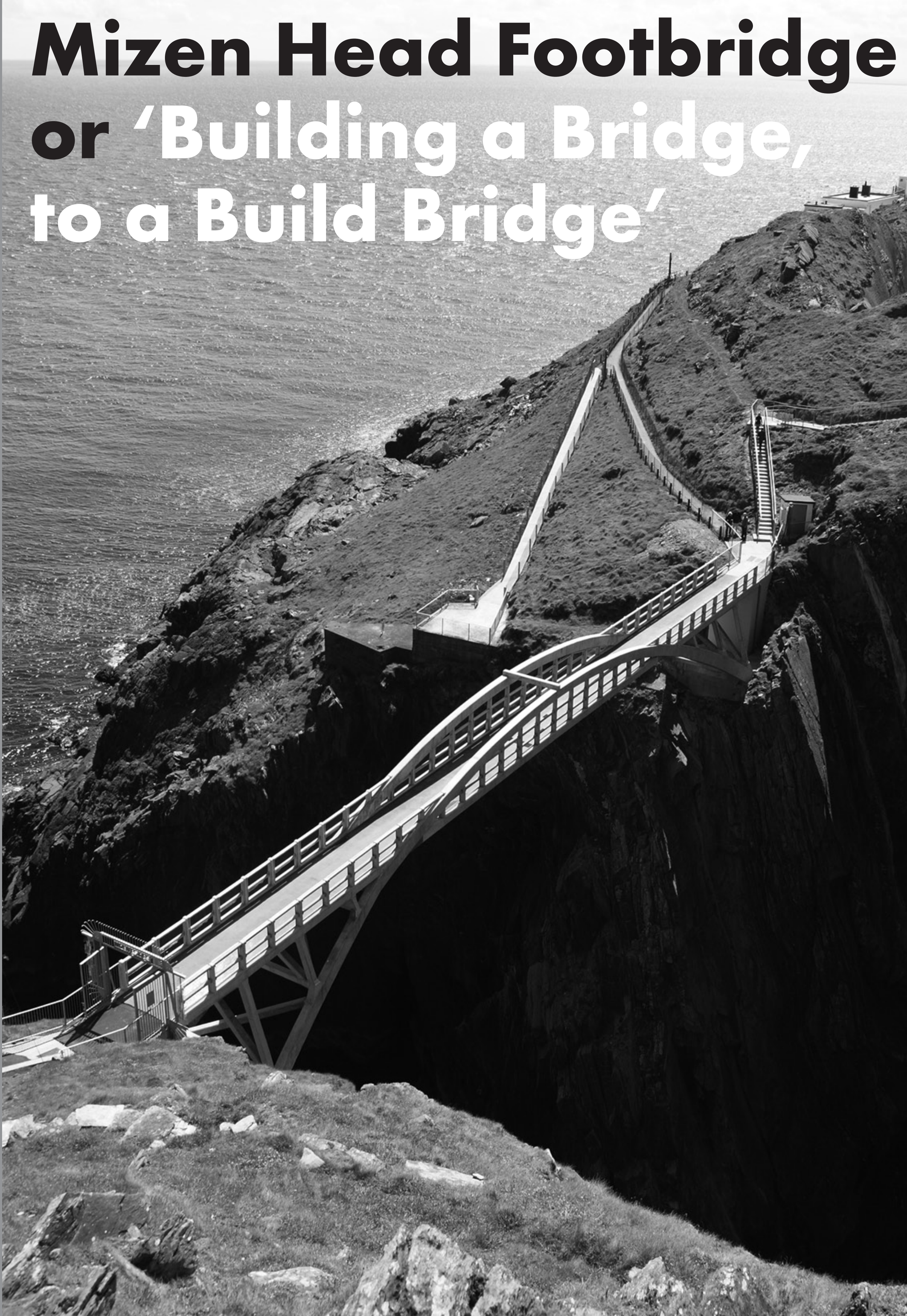
Mizen Head Footbridge or 'Building a Bridge, to a Build Bridge'



MIZEN Head Footbridge in County Cork is a reinforced concrete through-arch structure spanning 50 m. The original structure was demolished and rebuilt 2009-2011, 100 years after its completion. This article describes the construction challenges of safely reconstructing a bridge in a difficult site location.

