

## ACI Excellence Awards – 2016

### The “Ring of Memory” International Memorial of Notre-Dame de Lorette – Infrastructure

#### Project Information

Please choose the category for your project [Infrastructure]

Name of Project [The International Memorial of Notre-Dame de Lorette]

Address [ ]

Country France

City [Ablain Saint-Nazaire]

State - Postal Code [62153]

Project Size (Dimensions, Area, Span) [ring shaped structure (perimeter of the ellipse 328 m) - floor area 1155 m<sup>2</sup>]

Concrete Quantity - Volume Area Tonnage [300 m<sup>3</sup> of UHPFRC (BSI®)]

Concrete Work Duration [2013-2014]

Date of Project Completion [November 11, 2014]

#### Overall Project Description

The “Ring of memory” International Memorial has been built to celebrate the first World War Centennial at the very place of one of its most murderous battlefields near Arras (Northern France), close to the largest French War Cemetery on the crest dedicated to Notre-Dame de Lorette.

The Memorial is an elliptical ring of 328 meters of perimeter. It is a balanced ultra-thin and lightweight structure like an alliance ring laid on the top slopes of the hill. From outside, it is a dark ribbon symbol of war and mourning. Within this closed frame, symbol of recovered yet fragile Peace and Brotherhood, though open to the landscape of former horrific trenches, the monument honors 579,606 dead soldiers. Contrasting with the dark outer mineral facings, their names are listed on glossy stainless plaques inside the ring in alphabetical order, regardless of nationality. Visitors are invited to walk around the ring in memory of them, and at both large windows they can enjoy the scenery of former monuments and countryside.

The International Memorial is an outstanding architectural achievement but it is also a technical challenge. The Ring is composed of two distinct structures. The first one consists of standard precast segments with thin walls (4 cm-thick), resting directly on the ground. The second is a three span curved bridge, 125 m in length, with a main span of 56 m, realized using precast segments assembled by post-tension. Indeed, its very particular geometry is associated with very high flexural-torsional stresses. Only ultra-high performance fiber-reinforced concrete, namely the BSI® (Béton Spécial Industriel) developed by Eiffage Group, made it possible to meet the special structural, durability and architectural requirements to create this impressive fence favoring meditation.

The International Memorial was inaugurated on Armistice Day, November 11, 2014 by François Hollande, the President of the French Republic.

# Concrete Description

Only the outstanding performances of Ultra-High Performance Fibre-Reinforced Concrete made it possible to design and build such a slender 100 years-lifespan structure in about 18 months: material requirements namely combined the extremely thin and complex shape of the ring, high aesthetical quality facings, record mechanical strength and durability. The project detailed design constituted a pioneer application of revised UHPFRC AFGC Recommendations (2013) and new UHPFRC standards, under preparation at that time.

In parallel with the design studies, all required properties of the UHPFRC were evaluated and controlled on laboratory samples and on specimens sawn from a full-scale mock-up. The selected UHPFRC is a “dark gray BSI®” reinforced by steel fibers which ensure ductile behavior under tension and allow eliminating passive reinforcement, enabling to achieve lightweight structurally optimized elements.

The concrete is made from premix (mix of the dry materials: cement, silica fume, sand and coarse aggregates, previously elaborated with controlled homogenization and strict composition) combined in the mixer of the precast plant with water, superplasticizer and metallic fibers according to a defined mixing procedure. Mix-proportions are controlled within less than  $\pm 2\%$  tolerance. With a design compressive strength of 165 MPa, one advantage of BSI® is to obtain a high compressive strength at early age without thermal treatment: up to 80 MPa at 18 hours. This allows scheduling the casting of elements every day, on the principle of one piece per mold and per day.

