Ave River Bridge – A Major Precast Prestressed Concrete U-Girder Bridge in Portugal

Only within the last 20 years has precast concrete construction been used in the Portuguese infrastructure. This paper presents the new bridge over the Ave River in northeast Portugal as an example of the current technology of precast concrete. The 280 m (919 ft) long bridge is one of the most innovative precast concrete highway bridges built in northern Portugal. A detailed description of the design, fabrication, and construction is provided to explain the complexity of the designer's structural solution. The structural division of Minho University in Guimarães, Portugal, provided scientific and technical support during the instrumentation of the girders and prepared the long-term monitoring plan. Results of load tests, details of the monitoring plan, and measurements obtained during prefabrication and in various construction stages are presented.

Construction of precast, prestressed concrete bridges does not have a long history in Portugal, on Europe's western coast. For many years, all highway and railway bridges were constructed as cast-in-place concrete structures or, rarely, as steel structures. Most of the concrete bridges built were reinforced with ordinary mild steel, and where it was necessary and economically justified, prestressed with post-tensioning cables.

The first applications of precast, prestressed concrete girders for highway bridges occurred as recently as the late 1980s and the beginning of the 1990s. Portuguese engineers familiar with the precast industry relate that in the 1970s and 1980s some viaducts were probably constructed from concrete girders prefabricated on site, but these were isolated instances and not a reflection of the country's general construction trends.

The first precast concrete bridges built in Portugal were simply supported structures of secondary infrastructure importance. Bridge owners and major contractors did not have much experience or confidence in using this type of structural solution. As a result, Portuguese precast concrete companies faced inherent challenges in entering the bridge construction market.
During the last decade, the Portuguese Road Network began a major highway construction initiative. The demand for decreased travel times, increased transportation efficiency, and vehicular volume prompted the construction of new highways between the major cities. The necessity for minimizing construction time, project costs, and the related overhead for program administrators, contractors and bridge owners led to the consideration of — and preference for — the system efficiencies afforded by precast concrete solutions.

In the last ten years, precast concrete bridge systems have become a more common method of construction, and the evolution to more novel structural solutions is apparent in Portugal. Different types of precast concrete I-beams became available in the market. The precast industry also introduced new bridge components, including double tees and other precast concrete girders. Structural engineers increasingly proposed special precast concrete solutions for multispan structures.

In the beginning of this transition toward precast concrete systems, structural continuity was specified using cast-in-place (CIP) diaphragms and mild steel reinforcement at the ends of the girders. Later, continuity using post-tensioning parabolic cables became common in bridges with longer spans. A few years ago, the largest precast companies in Portugal launched the production of U-shaped girders because these precast elements were more economically competitive and aesthetically pleasing for several types of bridge design.

Some new methods of continuity had to be developed, namely, by utilizing post-tensioning bars in the top diaphragms and straight cables in the CIP slab. This structural solution, with continuous box girders made of precast U-beams, is becoming more popular. Within a relatively short period of time, many bridges have been erected using precast concrete designs.

During the construction of new highways, contractors decided to use U-shaped precast concrete girders in most structures with spans between 20 and 30 m (66 and 98 ft). Precast concrete bridges with spans up to 40 m (131 ft) have been built and the technology exists for increasing the length limits.

**BRIDGE DESCRIPTION AND DESIGN**

The new bridge over the Ave River was constructed during 17 months beginning in 2001, and was opened to traffic in July 2003. The Ave River Bridge is an interesting example of arguably the most innovative of the precast system possibilities for bridges constructed in Portugal (see Fig. 1).

The purpose for building this transportation link was primarily to diminish traveling time between the cities of Braga and Guimarães, and to reduce traffic on the existing regional road, which passes through many small villages.

Because of the difficult conditions of the terrain and demographics (mountains, valleys and high population density), this highway is characterized by a fairly complex geometry in plan and profile that is reflected in the innovative solutions of the engineered structures.

The Ave River Bridge was designed in a horizontal curve in plan view (see Fig. 2) with a radius of 1.65 km (1.03 miles) and a vertical curve in profile with a radius of 16.0 km (9.94 miles). The crossing angle of the highway in relation to the Ave River is 71 degrees, which causes a 19-degree skew of the main bridge.