The bridge provides access to a lighthouse on the tiny island of Cloghán, at the tip of Mizen Head in Southwest Cork. It is the result of a design competition held in the early 1900's. The winning entry was by Mr. Noel Ridley of Westminster, London. It had the form of a pair of parabolic arch ribs spanning 50 m supporting a pedestrian deck, suspended by vertical hangers from the ribs in the central section.[1]

By Kieran D. Ruane

ON October 18, 1907, sanction was given for the erection of a reinforced concrete bridge to give access to the island. Construction commenced in 1908 and was completed in 1909. The Contractor was Alfred Thorne and Sons of Westminster, London, at the cost of £1,272.

The original bridge comprised both precast and *in situ* reinforced concrete elements. The arch ribs were constructed in stages both onshore and *in situ*.[2,3] The initial rib cross section was an open precast concrete trough to allow launching of the ribs. The section allowed precast concrete trestles and deck edge beams to be added before the ribs were completed with in–situ concrete. The bridge deck and the hangers were cast in–situ. The reinforcement in the structure was in the form of round bars, rectangular bars and sheets of steel folded in a corrugated manner. It was a construction of an era of proprietary reinforced concrete, following the Ridley–Cammell system.[4]

The Site

It is difficult to get access to the bridge site, a sea gorge between the mainland at Mizen Head and the tiny island of Cloghán. The soffit of the bridge is some 45 m above the bottom of the gorge. By vehicle it is possible to access to within 300 m of the mainland abutment. Thereafter, access becomes a narrow and steeply inclined footpath.

Origins

From the start maintenance activities on the bridge have been carried out by the Commissioners of Irish Lights. A maintenance contract was undertaken in 2000 for repainting the bridge and carrying out concrete repairs. An inspection at this time revealed areas of spalled concrete and severe reinforcement corrosion, particularly at a joint between a deck hanger and the northern edge beam. In 2002, structural engineers RPS (then M.C. O'Sullivan and Company Ltd.) were appointed to conduct an inspection and assessment of the footbridge. Specific information was collected by material tests, observations and geometrical surveys. This information helped to establish the condition of the structure and provide material and geometric parameters for analytical models and for maintenance, repair or strengthening scheme development. The defects noted during the inspection were summarized as rust staining, areas of hollow sounding concrete, cracking and localized areas of missing concrete. All the defects noted were related to corroding reinforcement. No defects caused by structural actions were observed. In general, the visual inspection of the bridge found it to be in good condition given its age and its location in an exposed site.[5] This was due to the quality of the original construction and to the regular maintenance of the bridge.

Material tests were used to determine the integrity and strength of the concrete and to investigate reinforcement corrosion mechanisms. Both non–destructive and destructive tests were used ranging in complexity from hammer tap surveys to petrographic examination. BA 35/90[6] presents information on these and other tests with useful references.

Two 105 mm diameter cores were taken from the deck of the bridge. One of these cores was compression tested and found to have an equivalent cube strength of 27.5N/mm^2. Three cores removed from the arch ribs in 1990[7] were compression tested and found to have equivalent cube strengths of 70.3, 46.4 and 72.9N/mm^2.

Petrographic examination was carried out on two core samples taken from the structure. The coarse aggregate used in the deck construction was dominated by crushed greywacke and sandstone particles having a nominal maximum size of 14 mm. The aggregate in the coarse fraction was probably locally derived.

< Mizen Head Footbridge by **Mr. Noel Ridley**, in 2004.

