansion (CTE) of the laminate can be calculated based on an accurate knowledge of the fibre and resin material found within individual layers, as well as the stacking sequence and thickness of the laminas. Unsymmetrical stacking sequences can result in part warping upon thermal expansion. The resin content in a laminate influences the CTE, as does the direction of the fibre reinforcement. Like design of any dissimilar material part assemblies, for FRP parts assembled onto an interfacing part of different material, the designer would account for differences between the CTE of the FRP composites and that of adjoining or attached materials to avoid distortion or differential movement between components.

Since ambient temperatures of architectural panels are well below the glass transition temperature of the FRP, the thermal expansion response is uniform and relatively easy to predict. A typical CTE value for a chopped strand and woven glass laminate with approximately 35% glass content in a Polyester resin is (10-11 x 10-6 mm/mm per °C). This value will decrease with higher glass fibre content. The CTE value will differ substantially for highly unidirectional laminates. The CTE for carbon-FRP composites differ substantially and may actually become zero or negative along the fibre direction. However, with commonly used Glass Reinforced FRP, differential CTE accommodations are easily possible with conservational expansion joints as well as BFG’s proprietary designs.

Thermal Conductivity

The typical range of thermal conductivity for an E-glass-reinforced FRP laminate is from 0.3 to 0.7 Watts/m °K. However with commonly used foam core based sandwich FRP panels, values of 0.035 Watts/m °K are commonly achieved.

Bonding

Successful bonding requires intimate knowledge of the adherent surface chemistry, adhesive application methods, surface preparation techniques, curing conditions, lifecycle load and environmental exposure considerations. The bond strength between two adherents, including FRP to metal, wood, or another material, is considered when an FRP designer determines the expected strength and stiffness values and the appropriate and representative test method(s) to confirm such values. The Lap Shear Test to relevant standards has been used successfully for many construction applications; however, numerous other standard and non-standard methods have been employed successfully when necessary. Realistic load conditions can be specified and checked against the bonding strength values to create a very safe design.

FRP: Performance characteristics

Fire

The fire performance of FRP has improved greatly in recent years with better synergy through chemistry and the incorporation of fire retardant additives. Today, FRP products can be made flame retardant or self extinguishing with very low smoke emission and toxicity. Unlike plastics, FRP does not drip or melt. It has the ability to maintain the integrity of the structure as advised by the building codes which set the norms for overall fire safety.

At BFG, we have gathered significant knowledge in this field by constantly testing our products to all relevant international standards. Today we may be the only company in the world which has a comprehensive database

FRP: Properties

and can provide compliance to codes set by British, European and American standards. We have tested and approved materials to BS 6853, EN 13501, ASTM E 84, ASTM E 119, NFPA 285, NFF 16101, EN 45545 and DIN 5510 to name a few critical standards.

Designers can choose from these standards bearing in mind a range of parameters including whether the FRP product is to be used indoors or outdoors and whether fire control mechanisms are available, and apply the provisions of the relevant codes to specify the fire performance characteristics which will comply with these standards.

International Building Codes such as IBC or NFPA provide appropriate guidelines, considering building type, height, adjacent structures, safety barriers and controls, to enable architects, contractors and developers, and government agencies to address fire safety as a joint goal. At BFG, we are always happy to advise our customers in detail on the importance of fire performance and the contribution that FRP products can make to fire safety.

Temperature

The thermal performance of FRP composites is largely determined by the polymer matrix, fillers, fibre type, and curing process. In general, isophthalic unsaturated polyester, most epoxy and epoxy-based vinyl ester, and most phenolic-based composites have excellent thermal performance for typical interior and exterior exposure.

A characteristic concerning the use of FRP composites is a gradual increase in modulus, or stiffness, in lower temperatures, as compared to higher temperatures. In increased temperatures, a gradual decrease in modulus is notable when the resin matrix polymer reaches a point where it transitions from a glassy to a rubbery state. This transition is called the glass transition temperature, or Tg. When the working temperature of an FRP composite approaches or is above the Tg, mechanical properties (in general) will decrease. There are several options of matrix resins that can provide operating temperatures in the range of 90 to 400°C.

The other thermal property that may be considered is the Heat Distortion Temperature (HDT). The HDT of FRP composites is often reported in excess of 260°C, and is mainly influenced by the fibre type and content (%).