Two separated roadways for east and westbound traffic compose the cross section of the highway bridge. Each roadway consists of:

- Two demarked lanes and two external hard shoulders, 3.25 m (10.66 ft) wide
- An internal hard shoulder, 1.0 m (3.3 ft) wide
Fig. 3. Elevation of entire structure, showing three structural solutions.

- A 2.25 m (7.38 ft) wide central median
- An inspection gangway, 1.0 m (3.3 ft) wide

This configuration permits the future launch of an additional lane without necessitating any major structural alterations to the existing bridge.

As a critical transportation link, the new bridge was designed for Class A traffic loads according to relevant codes and specifications. Allowance for a future increase in the number of lanes was taken into account during design. To reduce the total cost of the bridge and to simplify the construction process as much as possible, contractors and designers decided to divide the 280 m (919 ft) long bridge into three separate structures.

Shown in Fig. 3 are the 128 m (420 ft) long west access viaduct on the Ceirós side of the river, the 120 m (394 ft) long main bridge, and the east access viaduct on the Guimarães side, with a total length of 32 m (105 ft). Different structural solutions were proposed for the design of the viaducts and bridge.

Access Viaducts

The west access viaduct is a continuous structure with eight 16 m (53 ft) long spans. Due to the horizontal curve, the actual length of the spans in different girder alignments varies from 15.85 to 16.15 m (52.00 to 52.98 ft). The east viaduct is a two-span continuous structure with a span length that also varies from 15.85 to 16.15 m (52.00 to 52.98 ft).

The superstructure of both viaducts consists of two separate, parallel and independent decks, each with a width of 14.95 m (49.05 ft). Each deck is composed of eight precast, prestressed I-girders spaced at 1.9 m (6.2 ft) and a CIP slab, as shown in Fig. 4.

The I-girders specified had the smallest typical Maprel manufactured section (Maprel is the precaster), with a depth of 0.75 m (2.46 ft), widths of 0.65 m (2.13 ft) and 0.70 m (2.30 ft) for bottom and top flanges, respectively.

The concrete used for the beams is a C45/55 concrete according to Eurocode 2 class notation. In this notation, the first value is the 28-day characteristic (5 percent) cylinder strength in MPa obtained on test cylinders 30.0 cm (11.8 in.) long and 15.0 cm (5.9 in.) in diameter. The second value is a
28-day characteristic (5 percent) strength obtained from 15.0 cm (5.9 in.) cube specimens.

A total of 12 strands of 1860 MPa (270 ksi) steel were designed for girder prestressing; 10 strands of 0.6 in. (15.2 mm) in the bottom flange and two strands of 0.5 in. (12.7 mm) in the top flange. The continuity between precast beams of consecutive spans was provided by ordinary mild steel reinforcement.

The precast beams are positioned on inverted T-diaphragms designed to be cast-in-place in two stages: the first stage provided the necessary support for the precast beams and the second stage connected all precast girders and CIP elements into one continuous structure (see Fig. 5).

The deck slab is composed of 50 mm (2 in.) deep precast, prestressed concrete panels topped by 200 mm (8 in.) of CIP reinforced concrete. Precast concrete panels with the relevant shape and special reinforcement allowed placement of the concrete without any additional support from the small cantilever elements at the edges of the deck.

As illustrated in Fig. 4, the substructure of the access viaducts was identical for both bridge decks and was designed as a frame composed of four circular piers with diameters of 1.0 m (3.3 ft) and a 1.40 m (4.6 ft) high rectangular beam. The bridge abutments were formed using six piles with a diameter of 1.0 m (3.3 ft) and a continuous rectangular beam with a depth of 0.9 m (3 ft) and a width of 1.5 m (5 ft).

In the construction of almost all of the viaduct piers, the foundations were built with reinforced concrete drilled piles, 1.0 m (3.3 ft) in diameter. Only the piers of the alignments P1 to P5 have direct (surface bearing) foundations. The loads from the superstructure are transferred to the substructure by a system of neoprene bearings.

Main Bridge

Due to hydraulic requirements, the main span crossing the Ave River had to be designed without any piers located in the river itself. In this location, the average width of the river is approximately 50 m (165 ft), and a typical precast solution could not be considered. Portuguese precasters usually do not manufacture precast concrete girders longer than 40 m (131 ft) due to transportation problems. Because of this logistical limitation, the Ave River Bridge designer had to propose a different, and not commonly used, structural design.