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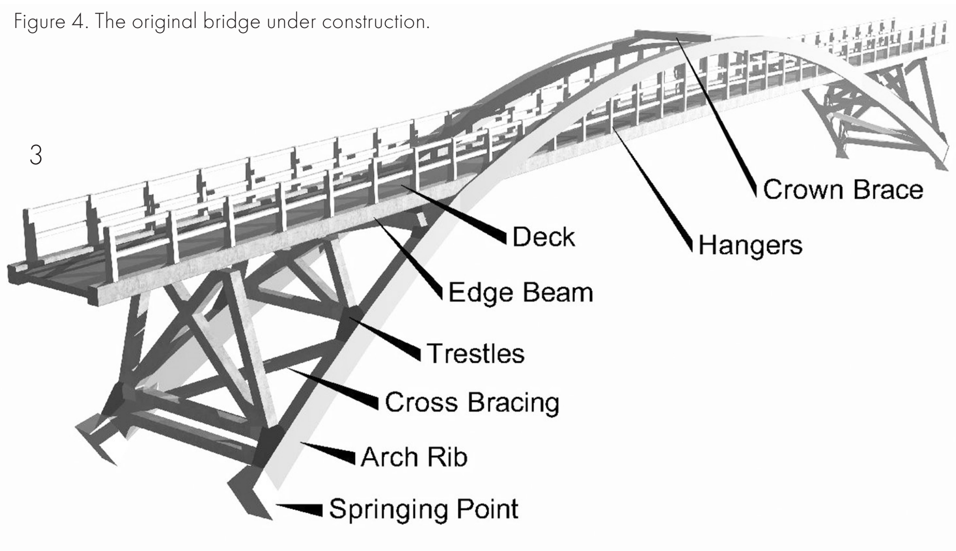
Figure 1. Temporary access scaffold supported directly from the arch ribs erected in June 2005.

Figure 2. Petrographic analysis of the original bridge concrete showing presence of sea shells.

Figure 3. The structural elements of the bridge.

Figure 4. The original bridge under construction.



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No evidence of damage due to alkali–aggregate action was found in the petrographic examination, although traces of gel were present in voids in the paste. Examination of a thin section taken from a portion of the core sample showed fine cracks running through aggregate particles into the cement paste. These were found to contain alkali silicate gel and indicated that an expansive reaction had taken place between the greywacke aggregate and alkalies in the paste, causing very localized damage to the concrete in the area where the core had been taken. This is considered to be the only reported example of alkali–aggregate reaction in Ireland to date.

In summary, chloride content levels were very high throughout the structure. This did not affect the integrity of concrete directly but it provided a mechanism for reinforcement corrosion to occur. Evidence of damage to concrete caused by the expansive product of reinforcement corrosion was clear in the inspection. Defects ranged from areas of hollow concrete where corrosion had caused delamination of the cover zone to areas of spalled concrete. Carbonation levels were very low. Based on the petrographic examination, low levels of alkali–aggregate reaction, low carbonation levels, high chloride levels, and strength estimates from cores and Schmidt hammer tests, it was concluded that the concrete, excluding the concrete in the cover zone, was of a sound nature.