– FRP: Appearance and interior properties

Acoustics

As a combination of both low-modulus matrix and high-modulus reinforcement materials, FRP composites provide very good damping and attenuation of low-to-mid frequency sound waves. High frequency sound waves are more likely to be reflected than absorbed. Properly designed FRP sandwich panels can be engineered to reflect a wide range of frequencies, exhibiting properties equal to those of higher density materials of greater mass. Sandwich-core laminates in particular can have excellent acoustic properties, with those properties being further influenced by the type, thickness, and density of the core chosen. These same cores will also provide excellent thermal insulation properties. Absorption of sound needs perforated surfaces and this is commonly achieved by providing a secondary false ceiling with perforated metal sheet beneath the primary structural FRP composite roof or wall or cladding.

Electrical Insulation

FRP composites are an excellent electrical insulator having desirable dielectric strength and low loss factor. Additionally, FRP composites are transparent to most electromagnetic fields. Properly designed sandwich-core laminates can also provide excellent radio electromagnetic transparency along with reduced weight and improved mechanical performance. Electromagnetic Interference (EMI) shielding and signal reflectance can be provided by incorporating metallic fillers or fibres into the laminate.

Finishes

FRP composites can either be moulded with or post applied with a wide range of surface finishes. A common surface finish for FRP composites is gelcoat, a specifically formulated polyester resin that is applied to the mould surface prior to laminate build-up. A wide range of colours, including clear and metallic, is available. Recent advances in ultraviolet (UV) stability technology have enabled resistance to photochemical degradation which allows properly applied gelcoats to produce years of quality service without significant changes in colour.

Since these are sometimes organic pigments, certain colours react differently under specific climates and exposures. Clear finishes and very dark colours represent the greatest challenges. Clear gelcoats rely to a great degree on chemical UV stabilisers, which deteriorate over time and ultimately allow UV radiation to affect laminates. Additionally, dark colours absorb heat and can result in surface distortion or reduced physical properties in extreme conditions.

FRP: LEED Certification

Texture and Colour
A wide variety of textures and colours is available on multiple surfaces of FRP products. Textures including sandblasted surfaces with aggregates, flat, semi-gloss and glossy finishes are routinely provided. Since FRP composites are inert when cured, they can also accept a wide variety of coatings applied to the surface after curing. Different finishing techniques can have a significant impact on cost.

At BFG, we use our creativity and expertise to fully reflect the architect's vision for internal and external finishes. In addition to standard colours and textures, a range of simulated finishes including stone, wood, and chrome can be achieved with special materials. Based on years of research and development, BFG is also able to deliver highly imaginative, creative finishes including translucent, fluorescent, pearl and dual-colour effects (where the colour changes with the angle of observation), as well as raw metallic, patterned and picturesque finishes.

For architects who want to reflect themes from nature, we can replicate natural textures through in-mould coatings or post-applied finishes. BFG also has multiple controlled spray booth facilities for achieving Class A painted or varnished finishes. Our materials selection is application-based, providing the best solution to the customer with enhanced scratch resistance, impact resistance or graffiti resistance depending on the demands of the project.

Size and Shape
There is no technical limit to the size of an FRP composite part, although size may be limited by transportation and installation constraints. As with traditional materials, project-specific tolerances must be considered when designing FRP composites parts. Installation considerations should be discussed when selecting the optimum size of an FRP composite part.

FRP: Long-term performance

Durability
The durability of FRP composites products is widely considered superior to the durability of mild steel, aluminium alloys and stainless steels, or typical steel-reinforced concrete. FRP materials have been in widespread use since the late 1940s under a variety of conditions and in numerous applications. Due to the materials' inherent corrosion free character, FRP products are in widespread use in harsh environments such as sea water and air with high salinity, chemical processing plants, coal-fired power plants, semiconductor facilities and sewage treatment plants.

Moreover, FRP designers have created innovative components and systems capable of withstanding temperature and/or moisture levels in extreme climatic regions, such as the tropics and poles.

Creep
Thermoset composites are less susceptible to performance degradation as a result of long-term loads as compared to thermoplastic FRP materials. Large-scale structural applications such as pressure vessels and radomes demonstrate that FRP composites are capable of safely withstanding sustained loads over prolonged periods.

Creep studies of FRP composites indicate that these properties are controlled largely by the matrix material. Creep-related strains and deformations can occur in long-term, axial-loaded columns and beams at significantly high applied load levels.