The solution to these industry restraints was to use a frame bridge with inclined piers in a V-shape and precast U-beams (see Figs. 6 and 7). The V-piers made it possible to reduce the main span to 36.5 m (120 ft) and the length of the longest girder to 28 m (92 ft).

The completed central structure has a total length of 120 m (394 ft) and consists of five spans. The central span and the spans over the V-piers have a length of 36.5 m (120 ft) and...
19.0 m (62.3 ft), respectively. The lateral spans of the bridge are variable due to the 19-degree skew, with lengths from 18 to 27 m (59 to 89 ft).

The superstructure of the bridge consists of two separate, parallel and independent decks, each 14.95 m (49 ft) wide. Each deck is composed of two precast, prestressed U-girders spaced 7.50 m (24.6 ft) from centerline to centerline and a CIP slab (see Fig. 7).

The selected Maprel type U-girders are 1.70 m (5.6 ft) deep with a 2.2 m (7.2 ft) wide bottom slab. The bottom slab thickness is 240 mm (9.5 in.), with the exception of the areas where anchor blocks are located. The web thickness is 180 mm (7.09 in.).

Girders were designed as cast from C60/70 concrete. The prestressing of the precast beams was designed as a group of post-tensioning straight cables located at the bottom slab. In the beams over the V-piers, some straight post-tensioning cables were also designed in the top of the webs (see Fig. 8). In this case, the designer used post-tensioning cables instead of strands (a more common solution) because of the difficulties in verification of serviceability limit states (cracking, decompression and maximum compression in concrete). Cables generally allow more freedom in the design.

Girder continuity is provided by post-tensioned bars connecting end diaphragms, by post-tensioned cables on the bottom slab of the girder, and by cables in the CIP top slab (see Fig. 8). The monolithic joints connecting CIP V-piers with precast girders are reinforced with mild steel. Reinforced CIP central diaphragms 0.8 m (2.6 ft) wide and 1.7 m (5.6 ft) deep connect two alignments of girders at the point of intersection with the V-piers.

In the joints between the bridge and viaducts, special diaphragms were designed to provide support for I-girders (see Fig. 9). CIP diaphragms are 2.0 m (6.6 ft) deep and 1.3 m (4.3 ft) wide concrete with ordinary steel reinforcement. The deck slab is composed of 0.07 m (2.8 in.) thick precast concrete panels and a 0.23 m (9.1 in.) thick CIP reinforced concrete slab.

Precast panels forming cantilever elements were designed with support from a steel lattice (made from mild steel reinforcement) anchored in the panels covering the U-girders (see Fig. 10). This solution permitted concreting without any additional supports and eliminated the need for carpenters' formwork. Separate V-piers support each alignment of girders at both riverbanks (see Fig. 11).

Separate circular piers were designed to provide support for the lateral beams and viaducts of the bridge. Columns 1.2 m (3.9 ft) in diameter were placed under the alignment axis of the U-girders. The foundation of each V-pier consisted of four drilled piles with a diameter of 1.2 m (3.9 ft).
Circular piers were founded on a single drilled pile of equal diameter. The loads from lateral diaphragms were transferred to the substructure with pot bearings (see Fig. 9).

**INSTRUMENTATION AND MONITORING**

Considering the complexity and the innovation of the Ave River Bridge, the highway operator and the bridge owner, AENOR, invited the Structural Division of Minho University in Guimarães, Portugal, to prepare a monitoring plan and provide all scientific and technical support related to instrumentation and measurements.

The aim of the monitoring program was not only the verification of the design assumptions and quality of the execution, but also the establishment of a record of long-term observations of the bridge’s structural behavior during its service life. For this purpose, several types of strain gauges, temperature sensors, and corrosion sensors were installed.

Since instrumentation of all the girders would be very expensive, it was decided to install sensors at just one alignment of the U-beams and V-piers. Some sections in the beams and piers of adjacent viaducts were also equipped with sensors. A total of 256 sensors were installed.

Sensors included: 74 full-bridge strain gauges to measure the strain in the reinforcement; 42 embedment strain gauges; a 88 PT100 sensor to measure the concrete temperature; and 52 ICORR® corrosion sensors to monitor the level of concrete corrosion at different depths of cover (see Fig. 12).

Special care was taken when protecting and installing the sensors to avoid damage during concrete placement and in subsequent construction stages. Due to a growing interest at AENOR to enhance the durability of concrete bridges, the University of

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Fig. 11. Elevation of V-piers at embankment.

