ARCHITECTURAL STRUCTURES
CASE STUDIES
Bridges, Facades, Roofs

- SkyPath, New Zealand, 2014
- Dragon’s Bridge, Wales, 2013
- Marsden Cross, New Zealand, 2013
- Makkah Clock Tower, Saudi Arabia, 2011
- Ministry of Foreign Affairs, Turkmenistan, 2011
- Bradkirk Bridge, UK, 2010
- Whitestone Bridge Fairing, New York, 2003
- EXPO Bridge, Portugal, 1998
Auckland Harbour Bridge (AHB) has not provided any walking or cycling access since it was built in 1959. The two box girders “clip-on” lanes added in 1969 did not change that as they merely provided additional road traffic capacity. With SkyPath, the famous Auckland harbour crossing will provide a shared walking and cycling path on the city side of the bridge.

Due to the location of the building, in the mountains surrounding Basle, it was almost impossible to reach the villa by road. The entire roof was shipped by barge from Rhebergen’s yard in Amsterdam to Basle, where a helicopter was used to transport the roof the last few kilometres. The fabrication and installation of the roof is documented in a video by Rhebergen.

SkyPath is the talk of the town. It is being developed and championed by the Auckland Harbour Bridge Pathway Trust, a charitable trust whose aim is to have a world class walking and cycling facility on the AHB. In order to implement SkyPath as a community facility, it is proposed to provide funding by charging fees for users, including tourists, recreational users and commuters. Optimised cost, low maintenance and longevity are obviously very important to a project like this.

The New Zealand Herald applauds that SkyPath will be built out of “space-age materials”. Well, if not tried and tested in outer space, composites certainly have proved their supremacy over traditional building materials in marine and maritime conditions.

SkyPath is capitalising on New Zealand’s marine expertise by proposing the use of composite materials and manufacturing technology developed for the America’s Cup. SkyPath will be constructed by Auckland yacht builders who built the Team NZ and Oracle America’s Cup catamarans. Project Director Bevan Woodward says: “Whilst we’ve had to go through a significant design update and testing programme, we have now achieved a composite solution for a similar price to steel and aluminium construction. This means Sky-Path will be stronger and lighter, will be easier to implement and have much lower maintenance costs with a service life of at least 50 years.”

Over the past decades, the two box girder lanes of the Auckland Harbour Bridge have been the object of significant structural issues, strengthening work and on-going maintenance. As those in the marine industry would be well aware, when a stiffness critical structure requires reduced weight and low maintenance, composite structures have a distinct advantage. Gurit has lent its expertise to provide the Auckland Harbour Bridge Trust, Airey Consultants and Core Builders Composites with a practical solution utilising all the benefits of composite construction.

Core Builders Composites project manager Tim Smyth says: “The use of composite materials for buildings and bridges has been proven overseas. We propose to work with a
number of Auckland composite manufacturers in a similar programme as the successful production of the 14 America’s Cup AC45 catamarans.

We would deliver SkyPath in 14 metre long, 4 metre wide sections ready for nightly installation onto the city side of the Harbour Bridge.” According to Gurit’s and Core Builders’ proposal, SkyPath requires over 4000m² of sandwich panel decking, some 250 10-metre long E-Glass and carbon reinforced ribs.

Gurit has been involved working closely with the team from an early stage developing a composite solution from a newly developed geometry and the loading constraints of the existing steel bridge structure as outlined and studied by Airey Engineering. The conceptual geometry including the main deck / pathway and structural beams and ribs were modelled and a finite element analysis was carried out on the modules in the central navigation span which were deemed to be the most critical due to the lack of available depth. The design of the FRP structure was carried out in accordance with a coherent Limit State methodology with the actions and load combinations taken from a relevant design codes. This design approach has been used by Gurit for the design of a wide range of civil and architectural FRP structures installed around the world using Euro Code or International Building Code to define actions and load combinations.

Global laminate specification was found to be driven by deflection criteria at the Serviceability Limit State. Local reinforcement and additional structure in way of the connections to the steel bridge structure is driven by static strength criteria at ULS. Fire performance was considered and the structural material choices meet NFPA Class B.