Fatigue
Properly designed FRP parts have excellent service lives under cyclic loading conditions as proven in automotive leaf springs, helicopter rotor blades, pressure vessels, boat hulls and aircraft structures.

Moisture
The moisture absorption found in E-glass polyester or vinylester FRP parts is typically less than 1% for ambient environmental (temperature and moisture) conditions applicable to installed architectural panels and given recommended service-load to ultimate-load ratios and surface finishes.

Ultraviolet (UV) Exposure
As with other building materials, UV can cause colour shift or yellowing and gloss changes. The structural layers of FRP composites are protected from UV by an opaque gelcoat surface or by painting the exposed surfaces. Incorporating UV screens into the matrix is also commonly done in modern resins. Of these techniques, gelcoating is the most common since it provides a desired surface finish and a deep 0.25-0.51mm thick protective layer. Gelcoating is used by the marine industry to provide a durable, long life finish on boat hulls.

FRP: Design and tolerance

Properly prepared FRP composites can also accept a wide variety of other surface coatings, including oil and water-based paint, as well as plural component systems such as urethanes. Factors influencing the weatherability of a gelcoated surface include the type of gelcoat resin, the amount and type of fillers, and the colourants in the gelcoat.

Corrosion
FRP composites are corrosion-free material as against corrosion protected metals. Fibreglass reinforced composites are commonly used in architectural applications where other construction materials corrode or decay rapidly. FRP composite materials are frequently used in components that are exposed to aqueous chlorine solutions, from seawater to bleach and hydrochloric acid. The use of composite systems for the storage and transport of strong acids and bases is common.

Composite laminates can also be used where resistance to corrosive gas is required throughout a wide range of temperatures, depending upon the FRP laminate composition. To store chemicals in an FRP composite vessel, proper design is necessary for storing such chemicals for extended periods of time. Because the period of exposure, temperature, and chemical composition vary widely between applications, guidelines and case histories provided by resin suppliers and glass fibre manufacturers should be reviewed to determine the viability of employing FRP materials. Numerous standards govern the design of tanks, piping, ducting, lining systems and other structures used in corrosive environments.

FRP: LEED Certification

Leadership in Energy and Environmental Design (LEED) is one of the world's most popular green building certification programmes – a sustainable build ratings system developed by the US Green Building Council. Its goal is to enhance environmental performance, improve wellbeing and enhance the economic returns of new build facilities, and covers design, construction, operation and maintenance.

FRP materials can make a positive impact to securing LEED certification for your next project.

Low resource requirement
Lightweight FRP materials have low ecological and carbon footprints. The overall materials and resource requirement in FRP production is significantly lower than for traditional building materials.

Low energy
FRP uses less energy in the production process - from the raw materials stage all the way to product delivery.

Long product life cycle
FRP is a durable, low maintenance, long lasting material, with a long life cycle as determined by Life Cycle Assessment (LCA) studies. This reduces the need for replacement, repair and repainting over time.

Natural, non-depleting materials
Glass, the main ingredient of the fibreglass reinforcement in FRP, is made from sand which is a natural, non-depleting resource.

Resistance to damage
FRP materials are resistant to damage by moisture, weather conditions, salinity, as well as by termites and other insects, which reduces the need for toxic pesticides.

LEED certification standards
To attain LEED certification, a building project must satisfy all the LEED requirements and earn a minimum of 40 points (or 'credits') out of 110 on the LEED rating system scale. The number of points determines the overall LEED certification level:

80 points	Platinum Certificate
60 points	Gold Certificate
50 points	Silver Certificate
40 points	Minimum for Certification

FRP: Design and tolerance

FRP's contribution to LEED credits

Using FRP components in building fabric can contribute to LEED credits in a number of key categories:

Heat Island Effect
SS Credit 7 (1-2 points)

To minimise the impact on microclimates by reducing heat islands - thermal gradient differences between developed and undeveloped areas. BFG's FRP roof structures such as domes and roof panels are custom made to a range of SRI values to meet project requirements. SRI values tested as per ASTM C 1549-09 are >49.

Energy Performance
EA Credit 1 (1-19 points)

To achieve energy performance above the baseline standard and reduce the environmental and economic impacts associated with excessive energy use. U-value, the fundamental unit of heat flow, is used to determine the thermal transmittance of systems. In a typical FRP sandwich structure composed of two fibreglass skins and a PET core the U-value is 1.65 W/m2/°K for a 20mm-thick core and 1.32W/m2/°K for a 25mm-thick core.

