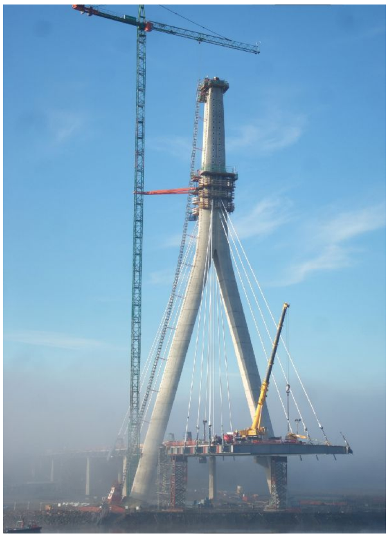
SINGLE CONCRETE PYLON SUPPORTS IRELAND'S LONGEST CABLE-STAYED BRIDGE

Eugene O'Sullivan, Construction & Civil Engineering Department, Waterford Institute of Technology.

Joint venture contractors, BAM (Ascon) and Dragados, are expected to close out construction of the €530 million Waterford Bypass PPP project in the final quarter of 2009, well ahead of the August, 2010 contract deadline. The centre-piece of the project is the record-breaking 465m cable-stayed bridge being constructed across the river Suir, 2km west of Waterford city. Designed to carry two lanes of traffic in each direction, the river crossing will be Ireland's longest and tallest cable-stayed bridge. It will have a 230m uninterrupted span across the river, two back spans of 91.5m and 66.5m and end spans of 35m and 42m.

The river span will be the longest constructed in the Republic of Ireland, and will join Kilkenny on the north side to Waterford on the south side of the river. The total height of the dramatic inverted Y pylon, from the base of the pile cap to the top of the beacon is 118m.



The bridge deck will be supported by steel cables radiating out in a fan shaped arrangement from the single pylon constructed within a reclaimed peninsula on the south edge of the river. The river span will provide a clearance of 14m at mean high water springs over the navigation channel.

Almost three years after start of construction in mid 2006, the cable-stayed bridge has reached a number of significant milestones; the topping out of the reinforced concrete pylon, the erection of the majority of the composite deck and the simultaneous installation and stressing of the cables.

In addition to the cable-stayed bridge, construction is continuing apace on 23km of dual carriageway and other link roads, sixty other structures, including bridges, culverts, a toll plaza and two complex grade-separated junctions. The project will tie in with the M9 motorway from Waterford to Dublin, which is expected to be fully completed by the end of 2010.

The National Roads Authority awarded the PPP design, build, finance and operate contract, with a 30 year concession, to the Celtic Roads Group; comprising BAM PPP (Ascon), ACS (Spanish contractor Dragados) and NTR.

Through the valued cooperation of the engineering personnel from the contractors, consulting engineers and client, the Construction & Civil Engineering Department at Waterford Institute of Technology (WIT) implemented a 'project watch' to monitor progress and allow students become aware of the innovative thinking and problem-solving strategies used on one of the most complex infrastructural projects ever undertaken in Ireland. The expertise gained from the project will be linked back into the undergraduate and postgraduate curricula at WIT.

Pylon foundation

The combination of difficult ground conditions and the use of a single pylon design challenged the contractor in developing a radical solution for the design of the pylon foundations. Geocisa, the geotechnical division of Dragados, used a rotary-bored micropiling system to penetrate the fragmented strata of very hard sandstone and weathered mudstone. Micropiling, not used previously on heavy structures in Ireland, is more associated with underpinning, but has been up-scaled for use under large structures in the USA. The micropiling for the pylon took place inside a bunded cofferdam in the river, reinforced by a double line of vertical sheet piles to prevent water ingress.

The micropiles have lengths of up to 35m and are socketed on average 12m into the underlying rock strata. The majority of the micropiles are vertical, while the remaining piles are at an angle of 10 degrees, designed to resist forces during installation of the deck and to combat wind and transportation forces in future service. The micropiles depend largely on frictional bond between the pile and rock, rather than on toe resistance from the sometimes weathered rock.

Essentially each micropile is made up of three steel cylinders, one inside the other. The 410mm diameter sacrificial outer casing (5mm wall thickness) goes through the soft clay of the river bed and penetrates about 1m into rock.