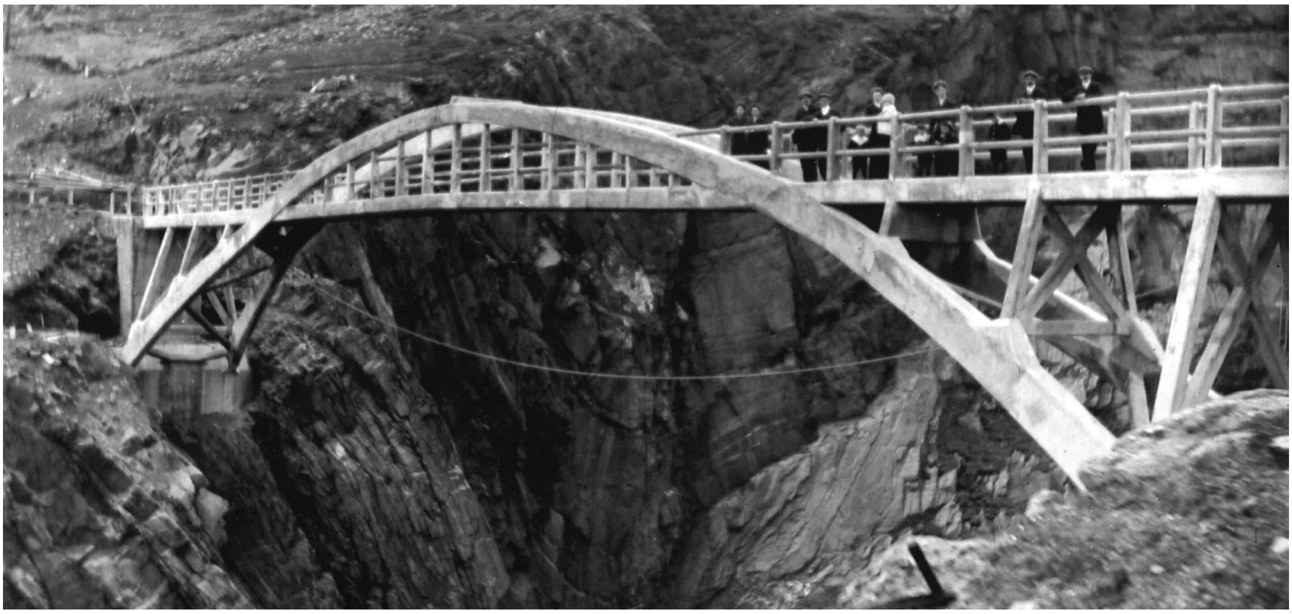
Based on the original construction drawings and the information gathered during the principal inspection, a finite element assessment of the structure was performed by RPS. The results indicated that the structure was adequate for continued use due to good reserves of structural resistance to applied dead and live loading effects.

However, given that the central suspended span of the deck was relying on reinforced concrete hangers in direct tension and given the high chloride induced steel corrosion throughout the structure, it was recommended that the hangers be strengthened and that measures be taken to halt the corrosion of reinforcement in the structure. A monitoring regime was placed on the structure to allow regular inspections at six–monthly intervals.

In 2004, a Preliminary Report for Strengthening and Repair of the Mizen Head Footbridge was produced. It was recommended that the hangers be reinforced with Near Surface Mounted Fibre Reinforced Polymer (NSM FRP) bars, that concrete repairs be undertaken to repair defects on the structure and that a cathodic protection system be installed on the structure to stall the rate of reinforcement corrosion. However, it was noted that the suitability of the structure to receive a cathodic protection system would need to be confirmed by specialist testing before a definite recommendation could be made.

In February 2005, electrical continuity testing of reinforcement in the structure was undertaken to assess the feasibility of providing a cathodic protection system for the structure. The specialist testers concluded that there was a limited amount of reinforcement continuity within the arch ribs and within some hangers but that there was no general continuity of reinforcement steel within the structure, either between structural elements or within individual elements.

Following the issue of the electrical continuity testing of the Preliminary Report, the Mizen Footbridge was closed to pedestrian traffic. In June 2005, an access scaffold for the bridge was procured. The scaffold was sup-



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ported directly from the arch ribs only and provided an independent bridge deck for the structure. The scaffold allowed access to be maintained at Mizen Head until a permanent solution was developed. It was expected that the scaffold would have a lifespan in the region of three to five years.

Detailed Scheme Development

A revised Preliminary Report was presented to the Commissioners of Irish Lights in September 2005. It considered the following solutions:

Option 1: A strengthening and repair scheme which involved an initial strengthening and repair of the arch ribs and rib braces followed by a sequential removal and replacement of the remaining elements of the deck superstructure. The mass concrete foundations at the arch springing points and deck ends would be retained.

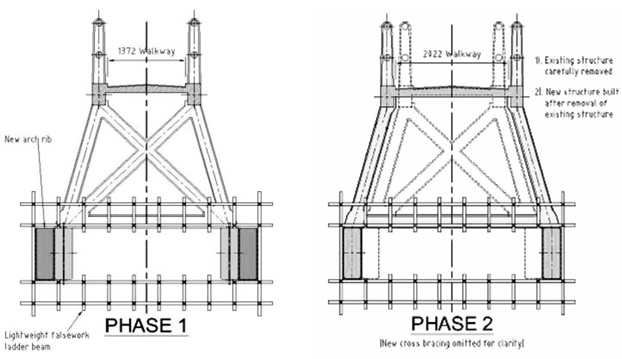


Figure 5. Sectional elevations through the bridge indicating the solution to use the existing ribs as falsework for the construction of new ribs. The new ribs would then be used to support demolition works on the old bridge.