Four types of precast elements compose the structure of the ring:

- 256 corbels (1.90 m long, 1.30 m wide, and 2 to 10 cm thick) made in a specific metallic mold, are visible from all sides; the self-compacting ability and fluid rheology of the fresh UHPFRC allowed achieving the geometric requirements for these down to 2 cm-thin elements.
- 768 floor slabs (1.25 m long, 1.10 m wide, and 4 cm thick) have been cast on a specific polyurethane matrix (sand finish) fixed on the mold to ensure the appropriate surface.
- 73 independent box-shaped segments (3.2 m high, 2.5 m wide and 4 cm thick), fixed on long beams, correspond to the two thirds of the ring resting on ground. A specific metallic mold has been used, with the segment N+1 cast on edge of the segment N to ensure perfect geometrical matching.
- 49 box-shaped segments (3.2 m high, 2.5 m wide and 10 cm thick) assembled by post-tension, constitute the suspended part of the ring, namely a curved bridge resisting intense and complex bending and torsion efforts. The same casting procedure has been used with another specific mold. Precision in the four 19T15S and six 7T15S tendons location and application of the pre-stressing force resulted in a successfully met challenge.

By extending UHPFRC production and design in unexplored uses, the “Ring of Memory” was made possible by a shared spirit of challenge, professionalism and enthusiasm in demonstrating the local capacity of excellence. This collective technical and aesthetic success has turned to evidence of UHPFRC as a new building material for History.

# Construction Team Members

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Sponsoring Chapter: ACI Paris Chapter

Name of Chapter Contact (Name of the representative of the Sponsoring Chapter who invited the submitter to submit the entry)

[François Toutlemonde, president of ACI Paris Chapter]

Should your project win an award, please indicate the company and address the award should be sent to.

**EIFFAGE INFRASTRUCTURES**

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# Photographs

Photo 1: [Overview of the International Memorial of Notre-Dame de Lorette]



Photo 2: [Segments, corbels and floor slabs just assembled]

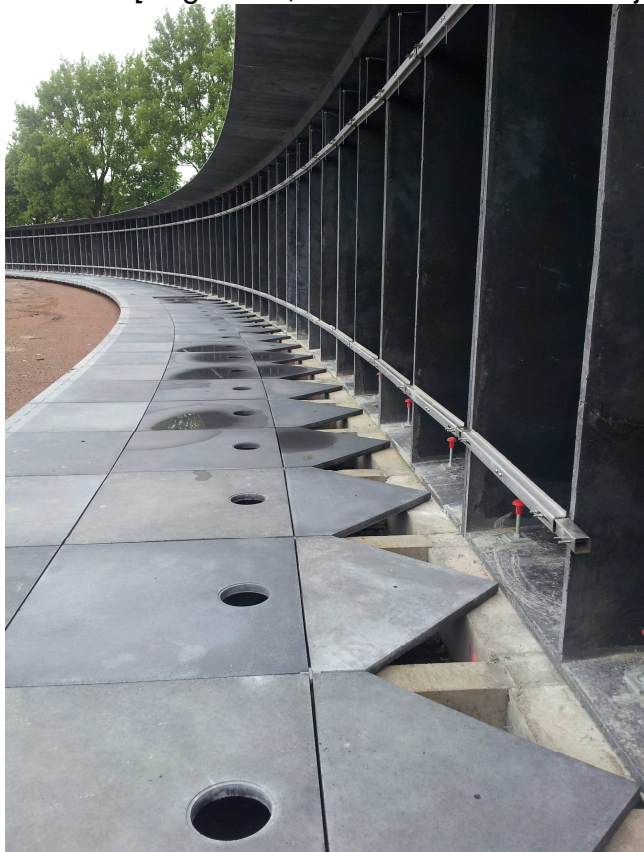


Photo 3: [The suspended part of the Ring just completed]



Photo 4: [Winter vision: dark grey wall, golden memory plates]



Photo 5: [UHPFRC outer facings: suspended part of the ring and window]



Photo 6: [Night Vision inside the Ring of Memory]



Photo 7: [The Memorial enlightened]



Photo 8: [The Ring of Memory at the crest of former battlefields]



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François TOUTLEMONDE, president of ACI Paris Chapter  
On behalf of the applicants