Further boring was then carried out inside the casing to approximately 12m into the underlying rock and a 340mm steel cylinder (13mm wall thickness) was pushed down the full distance inside the excavated space, followed by a third steel cylinder of 178mm diameter (11mm wall thickness). The three steel cylinders were kept apart by incorporating spacer bars at 10m centres.
After flushing all debris out of the borehole, a 35MPa grout was pumped into the space between the steel cylinders, to form what might be loosely described as a steel cylinder-reinforced concrete bored pile. After the 9/11 terrorist attacks in New York a similar idea has been used in the design of columns of tall buildings, whereby structural steel and reinforced concrete can be substituted by concrete filled tubes (CFT) to provide significantly greater strength.

Each of the two legs of the inverted Y pylon sits on a 5m deep pilecap, which are connected by a 30m long post-tensioned tie beam; approximately 2150m^3 of concrete was required for the combined pylon foundation. A 40MPa concrete, 0.45 water/cement ratio and 50% Ground Granulated Blast Furnace Slag (GGBS) was specified, primarily to provide higher durability and to control temperature in the large foundation pour. GGBS is a by-product of the iron industry and is used as a partial replacement for cement. GGBS concrete is designed to counteract de-icing salts splashed on to the concrete surface of the pylon by passing vehicles and also to be resistant to the saline conditions of the Suir estuary. From an environmental viewpoint, GGBS requires significantly less energy and emits only 10% of the carbon emissions of cement.

Foundations' specialist, Bachy Soletanche, piled the back supports of the bridge, using a more conventional bored piling system to that deployed by Geocisa. Piles up to 1500mm diameter were bored to a depth of 48m with 18m rock sockets. The piles required temporary casings to support weak rock and soil. Prefabricated reinforcement cages were dropped in, extended by welding the reinforcement bars and up to 90m^3 of concrete pumped in to each pile.

Bridge pylon

The inverted Y-shaped pylon dominates the skyline on the approaches to Waterford city. The contractor used Doka's SKE 50 automatic climbing formwork system, which has four different platform levels, allowing the reinforcement to be placed ahead of the concrete pouring operation. Climbing was done hydraulically without a crane and a lift of 4m was completed per week, with a 42m^3 concrete pour achieved per pylon leg over a six hour period on the same day. The 50MPa concrete, again with 50% GGBS mix, was initially pumped to an approximate height of 40m and thereafter placed by skip, using the tower crane.

Marciano Duro, Chief Surveyor, Dragados, said that setting out tolerances were very strict for the pylon and extreme care had to be taken to ensure that the profiled timber forms were dimensionally correct to adapt to the changing pylon section. The pylon from foundation to deck level is constructed of a solid reinforced concrete section; from deck level upwards the legs are hollow with a thickness of 620mm on the interior wall to 1390mm on the exterior wall. The legs of the pylon merge at a height of 66m above pile cap level. The climbing platforms had to be adapted to suit the sectional requirements of the tapering vertical 46m head of the pylon and the same formwork components were used on both the pylon legs and the pylon head.

The Doka platforms also facilitated the construction of openings to install the sleeves for the cable anchorages. To facilitate inspection and maintenance of the cable anchorages, lifts are incorporated into one of the pylon legs and the pylon head, while there are stairs in both pylon legs and steps in the pylon head.

A number of issues had to be considered in the lower pylon construction. Firstly, accurate setting out was required, due to the varying thicknesses and profiles of the pylon wall rising at 15 degrees. Secondly, as the two legs of the pylon leaned towards each other and became heavier with increasing height, a temporary horizontal bracing system had to be incorporated at near mid height level to minimize deflection of the legs.

The bridge design company, Carlos Fernández Casado, has incorporated attractive architectural finishes into the pylon and the other piers supporting the bridge. The bases of the legs of the pylon resemble the prow of a ship and the inverted Y pylon section itself has graceful lines and curves, all of which posed a challenge for the formwork specialists.