This preliminary analysis has led to a conceptual laminate based upon a Gurit® GPET 100 FR foam core with a quadraxial E-glass skins for the path way and beams. The FEA was beneficial in determining the most efficient use of carbon uni-directionals and E-glass unidirectional in the rib and frame specifications.

A weight and costing study was carried out carefully due to the weight critical requirements of the existing bridge allowing for a comparison and review of the loading to the original metal concept that had been proposed previously. Further development in the full design stage will be needed to extensively review all sections and details but at this concept stage 250 tonnes saving is predicted.

For a project of this scale and given the tight timeline that aims at completing the construction of SkyPath by the end of 2015, the cooperation of the wider New Zealand composite industry will be required. NZ Marine Industry Association’s Peter Busfield says “We believe SkyPath will be an exciting showcase for the NZ marine and composites industries. It will be a high profile demonstration of our expertise that will enable us to talk to many other sectors about utilising our services, and not just in NZ but internationally.”
The new lifting bridge over Rhyl Harbour in North Wales, serves as an additional crossing for pedestrians and cyclists. Spanning the River Clwyd from Rhyl’s West Parade to a newly created public area on the Kinmel Bay side of the river, the elegantly opening lightweight bridge named “Pont y Ddraig” has already become an iconic landmark attracting visitors. Hundreds watched the two lightweight composite decks – or dragon wings – being lifted into place in early Summer.

In response to a tender call from Denbighshire County Council, Ramboll and Dawnus developed a design proposal consisting of two mirroring, 30 metre long decks, which are hinged on a central caisson and lifted by cables running up to a central mast. Almost 50 metres tall, the mast is stayed by a rigging similar to a sail boat’s and makes the bridge and the harbour visible from miles around. The mast houses the pulley mechanism and lifting cables. To balance the lift, the decks, engineered by Gurit (UK) and built at AM Structures using many Gurit materials, are lifted simultaneously.

To give access to moorings upstream of the bridge, the new pedestrian and bike crossing is likely to open many times a day. So, the Denbighshire County Council was interested in minimising the use of energy for lifting. The use of advanced molded fibre reinforced plastic (FRP) for the bridge decks was an integral part of the design concept to save as much weight as possible to make lifting cycles fast and energy efficient. It also allowed a sculptured deck shape, which provides a striking, iconic sight when the bridge is opened.
Ramboll approached AM Structures in early 2009 to review the concept of the bridge deck construction and to provide feedback on the construction and weight estimate for the FRP decks. AM Structures asked Gurit to review the structure of the bridge, and initial studies confirmed that the bridge concept was feasible with some minor changes in the geometry, and that the FRP decks would result in considerable savings compared with a steel structure.

The design proved to be successful, and AM Structures was approached for the fabrication of the decks. Gurit was contracted by AM Structures to carry out the detailed engineering of the bridge decks, which presented some interesting challenges. The decks are very slender, partially for aesthetic reasons, but also to ensure that the inshore lifeboat would have sufficient headroom to pass under the lowered bridge at all tide levels.

Due to the lightweight and slender structure of the decks, detailed consideration of the dynamic behaviour of the bridge under pedestrian loading was required. The bridge was designed with predominantly glass reinforcements with longitudinal stiffness enhanced by local planks of carbon fibre. Gurit made extensive use of finite element analysis to carry out transient dynamic analysis of the bridge using load models from Eurocodes. A number of load conditions were analyzed, corresponding to groups of pedestrians walking and running over the bridge, in addition to a crowd loading case. This analysis led to optimisation of the laminates for both longitudinal and torsional stiffness of the bridge decks to meet the required comfort criteria.

AM Structures built the decks using Gurit® Corecell™ M, Ampreg 21 resin, and a mixture of glass and carbon reinforcements supplied by Gurit. The build of the decks was already a spectacular sight. But the shipment from the Isle of Wight to the mainland, the transportation to Wales and the lifting of the decks into place, all attracted crowds.

The new crossing needed a catchy name. A naming competition was open to pupils at local primary schools. An independent panel considered over 30 names and finally selected “Pont y Ddraig”, as one student had suggested. By the middle of July, hundreds of people had flocked to Rhyl with their cameras to catch the moment when the second deck – or is it a Dragon wing? – was lifted into place. A large crane hoisted the 30m long, FRP deck into place.