Option 2: A scheme which initially involved the construction of new arch ribs (parallel to and outside the existing ribs) using the existing ribs (strengthened if required) as falsework, followed by the sequential demolition of the existing bridge, followed by the construction of
trestles edge beams, hangers, and the deck slab. This scheme produced a replica of the existing bridge though the deck would be 700 mm wider. The mass concrete foundations at the arch springing points and deck ends would be retained.

Option 3: A scheme which involved replacing lost steel throughout the structure with small diameter FRP (Fibre Reinforced Polymer) bars using the NSM (Near Surface Mounted) method followed by a large concrete repair scheme.

Various factors fed in to the selection of the preferred option. These included heritage considerations, cost, environmental issues, ease of construction, health and safety, and durability.

Option 2 was recommended as the preferred option

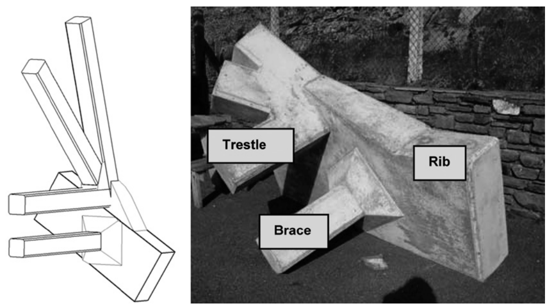


Figure 6. Trial panel comprising braced arch rib section at trestle support.

as it maintained the current appearance and form of the bridge, it gave the best long term solution and provided an economic solution which could be built safely with minimal impact on the environment.

The replacement structure was designed as a two-pinned arch. Analysis was undertaken using the LUSAS finite element system and design was undertaken to British Standard BS5400. The live loading consisted of $5kN/m^2$ nominal pedestrian loading and a maintenance vehicle load case.

Construction

A tendering process took place in 2009. Funding for the project was provided by Fáilte Ireland (the Irish Tourism Authority), Cork County Council and the Commissioners of Irish Lights. Under an agreement between Cork County Council and the Commissioners of Irish Lights, Cork County Council undertook the role of Employer and entered in to agreement with Irishenco in September 2009 for the demolition and reconstruction of the bridge. Works commenced in October 2009 with measures to improve access to the bridge. There was limited scope to widen the lower reaches of the footway to the mainland abutment. However, the upper reaches of the footway were locally widened to allow limited access for delivery vehicles and construction plant.

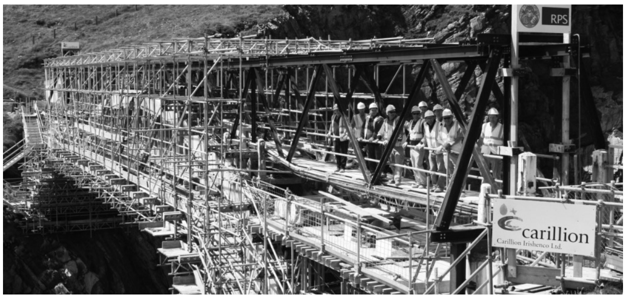


Figure 7. Erection of the temporary truss. All of the members were delivered and erected by hand.

Construction of the trial panel was an early activity in the construction program. It allowed the engineers, carpenters and reinforcement fixers to develop their detailed construction plans before undertaking the permanent works. The geometry of the bridge was difficult to form. The ribs vary in depth and they are flared out in the back-spans. Where members such as braces and trestles intersect the ribs, the member ends are locally widened with tapering faces. Each of these details was faithfully reproduced from the original bridge and detailed in to the new works. The carpenters likened the formwork required to construct the new bridge to cabinet-making such was the complexity involved.