Fig. 12. Sensors used: top left: strain gauges on reinforcing bars; top right: concrete strain gauges; bottom left: temperature sensor; and bottom right: ICORR® corrosion sensor.
Minho proposed to test the corrosion behavior of new concretes using various additives. Several different concrete mixture compositions were placed in the P11 and P12 pier alignments, including: the addition of silica fume (10 percent by weight of cement); fly ash (20 percent by weight of cement); metakaolin (15 percent by weight of cement); and the addition of latex and corrosion inhibitors.

For the purpose of future evaluation and quantification of concrete corrosion, several tests on concrete specimens were performed, including those for chloride penetration and carbonation. Concrete creep and shrinkage were also assessed. Results of all testing and monitoring are beyond the scope of this paper, but may be found elsewhere.

**GIRDER FABRICATION**

Portuguese precast producer, Maprel, prefabricated the U-girders. The Maprel precast plant used two 100 m (328 ft) long-lines dedicated to U-beam fabrication. Each girder form (see Fig. 13) consists of a fixed platform (an external mold), and two vertical movable panels (an internal mold).

No major problems occurred during the fabrication of the precast members, but as all U-girders were designed with only post-tensioning, different fabrication sequences from those commonly used were instituted. The reinforcement complexity of end diaphragms (see Fig. 14), anchorage zones, and connection joints might cause difficulties for ironworkers not familiar with atypical design installations. Special care had to be taken to avoid worker error and to ensure the required quality of the girders.

The fabrication sequence began with the placement of ordinary mild steel reinforcement. Later, cable ducts were located and fixed to the network of reinforcement. In required places, anchorage blocks were installed and additional reinforcement was added in these areas. All sensors were then fixed in specified positions and the internal forming was positioned. Finally, concrete was placed and vibrated to obtain the required level of compaction.
After five days of curing, the concrete attained the specified strength, 31.5 MPa (4.57 ksi), required for post-tensioning. The internal part of the mold was first removed. The cables were then placed in the ducts and the anchorage systems were installed. Finally, the prestressing crew from the main contractor, ENGIL, applied the necessary force to stress the cables and injected the ducts with mortar.

After application of prestressing, the girders were removed from the molds and stockpiled in the precast yard. Some finishing work was required, including the painting of visible surfaces and roughening the surfaces in the connection zones. Girders were later transported by a special truck to the bridge site, located about 200 km (124 miles) from the factory.

CONSTRUCTION

The bridge over the Ave River was constructed between July 2001 and November 2002, following the sequence illustrated in Fig. 15. Erection began in July 2001 with the installation of piles, pile caps, supporting V-piers, and temporary support foundations. Subsequently, the vertical piers at the extremities of the bridge and on the base of the V-piers were constructed.

During the second stage, the formwork for the V-piers was assembled and corresponding parts of the structure were cast. It is important to mention here that the V-pier falsework that overhung the river was supported by temporary struts anchored to the core formwork. In this way, formwork for two bridge sections was structurally interconnected, and few additional supports from the riverbanks were required to provide stability (see Fig. 16).

In the third stage of construction, prestress stays were placed on the top of the V-piers to provide a connection for the two arms of the piers after removal of formwork. Formwork was then disassembled and the riverbanks were prepared to provide better access for cranes and trucks. During this period of construction, the river channel was narrowed.
In June 2002, the next stage of construction began. First, U-girders were placed over the V-piers, and CIP joints connecting beams and piers were placed (Fig. 17). Diaphragms between two alignments of girders were completed. To provide support for lateral beams, temporary steel towers were mounted on the previously prepared foundations.

In the fifth construction stage, lateral beams were placed. Continuity prestressing between beams was then applied; initially, short bars connecting the extreme diaphragms of the beams were stressed. Afterward, cables in the bottom slab of the girder were placed, stressed and injected.

During the next construction stage, precast concrete panels were placed on the erected girders and additional reinforcement for negative moments in the deck slab was installed. Ducts for post-tensioning tendons were situated in the required position.

On the horizontal extensions of the bridge, lateral diaphragm formwork was prepared. Afterwards, the CIP slab and the lateral diaphragms were concreted. When the concrete reached the required strength, post-tensioning was applied in the slab over the V-piers.