Following installation, Gurit will now carry out a testing program to verify the dynamic behavior of the bridge, using in-house accelerometers and data acquisition equipment.

The official opening was scheduled for September, when all pupils who had participated in the naming competition led the first walk across the bridge.
Case Study

Marsden Cross, Bay of Islands, New Zealand, 2013

Marsden Cross commemorates the place that became New Zealand’s first missionary settlement, where Reverend Samuel Marsden preached his first sermon on Christmas Day 1814. Plenty of celebrations are planned to mark the 2014 bicentennial anniversary and Gurit was involved in the creation of an impressive new landmark, the Interpretive Centre.

The Interpretive Centre is orientated directly towards the historic Cross where visitors can also walk down to. Its design is characterised by the contrasting curved rammed earth walls, symbolic of its grounding into tradition, with the thin triangulated composite roof, symbol of high technology, engineering and lightness.

Gurit was brought in to help the project managers meet the budget while achieving the modern geometric design and ensure the roof is structurally sound for years to come. After extensive engineering analysis, using a parametric model to combine shape and laminate optimisation, a final epoxy infused laminate of E-glass/Gurit® G-PET™ 90 was derived.

In the end, the addition of posts along with geometrical modifications allowed for additional structure not to be used, and achieved the lowest cost. The geometrical modifications were devised thanks to the optimisation functionalities of the Altair Hyperworks software, which allowed for varying the heights of the peaks of the structure, concurrently with varying the laminate.
Definition of the material cost as a custom design variable within the software allowed for driving the optimisation towards minimising cost rather than the more usual objective of minimising weight. Finally an optimum was found between minimum material cost, and structural integrity, while realising the artistic intent.

One of the benefits of having chosen composite materials for building the roof is that Core Builders Composites was able to pre-assemble the roof in two large parts at their factory. These were then trucked to the construction site where they were joined into the full roof assembly, which was lifted as one piece onto the supporting posts, thus minimising installation time.

Gurit was initially engaged to start work on the project in May 2013 and installation commenced in October, resulting in just 5 months to engineer and build the composite parts. The architect is thrilled with the results and has made very positive comments about Gurit’s involvement in his numerous public presentations of the project.
The Makkah clock tower, the central tower of the Abraj-al Bait development in Makkah, KSA, features FRP composite materials and structural engineering from advanced composite specialists Gurit.

At 607m tall the building is the second tallest in the world. The top 200m of the tower is clad with over 40,000m² of advanced FRP composite panels, including the largest clocks in the world - 43m in diameter, with 23m long minute hands. The cladding of the tower top includes intricate calligraphy and ornamental patterning, finished in glass and ceramic tiles. Illumination of the clock hands, clock faces and media wall, called for over two million LED’s to be integrated into the cladding panels.

Gurit worked closely with the tower top designers, SL-Rasch (Stuttgart, Germany), to carry out the structural engineering of the composite tower top cladding, clock hands, and the 23m diameter crescent, a self-supportive FRP composite structure which is located at the top of the building. Gurit supplied a range of advanced composite materials, to Premier Composites Technologies (Dubai, UAE), the company that carried out fabrication and installation of the cladding, clock face, clock hands and crescent. This included a new fire retardant wet laminating system from Gurit, Ampreg 21FR which was developed for lamination of the façade.

Lamination was carried out on direct CNC-cut moulds fabricated using Gurit’s T-Paste tooling paste on a polystyrene blank block. The easy machining, low cure shrinkage and high level of detail achievable with T-Paste enabled rapid production of accurate direct moulds for the part production.

The clock hands presented a particular challenge due to their long slender geometry and the potential for high wind loading. The clock hands were manufactured using Gurit’s WE91-2 carbon fibre prepreg material and Gurit® Corecell™ T structural core. Gurit originally developed WE91-2 and Gurit® Corecell™ T for use in modern large wind turbine blades. The excellent stiffness to weight ratio of the carbon WE91-2 prepreg combined with the mechanical properties, toughness and low resin uptake of Gurit® Corecell™ structural core enabled the realisation of a lightweight, stiff clock hand.