At tender stage, Irishenco proposed the concept of 'Building a Bridge, to Build a Bridge' i.e. to construct a temporary bridge prior to the commencement of full-scale construction and demolition works. The purpose of this temporary bridge was primarily to act as a fail-safe for the duration of the works. This concept was advanced after the contract was awarded and it fed in to the detailed development of Irishenco's temporary works design.

The temporary works design included:

- Use of the existing arch ribs to support the construction of the new ribs, an access scaffold in the back-spans and a temporary deck system.
- Use of a 52-metre-long steel truss to span across, and above, the existing bridge deck to act as a fail-safe for the works, to provide support to the main access scaffold and to provide support to an overhead winch and gantry capable of lifting and transporting a safe working load of 1,500 kg.
- Use of a large scale scaffold to allow full access to all parts of the central portion of the bridge.
- Use of the new arch ribs to support the demolition of the old arch ribs and the construction of other permanent works structural elements.

Key stages of the integrated demolition and reconstruction sequence are detailed below.

Demolition of Suspended Deck and Hangers and Construction of New Deck and Hangers

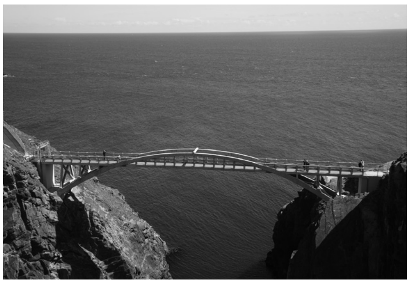
The existing deck was propped off the temporary deck and the hangers were removed using circular saws. The existing deck was wire-cut in to pieces lowered on to the temporary works deck and removed with the overhead winch. Formwork was installed for the new deck and edge beams, reinforcement was fixed and the new elements were poured. New hangers were subsequently fixed and poured.

Demolition and Reconstruction of Back Spans—Trestles, Edge Beams and Deck

The original deck and edge beams in the back-spans were demolished and removed from the bridge. A temporary deck was installed prior to demolition works. This was supported from the original arch ribs and it allowed the demolition of the deck and edge beams in the back-spans to be undertaken in the same manner as the suspended deck in the centre of the bridge. Trestles, edge beams and deck section were constructed.

Transfer of Loading to the New Ribs—Demolition of the Original Ribs and Braces

Prior to the demolition of the original ribs, all of the temporary works which were relying on the original ribs for



Images of the New Mizen Bridge completed in 2010.

support were transferred to the new ribs. As both sets of ribs were located at the same level, the exercise involved a careful inspection of the myriad of support details to ensure that all loads would be transferred smoothly. It was essential that no temporary works element could snag on other elements on removal of the original ribs. Such a situation could give rise to a suddenly applied load and a crush injury hazard. Supports were also adjusted so that the original ribs would be supported from the new ribs. The new ribs were also braced off each other for stability. Hinges were cut in to the original ribs at the springing points. Finally hinges were cut in to the crown of the original ribs. These were gradually reduced and eliminated so that the original ribs were directly supported by the new ribs. Demolition of the ribs now proceeded through the use of concrete circular saws, coring and mechanical expansion jaws.

Construction of Braces and Composite Deck Sections, Grouting of Mesnager Hinges

The final structural elements to be constructed were the braces between the ribs in the back–spans and the section of deck composite with the arch ribs at the quarter–span points. Following this, the main temporary works were sequentially dismantled and removed from the site. The Mesnager hinges were grouted and the remains of the original arch ribs were finished in concrete to provide a legacy of the original structure.

Conclusion

The New Mizen Bridge was completed in December 2010 and opened to the public on March 17, 2011. The project was delivered safely to program and within the scheme budget. It was a project marked by a very successful collaboration between client, contractor, and engineer. The new structure is a fitting testimony to the original concept and contractor and to the Commissioners of Irish Lights who looked after the original structure for hundred years. The new structure also preserves a landmark feature on the coast of Ireland for future generations to enjoy.

References

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The author gratefully acknowledges the support of the funding authorities throughout the project: Fáilte Ireland, Cork County Council and Commissioners of Irish Lights.