Construction Waste Management
MR Credit 2 (1-2 points)

To minimise construction debris and divert it away from disposal in landfills or incinerators, redirecting recovered resources back to the manufacturing process and reusable materials to the appropriate sites.
For most projects, BFG's FRP components are custom moulded to size and shape and assembled at the factory, minimising waste on site.

Recycled Content Credit
MR Credit 4 (1-2 points)

To use products that incorporate recycled materials.
At BFG, we use a green grade Polyethylene-Terephthalate (PET) core, which is made of 100% post-consumer recycled PET packaging material. The PET core weights 15% of the total weight of a typical FRP sandwich panel, exceeding the minimum qualification level (10%) required for LEED credit award.

Regional Materials
MR Credit 5 (1-2 points)

To promote the use of materials which are extracted, harvested and manufactured locally.
Most of the ingredients used in the production of FRP at our Bahrain site are made in Gulf Cooperation Council (GCC) countries within 500 miles of the factory location.

Acoustic Performance
EQ Credit 3 (1-2 points)

To provide workspaces promoting the occupant's well-being, productivity and communication through effective acoustic design.
BFG's FRP sandwich panels reduce the transferred sound by >30 db and make a significant contribution to improved acoustic performance.

Low Emitting Materials
EQ Credit 4 (1-3 points)

To reduce the concentration of chemical contaminants that can damage air quality, human health, productivity and the environment.
The high quality gel coat finishes that can be applied to FRP products reduce the need for painting at site and therefore lower the volume of Volatile Organic Compounds (VOC) released.

Mould Prevention
EQ Credit 10 (1 point)

FRP: Design and tolerance

To reduce the potential presence of mould through preventive design and construction measures.
FRP materials do not absorb moisture and do not contribute to mould growth.

Innovation and Design
IN Credit 1 (1-5 points)

For exceptional performance above the requirements set by the LEED New Construction Green Building Rating System.
BFG has a 40-year track record of supporting innovative ideas. With a dedicated innovation hub in Strasbourg, we welcome opportunities for future collaboration in all manner of pioneering FRP applications.

FRP: Design and Tolerance - Structural Design

FRP composites can be analysed by many engineering methods. Depending on the shape, panel stiffening system, and the intended use, a variety of choices exist to evaluate loads and structural performance. Often, due to the complexity of FRP panel shapes, the most representative method to predict actual field conditions is that of physical laboratory testing. Numerical methods such as finite element analysis (FEA) are valuable in the early design stage and beyond for laminates with or without stiffeners or laminates containing cores. This analysis should be performed by a professional engineer with experience in the intricacies of FRP composite numerical solutions and accurate modelling of connection details. BFG's experienced FRP experts can greatly assist in the laminate design as well as the composite structure design recommendations for a new project.

Service loads
Because of FRP composite panels' low self-weight, dead load is often relatively small as compared to live loads, and the designer should pay particular attention to uplift loads induced by wind. Care should be given to local aerodynamic effects and the geometry of the structure and panel.

Important thermal considerations are the temperature gradient through the panel, the effects of thermal differentials due to panel geometry such as soffits and returns, and the differential properties of facing materials such as ceramic tile, veneers, or polymer concrete. These effects can be exacerbated in multi-material systems such as sandwich-core composites. Consideration should be given to surface temperatures exceeding the ambient temperature due to solar radiation. This is particularly important where surface colours are dark or the FRP is bonded to a dissimilar material. It is possible to exceed the heat distortion temperature of certain resins and core materials under extreme conditions, particularly if heat-absorbing surface colours are specified. Consideration should also be given to the heat distortion temperature of the resin and the core since elevated temperature can affect the physical properties. FRP panels should be designed for the horizontal and vertical contraction and expansion of component materials without excessive buckling, the opening of sealed joints, excessive stress within panel components and fasteners, and other detrimental effects.
Minimum design loads in the governing building codes, along with additional service loads and conditions stated in this recommended practice, should be included when assessing development of the design load combinations.