During the seventh stage, the stays connecting the V-piers were removed and the central girders were erected. Due to the lack of temporary supports, girders were positioned on the cantilevered portion of the beams already in place over the V-piers; this operation required special care and precision for successful execution. After girder placement, continuity prestressing bars and cables were installed and the required forces were applied. All ducts were injected with mortar and anchor blocks were installed.

In the eighth stage, the temporary steel towers were removed and precast concrete panels were placed on the central zone of the bridge. Ordinary mild steel reinforcement in the slab and ducts for prestressing cables were installed.

During the ninth construction stage, 8 m (26 ft) long sections of the slab near the joints were concreted and post-tensioning was applied after curing. The top slab was post-tensioned to protect the concrete against cracking and to provide full structural continuity. Finally, incomplete portions of the slab were cast and the adjoining spans of the accessing viaducts were built. In November 2002, the bridge was ready to receive finishing work, including pavement placement and the installation of expansion joints and railings. All work was completed by April 2003.

**FABRICATION AND CONSTRUCTION MEASUREMENTS**

During the process of concrete curing, the hydration temperature was monitored for selected precast concrete girders. Temperature data were collected for use in calibrating numeri-
cal models to predict the evolution of concrete temperature and strain for different environmental and insulation conditions of the molds. The development of the temperature over time was recorded at five points in the beam web as illustrated in Fig. 18.

The distribution of the temperature in the beam web is presented in Fig. 19; it is apparent from the data that twelve hours after the concreting, the concrete temperature rose about 30°C (54°F), a significant thermal gradient. Measurement of strains with the installed gauges was recorded during the application of post-tensioning in one of the girders.

Fig. 18. Evolution of concrete hydration temperature over time in precast concrete bridge girders.

Fig. 19. Distribution of temperature in the beam web after 12 and 20 hours of curing.

Fig. 20. Strains measured during post-tensioning application.
The amount of post-tensioning force in the girder was applied in the following sequence: 50 percent to Cable 2 (8 min.); 50 percent to Cable 3 (5 min.); 100 percent to Cable 4 (29 min.); 100 percent to Cable 1 (16 min.); 100 percent to Cable 2 (3 min.); and 100 percent to Cable 3 (5 min.). See Fig. 20 for cable duct locations.

The development of strain during post-tensioning was measured by sensors installed on steel bars (see Fig. 12). The results of strains calculated for the described situation correspond quite well with recorded values in Fig. 20, verifying the assumed hypothesis and the efficiency and accuracy of the installed sensor system.

During bridge construction, several measurements were performed. These measurements were taken mainly to test sensors in the piers and to confirm that the structural response was, in fact, similar to the predicted response. While it is not possible to present all results obtained within the limitations of this paper, the authors hope to demonstrate the potential of the installed monitoring system.

The strain distribution in four sections of Pier P10A during U-girder placement is presented in Fig. 21. Fig. 22 illustrates the comparison between measured and calculated strain distributions; note that the observed results are almost equal to calculated values. The close correlation between measured and predicted results verifies the design assumptions and the reliability of the installed sensors.

**PROOF LOAD TEST**

In June 2003, the Structural Division of Minho University conducted a proof load test on the Ave River Bridge. The Portuguese Bridge Code does not require load testing, but as the structure is innovative, the project administrator requested the University to prepare and perform static tests to demonstrate the satisfactory structural behavior of the bridge.

As both the east and westbound
spans are structurally similar, only one of two lateral spans was examined. The authors decided to load test the portion of the structure equipped with the monitoring system. Due to the lack of national codes and standards for bridge testing procedures, assumptions were made regarding the load levels and acceptable criteria for the results.

After consultation with the bridge designers, it was agreed to determine the number, weight and position of trucks on the bridge so that the calculated bending moment did not surpass 65 to 70 percent of the moments caused by the characteristic values of traffic loads from the Portuguese Bridge Code.¹

The structure in ultimate limit state is designed for a load about two times greater than that applied in testing, but there was no reason to test the bridge at loads that would induce cracking.

The calculations for displacement and deformation were made using a linear finite element model (FEM) with 968 nodes and 1088 bar elements. The acceptance criterion of the obtained results was defined as a maximum percentage of the calculated deflection, i.e., the deflection measured could not surpass the calculated value by more than 10 to 15 percent.

Five load cases were used in the proof load test. Each load case was designed to obtain maximum moments in different sections of the girders. Five 275 kN (28 ton) trucks were used to determine all load positions during the proof load test. This load condition created the maximum negative moment over the V-piers only for the girders instrumented with sensors. Maximum positive moment in midspan was induced in both girder alignments.