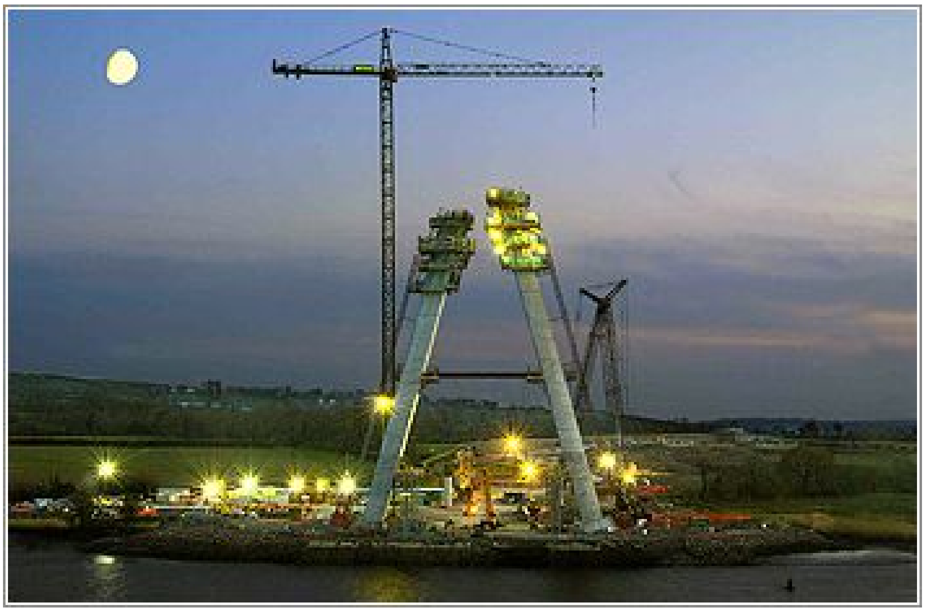
The contractor used a 12t Wolff tower crane to service the construction of the pylon and this required the provision of a pad foundation sitting on four micropiles to a depth of 25m. The crane is sited in a very exposed location in the river valley; the foundation had to initially support a free standing 80m high tower crane. To service the construction of the higher part of the pylon, the crane was re-erected to an intermediate height of 110m and finally to 128m, using a special long reach 500t crawler crane, similar to that used on the Dublin Spire. At the increased crane heights the tower crane was tied to the pylon to counteract excessive overturning moments. It takes the crane operator up to 45 minutes to climb the 440 steps to his cabin in the sky.

Bridge deck

The deck design is a composite steel-concrete structure, approximately 1.8m deep and 26m wide, with precast concrete panels on top of two steel edge girders connected by transverse floor beams at 5m centres. The gaps between the precast panels are stitched together with in-situ reinforced concrete. The overall design of the bridge demonstrates the effective use of steel-reinforced concrete construction. The cables and structural steel deck provide bending and tension resistance, while the reinforced concrete pylon and precast deck slab are mainly in compression.

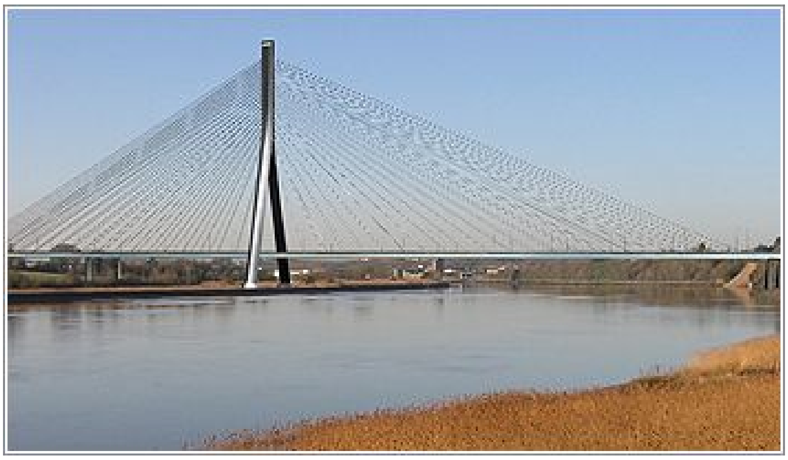
The structural steel deck units were fabricated by Fairfield Mabey in Wales, transported by low-loader/ro-ro ferry to Rosslare and then directly to the southern access road to the bridge site.