Handling loads
Loads due to transportation and handling can at times exceed the design service loads of the FRP components. Care must be taken to transport, store, and install FRP members in accordance with manufacturer's handling and erection instructions. Proper lift-points, approximate centre of gravity, and dead-load magnitude should be identified both on the part and on the shop drawings. In addition, any special handling requirements must be clearly stated on shop drawings. Any deviation from the FRP manufacturer's instructions must be approved by the manufacturer in advance.

Anchorages and connections
FFRP composite panels assemblies generally consist of inter panel connections as well as panel to support structure connections or anchorages. Typically inter-panel connections are of the following type:

1. Traditional fasteners using screws or bolts with inter panel gaskets.
2. Bonded and bolted connections or
3. Inter panel bonded connection.

Connections or anchorages to supporting structures such as concrete, masonry, timber or steel is generally using anchor bolts or high tension bolts along with gaskets to get a levelled surface for resting FRP panels.

The bearing strength check on pinned or bolted connections is important step in design with composites like that of aluminium, steel, wood, etc. Dimensions between adjacent holes and distance of holes from free edges should be appropriately considered. Laminate design, including lamina materials and fibre orientation, will also affect bearing strength, which subsequently is used to decide the requisite bolt dimensions and configuration. Proper design of bolted and bonded connections considering strength, durability, water / air tightness maintainability as well as practical assembly procedure considerations are needed to design the connections.

FRP: Design and tolerance

Provision for movement
The design and detailing of anchorages, connections and joints must allow for expansion and contraction of FRP components and the supporting primary structure due to thermal effects or differential deflection. Information related to joints and tolerances should be indicated on shop drawings.

Design and tolerance
Tolerances for products and assemblies are generally set out giving due consideration to the material, manufacturing and installation processes. At BFG, we will always discuss this with the primary structure designer and arrive at workable values on a project-by-project basis. Some elements for consideration are:

Inserts and embedments
Corrosion-resistant inserts are often used in FRP components. Inserts should be properly embedded in built-up bosses or bonding pads to achieve proper load distribution and prevent failure.

Joints
The design of the joints between FRP composites panels is an integral part of the total system design. Requirements for joints should be assessed with respect to both performance and cost. Joint designs are also made to accommodate structural movements.

Support structure
The support structure on which FRP structures are resting needs to have adequate capacity to resist reactions imposed by FRP structural members. Hence proper engineering interface between the FRP structural elements designer and the support structural designer. [BFG TO RE-WORD – THIS IS NOT CLEAR] This is a key phase in design of the overall structure.

Tolerance
Tolerance is a permissible variation from specified requirements shown within a project's set of shop drawings, architectural drawings, engineering drawings, or related specifications. Within a given project's contract documents, tolerances should be provided, as necessary, for dimensions, locations, and other critical features.

Appearance
At the time the sample, mock-up, or initial production units are approved, the acceptable variations of colour, texture, and uniformity should be determined. Acceptance criteria may be available in the project's contract documents. In general, the finished FRP surface should present a pleasing appearance with minimal colour and texture variations from the approved sample when viewed in typical lighting from an appropriate short viewing distance. No other obvious imperfections such as chips, cracks or foreign matter should be visible at an appropriate long viewing distance. Viewing distances depend on actual site conditions.

Product Dimensional Tolerances – Fabrication Tolerances
Part tolerances are normally established by economical and practical production considerations. Tight tolerance specifications will tend to increase the overall cost of the product. The individual skill of the craftsmen, including pattern makers, mould makers, and FRP laminators will determine the degree of accuracy of moulded components, and thus the tolerance of the manufactured part.

The actual thickness of FRP products may deviate, within given tolerances, from the design thickness, according to the method of manufacturing. The project contract and/or specifications should specify acceptable tolerance values. In case certain localised areas need tighter tolerances, this can be achieved using special tools, based on the agreement between both parties.

Installation tolerances
Cumulative errors from the primary structure, supporting structures, and FRP composites part can cause installation problems in the field if dimensional tolerances are not properly assessed. Compatible tolerances of all adjacent components, which take into account the properties of the materials and the capabilities of the manufacturing and construction process, will produce the best results. Therefore, close collaboration between the manufacturer and building design team is essential for the proper erection and placement of installed composites products.

Care should be taken to ensure that any stresses introduced during installation to accommodate alignment requirements do not exceed the allowable design stresses or compromise the ability of the component to withstand design loads. Gaps between adjacent members should be maintained in order to allow for free thermal expansion and contraction.