Dr Mark Hobbs, Senior Engineer, Engineered Structures at Gurit comments, ‘This has been a fascinating project to work on. It has presented numerous challenges, from the sheer scale and complexity of the project, to the integration of finishes and lighting into the cladding panels. It has been a pleasure to work as part of the talented multinational design and production team to find ways to realise the vision of the client and architect using advanced FRP composite materials. This project has made full use of Gurit’s wide range of expertise in the technology of advanced FRP composite structures, including materials development, processing, testing and structural engineering, and I think that we can be proud of our contribution to this landmark project’.

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The new Turkmen foreign ministry built in Ashgabat includes a unique 26m diameter spherical conference room at its top which is decorated with a map of the world realised in mosaic tiles. Gurit has worked along with the main contractor, Bouygues International to deliver a composite design for this sphere complying with the challenging technical brief and the tight schedule.

The sphere is made of 312 double curvature composite panels bolted together and supported by a metal substructure. Thanks to the use of a sandwich technology, panel weights have been kept low ensuring an easy and quick installation on site.

The climate in Turkmenistan required detailed thermal analysis to ensure that the composite panels would handle the wide range of temperature faced in this region, where variation in temperature is up to 60°C.

Gurit also provided an “on-call” daily support during the design & construction phase to ensure the project would be delivered on time.

The building was inaugurated in April 2011.
The new composite Bradkirk Bridge, featuring materials and technology supplied by Gurit UK, was installed in an impressive 6 hours in Blackpool, Lancashire during May 2010. The bridge replaced an existing metallic bridge that was life expired.

The bridge was manufactured by AM Structures Ltd for Network Rail and engineered by WYG and comprises of two 12m spans and two flights of steps.

Each span features a fully moulded composite monocoque structure and was manufactured using Gurit’s patented SPRINT™ technology which provides an autoclave quality laminate without the expense of using an autoclave.

Gurit’s Spabond 340LV and Ampreg 22 were also used for bonding, resulting in a virtually steel free construction with each span weighing only 1.6 tonnes.

A steel span designed to the current regulations would be likely to weigh around 16 tonnes.

The new Network Rail structure, with a total scheme cost of £665,000, was installed by Birse Rail during a routine line closure overnight on 17 May 2009 and was completed within 6 hours. The bridge is expected to last in excess of 60 years and be virtually maintenance free with the exception of routine inspections and replacement of non-slip finishes and stair noses.
The Bronx - Whitestone Bridge was completed in 1939, following a similar design concept to the Tacoma Narrows Bridge. Following the collapse of the Tacoma Narrows Bridge additional steel trusses were added to reduce the risk of resonance of the bridge under wind loading.

Over time the surface of the roadway was also increased to cope with heavier traffic loads. The resulting increase of dead load was resulting in excessive stretch of the main cable stays, and in 2003 a program of weight reduction was started for the bridge.

A major part of this was replacing the steel trusses on the side of the bridge with aerodynamic FRP fairings. Gurit engineered the fairings, which were manufactured in the USA using resin infused solid glass laminates.

The project had a total of 20,000m² of fairing, which made it the largest use of structural composites at the time. Replacement of the trusses and other changes to the decking reduced the bridge’s weight by 6000 tons, some 25% of the mass suspended by the cables.
Gurit engineered a composite footbridge span for installation in Lisbon for the 1998 EXPO. Two of the bridges span across roads, and the third crossed a railway line. Design was carried out to Portuguese codes, including seismic load cases.

The bridge spans over the road were supported by metal columns with metal stairs. The deck and soffit of the bridge span were constructed from moulded composites with a mixture of carbon and glass reinforcement. Carbon sections formed the shear webs, resulting in a light and airy structure. The resulting bridge had a mass of 6.2 tonnes for a 30m clear span bridge.

This enabled rapid installation, with the road closed for only 30 minutes whilst the span was lifted into place. In addition the light weight of the bridge minimised the foundations required, which avoided disturbing the services running underneath the pavement.

The FRP structure of the bridge has only been subject to a minimal maintenance routine, and a review of the structure after 12 years indicated that the FRP structure was in good condition, although fairly dirty. The metal supporting structure and stairs were starting to show significant corrosion.