Banagher Concrete, also heavily involved with precast concrete beams for other bridges on the Waterford Bypass, supplied the 10m x 5m x 280mm precast deck panels for the cable-stayed bridge. Deck erection commenced at the pylon and initially proceeded over the back span, requiring the use of temporary structural steel support trestles between the piers, with spans varying between 25m and 38m.



The erection of the deck over the river required more complex solutions. The contractor opted for transporting individual steel sections along the back end of the temporarily supported deck and then progressively erected the sections out over the river from the end of the completed bridge section. This required a deck based crane and a low-loader to travel over the precast concrete deck surface. The exception to this construction technique was the placing of the 85t double edge girders where the bridge widens to 36m at the north end. The giant floating crane, Mersey Mammoth, lifted the girders into position on the high spring tides on two consecutive evenings in mid March, 2009.
The asphalting of the bridge deck, directly on to the precast slabs, will be undertaken after the cabling operations and associated heavy construction activities have been completed.

Bridge cables
The function of the cables is to transfer the loads on the bridge to the foundations via the pylon. The cables radiate out in two planes from different levels of the pylon head in a semi-fan arrangement. In all there are 76 cables, ranging in diameter from 355mm to 455mm; the longest cable supporting the bridge is 224m and weighs 18t. Supply and installation of the cables is under the aegis of post-tensioning specialists MeKano4, Barcelona, while fatigue and static tests were undertaken in Zurich and Nantes.



Raimundo Saiz Pérez, Civil Engineer, Dragados, explained that each cable contains between 26 and 55 strands. Each 15mm diameter strand consists of 7 galvanized wires of prestressing steel and the strand is protected by wax inside a 1.5 mm thick PE sheath. The parallel strands are housed in a continuous ultraviolet-resistant HDPE stay pipe. Apart from providing corrosion protection, the pipe is equipped with external helical ribs, designed to suppress wind and rain vibration. The cables are connected at 10m intervals along the deck; the lower end of each cable goes through a steel pipe, connected through plates to the edge beams. Damping is incorporated into the deck anchorages.

Innovation on the bypass

While the river crossing is the landmark feature of the project, there are many other complex and innovative structures on the Waterford Bypass Project. Mark Phelan, Project Manager, BAM, pointed out that the scale of geotechnical and foundations projects carried out are impressive. Eleven bridges are under construction within a 500m radius of the Grannagh Interchange, including three bridges of 155m length and a pergola design skew bridge unique to Ireland. A 200m long, six-span reinforced concrete viaduct consisting of 30m high in-situ concrete piers and precast concrete U-beams has been constructed near Kilmeaden over an ecologically sensitive valley.

Approximately 900 precast concrete piles, 800 CFA bored piles and 90 micropiles were installed to support bridges, culverts and embankments for the complex junction at Grannagh, which includes railway, road and river crossings. The soil in this area consisted of a 12m layer of peat overlying rock, which was stabilised by inserting 500,000 metres of vertical geotextile band drains and applying ground surcharge. Three levels of gravel embankments were placed, each layer requiring an average period of three months to consolidate the underlying weak soil.

Multiple challenges

Tadhg Lucey, BAM, who is joint project director with Ruben Casanova, Dragados, commented that this diverse international civil engineering project has thrown up many technical, logistical and cultural challenges. Apart from the demanding site conditions, the less than perfect Irish weather and the use of innovative technology to simultaneously contain costs and meet quality criteria, the joint venture contractor has to operate within the confines of a PPP contract, manage a culturally diverse workforce and coordinate the input of many designers, specialists and suppliers from different parts of Europe. The use of advanced project management systems enabled the contractor to more effectively coordinate design information in real time from various stakeholders located in Ireland and abroad.

The new road transportation infrastructure should provide the south east region with the platform for a revival of its economic fortunes in these challenging times and the elegant cable-stayed bridge, crossing the river Suir at a historic location upstream of Waterford city, is set to become its symbolic gateway.

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Eugene O'Sullivan, Chartered Engineer FIEI is a senior lecturer in the Department of Construction & Civil Engineering at Waterford Institute of Technology. A civil engineering graduate of University College Dublin, he holds a Master of Engineering Science degree from UCD and is a Fellow of Engineers Ireland. Eugene previously worked on harbour, geotechnical, infrastructural and gas/chemical projects in Spain, Libya, USA, Holland, the UK and Ireland.

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