All structural frames and building facades (eg steel, concrete, wood) have an inherent erection tolerance described in the contract documents, building code, or other codes of standard construction practice. The design team should provide sufficient allowances in panel spacing to accommodate this tolerance plus the fabrication tolerances of the FRP panels. If clearances are realistically assessed, they will solve many installation tolerance problems.

Glossary

A

Additive
A material added to polymer resin, such as a filler or pigment, which modifies its characteristics.

B

Bi-directional
A type of fibreglass reinforcement in which the fibres are arranged at right angles to one another.

C

Catalyst
A substance added to a resin or gelcoat to start the curing process.

Chopped strand mat
A fibreglass reinforcement containing randomly arranged strands of fibre which are bound together.

CNC
Computer Numerical Control - the process for controlling machine tools via computer. In the FRP production process, CNC tooling is often used to create extremely complex but accurate moulds.

Composite
A new material - created from two or more separate materials - whose properties are superior to its original components. In the case of FRP, the composite is created when a fibre reinforcement and resin matrix are brought together.

Compressive strength
A measure of the stress a material can withstand when it is subject to compression.

Core
The polyester layer at the heart of a fibreglass mat.

Cure
The process in which a composite develops its full strength. In some cases, heat or pressure can be applied during this process.

D

Density
A measure of weight or mass by volume.

Dielectric strength
A measure of electrical insulation or resistance.

E

Epoxy resin
A polymer resin formed from epoxide molecules. Epoxy resin is a common matrix used in the production of FRP products.

F

Fabrication
Another word to describe the FRP production process.

Fibreglass
Fine glass filaments measuring between 9 and 32 microns in diameter. Using an advanced textile production process, the filaments can be woven into a range of different forms including mats, fabrics and veils.

Fibre reinforcement
The fibreglass layer, which when covered in a resin matrix forms the core structure of a composite part.

Fillers
Materials which can be added to resins or gelcoats to alter their characteristics.

Finish
The outermost layer of an FRP product, which can be styled to feature a wide range of colours and textures.

Fire retardants
Chemicals which are added to a resin matrix to reduce its flammability.

Fire retardant resin
A specially produced resin designed to reduce the spread of flame or the production of smoke.

Flammability
A value which describes the surface burning qualities of a given material.

Foam
A light, gas-filled plastic material such as PET. Foams are typically used in the production of composite sandwich panels.

FRP
Fibre Reinforced Polymer – the generic term for engineered composites. Also known as GRP (Glass Reinforced Polymer), GFRP (Glass Fibre Reinforced Polymer) and RP (Reinforced Polymer).

G

Gelcoat
A top coat of polyester resin which provides the aesthetic finish and weatherproofing to a composite product.

H

Hand lay up
A traditional manual process of fabricating composites using rollers, brushes and sprays.

L

Laminate
The product that results when a set of plies (or layers) are stacked in sequence and bonded together. One of the most common types of industrial laminate is plywood.

Lay up
The process of adding a fibre layer into a mould and impregnating it with resin.

M

Machine tool
A machine for shaping rigid materials – such as a mould – according to a pre-determined program.

Matrix
The plastic resin used in the FRP production process, which covers the fibre reinforcement and then cures to form a solid shape.

Mould
A rigid frame used to shape the elements of the composite product, which set inside the mould to adopt its form. In the composites industry, moulds are often known as tools.

P

Phenolic resin
A type of resin typically produced by condensing phenol with formaldehyde.

Pigment
A colouring agent which can be added to a resin.

Polyester resin
A common polymer resin frequently used in the fabrication of FRP products.

Porosity
A measure of the propensity for gas bubbles or voids in a gelcoat finish.

Pultrusion
A continuous process for manufacturing composites by pulling the elements through a heated tool under pressure.

Print-through
An imperfection in a composite part where the pattern of the fibreglass is visible through the surface.

R

Resin
A synthetic liquid used to impregnate a fibreglass layer to form a composite. Resins frequently used in FRP fabrication include polyesters, acrylics, epoxys, and phenolics.

RTM
Resin Transfer Moulding – a common method for fabricating composite structures.

S

Sandwich
A lightweight laminate in which a core material is bonded to a composite skin on both sides.

Skin
An outer layer of composite material, such as the cladding on the exterior of a building.

T

Tensile strength
A measure of the force required to pull a given material to the point where it breaks.