In addition to measuring strain with gauges, the authors measured vertical displacements at various points in the structure. On the western river banks, four positions for linear variable differential transducers (LVDTs) were identified. One transducer was located in the middle of the lateral span, the second was positioned at one intersection of the girders with the V-piers, and the third device was installed in the middle of the span over the V-piers.

An additional transducer was installed in the middle of the lateral span of the second beam alignment to determine the load redistribution between girders. For comparison of results, mechanical deflectometers were installed at all transducer locations.

For the load testing, trucks were positioned on the bridge as indicated in Fig. 23. The first, third and fifth load cases were designed to create the maximum positive bending moments in the central span, in the span over the V-pier and lateral span, respectively. The second and fourth load cases were intended to create a maximum negative moment over the piers.

To monitor deflections and strains during load testing and to check the linearity of structural behavior, all load cases were carried out sequentially. At the beginning, two trucks were positioned in locations marked on the pavement prior to the load test. Later, measurements were recorded for a period of ten minutes to allow
the structure to reach equilibrium under loading. Two additional trucks were then positioned in selected locations and measurements were again conducted for ten minutes; in load cases using all five vehicles, the same sequence was followed. At the end of each load case, all trucks left the bridge at the same time and measurements were conducted for an additional ten minutes to give the structure time to recover from the test load displacements.

Fig. 24 illustrates the development of vertical displacements registered by the LVDTs during the fifth load case. Curves L3 and L1 illustrate deflections of the lateral span and the span over the V-pier, respectively. Curve L2 shows displacement of the point of intersection of the piers with beams in the same alignment, and Curve L4 represents deflection of the lateral span of the second alignment of the U-girders.

Fig. 25 shows a comparison of displacement registered by the LVDTs and deflectometers, with values calculated using the FEM model. Note the difference between obtained and predicted results is about 30 percent; this relatively small difference was expected since the model used for calculation was quite simple (3D bar model) and the stiffening influence of passive and active reinforcement was not taken into account; simple calculations show that prestressing and ordinary mild steel reinforcement increase the girder stiffness by about 15 to 20 percent.

The deformations registered in the middle of the lateral span by the installed strain gauges confirmed the conclusions made. Calculated strains are also about 30 percent greater than those obtained during proof load tests – at least for the sensors located in the precast concrete elements, as shown in Fig. 26. Results from strain gauges embedded in the CIP slab are of a lower level of confidence due to the difficulties in verifying gauge position during concrete placement.

Deformation recorded in the CIP slab is greater than that predicted, suggesting a nonlinear structural behavior; this result did not occur in other monitored sections during testing, indicating a probable error in sensor positioning.

In general, the structure behaved as expected during the proof load test (see Fig. 27). In all load cases, results measured were 25 to 30 percent smaller than estimated values. The position of the neutral axis remained close to the design values, and the distribution of loads between girders was similar to the FEM model calculations.

The residual displacement registered was consistently close to the margin of error of the measuring system, and
was, therefore, neglected. A comparison between different deflection measuring systems also produced satisfactory results, establishing a rationale for using only electronic devices in the future.

Unfortunately, due to space limitations, the results obtained during other load cases are not presented in this paper, but some results are shown to provide a general overview and sufficient basis for the final conclusions, namely, that the Ave River Bridge behaved satisfactorily under loading and could be safely opened to traffic.

CONCLUSIONS

Since the Ave River Bridge has been in service, it has established itself as a graceful element of the local landscape (see Fig. 28). All travelers between Braga and Guimarães pass over the bridge, which is expected to have a service life of 50 years or longer.

The inventiveness of the designers led to construction of a bridge with an uncommon span length for precast concrete U-girders of a given height. An interesting prestressing system avoided the need to increase beam web thickness, reduced the weight of beams, and provided full prestressing in the deck.

The use of precast concrete components significantly reduced project costs and construction time. Compared to traditional structural solutions in Portugal, the precast concrete bridge reduces maintenance cost due to its high material quality control, and ensures a lower concrete permeability to environmental elements.

This bridge is an excellent example of the structural design innovation that may be attained when concerted efforts are made on the part of bridge owners, general contractors, designers and researchers. The Ave River Bridge in Portugal demonstrates the great potential for building novel precast concrete structures of outstanding aesthetics that are both durable and economically competitive.

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