Thermal coefficient of expansion
A measure that describes the change in a material when it is heated or cooled.

Thermoplastic
A material, such as polystyrene or nylon, that becomes elastic or melts when it is heated, and adopts a rigid form at lower temperature.

Thermoset
A material that undergoes an irreversible reaction under heat, and changes its form from liquid to solid.

Tool
In the composites industry, this is the technical term for a mould or die.

U

Unidirectional
A fibreglass reinforcement in which the fibres are arranged in one direction.

DIALOGUE
SHAPING THE FUTURE TOGETHER

At BFG, we embrace the challenges of an increasingly complex built environment – and seek to harness its opportunities. Inspired by a vision of ever more imaginative structures, we respond with ideas and innovation, pioneering new composite forms and taking a refreshing approach to progress through partnership. Together, we stay true to our company's spirit – shaping the future.

To shape tomorrow with confidence, start a rewarding dialogue with us.

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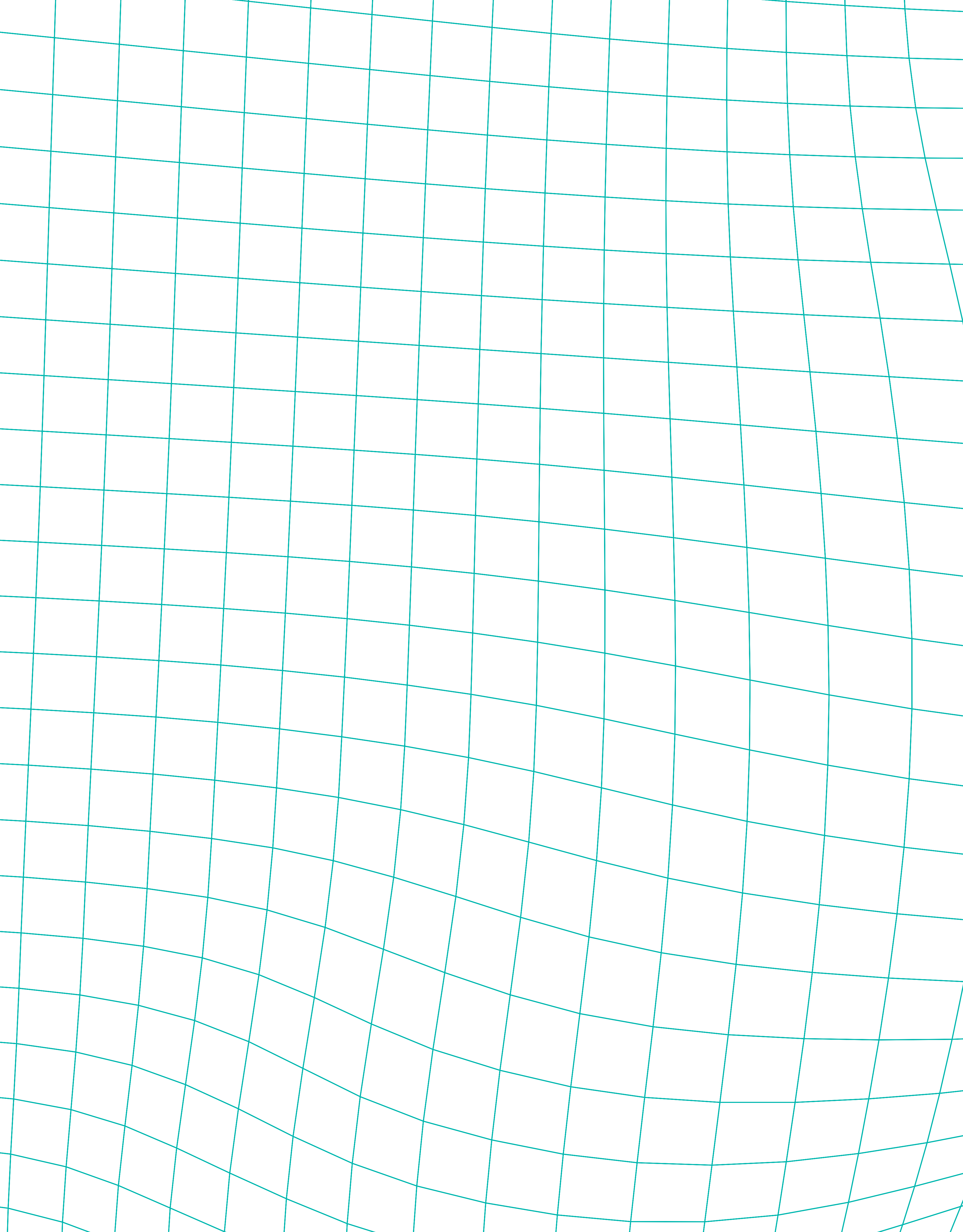

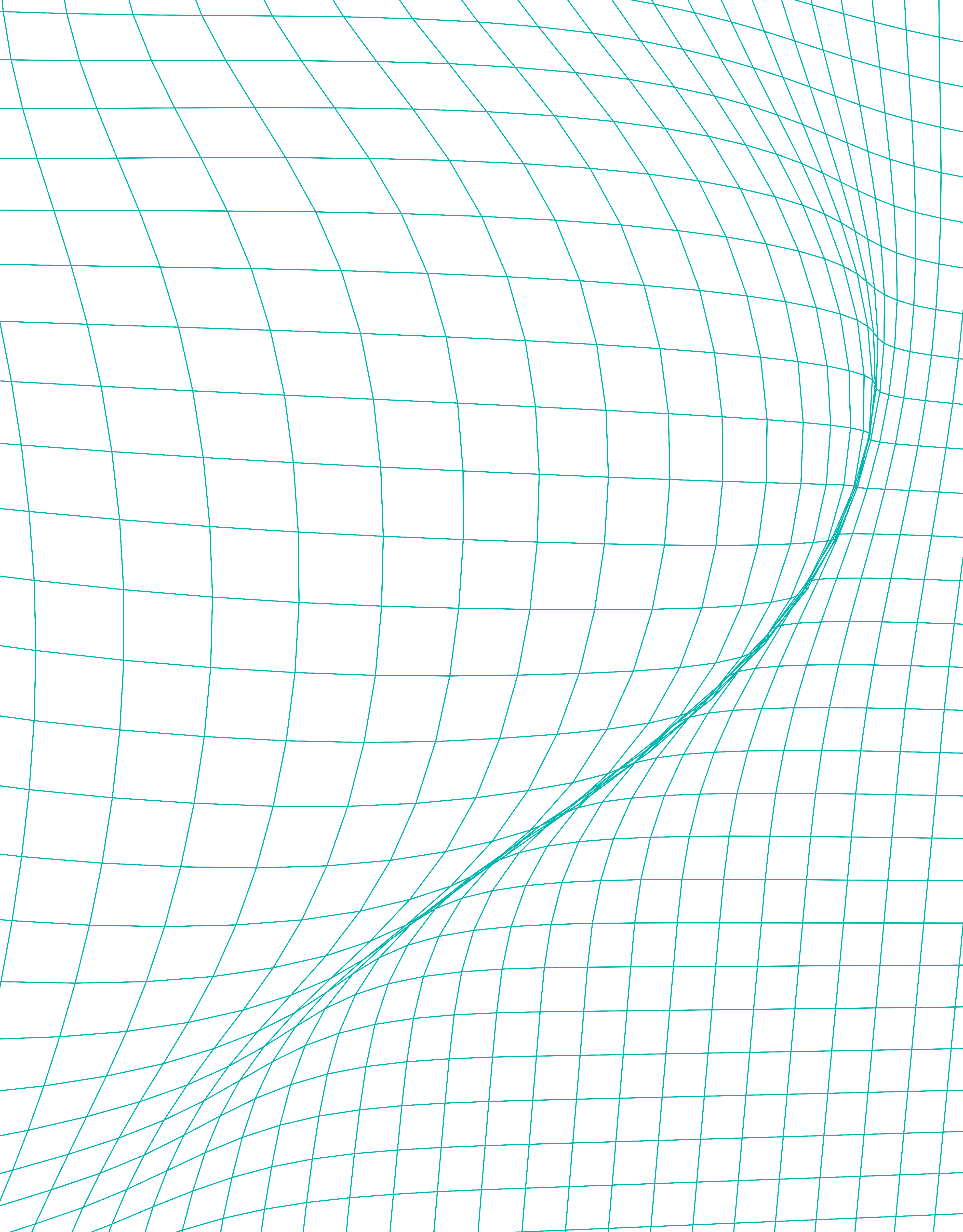

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