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Mega High Strength steel core for HTLS conductor on 2nd Scheldt long span crossing of new 380 kV OHL in the port of Antwerp

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SUMMARY

The 1st use of HTLS conductors in Belgium for a big river crossing was a challenge for elia. As elia has a large experience with the use of carbon core HTLS conductors, this project here was feasible due to the development of high tensile strength steel wires by Bekaert. In combination with Nexans they could develop a conductor meeting all the elia requirements in term of ampacity, diameter, sag and max tower loads. The installation of the conductors on towers reaching 200 m height was a challenge for the contractor as it was combined with the installation of many devices as vibration dampers, beacons and special bird diverters. A special focus was put on the long-term performance of the conductor installed in an industrial environment by applying specific protections. Therefore, a specific vibration study was also performed and led to the installation of many vibration dampers taking into account the presence of different types of diverters on the phase conductors. This had an impact on the tools to be used (e.g. work bench) and on the installation methodologies chosen by the contractor due to the steepness of the spans. The lessons learnt of such installations should be consolidated by all the parties (elia, Nexans and contractor) in specific manuals for future projects.

KEYWORDS

River crossing – HTLS conductor – High Strength steel core – long span – bird diverter

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1 Introduction

This paper will present the first use of a HTLS conductor in Belgium for a long span river crossing, namely the 2nd Scheldt crossing in the frame of the **Brabo project** [1], a major infrastructure investment in the port of Antwerp.

It was already Nexans (in that period named Câbleries de Dour) that had developed an innovative conductor in 1973 for the 1st Scheldt crossing, at that time using for the 1st time Z-shaped wires in the outer layer (Aero-Z design). Compact conductors using Z-shaped wires in the outer layer aim to minimize drag coefficient at exceptional wind conditions [2].

It was a challenge to design a system conductor-fittings that met all the requirements of the specification of Elia going far further than those of the 1st Scheldt crossing in terms of reduced diameter and audible noise, loads on the towers, UTS, ampacity and sag.

The installation of such a conductor in a very dense environment as the port of Antwerp was also quite difficult for the selected contractor on towers approaching 200 m height [3]. In this span, Elia had also to put special bird diverters due to the presence of protected birds along the Scheldt.

2 HTLS conductor solution

2.1.1. Design requirements (Elia)

The decision from Elia to opt for a single conductor has followed the same philosophy that applied with success to the first crossing (see [2]):

- a single conductor is less sensitive to galloping and requires no spacer dampers;
- a closed conductor (with Z-wires on the external layer) is more aerodynamical under transversal high wind speeds and less sensitive to humidity penetration (risk of corrosion of the steel core); in this case, you will see later that a special protection has been applied on the steel wires.
- a permanent ampacity of at least 2,766 A at 160 ºC (core temperature);
- a high catenary value for the crossing, but limited to 3,000 m in order to ensure acceptable sag in the descents to the small anchor towers to avoid the need for special vibration studies;
- a suitable diameter for audible noise limitation and compatibility with bird warning markers to be installed on the phase conductors.
- a maximum tension in central span under different loading conditions.

The design parameters of the phase conductor and earth wires were the following:

Conductor type	Unit	Phase: TACSR	Earth: AACSR
Required length	m	6x1,750m	2x1,750m
Steel cross-section	mm²	300 to 400mm²	>300mm²
Aluminium cross-section	mm²	900 to 1,100mm²	>300mm²
Type of aluminium alloy	-	AT1 or AT3	AL4
Outer diameter	mm²	43 to 44	≤ 31,5
Catenary parameter at 15°C	m	≤ 3,000	≤ 3,200
Minimal level (TAW) of lower phase conductors on the crossing	m	117,3m TAW	-
TAW level fondation	m	10,25m TAW	
Min. permanent ampacity	A	≥ 2,766	-
Max. operating temperature (at core)	°C	160	-

An HTLS conductor was chosen, not only to limit as much as possible the sag of the conductors and thus the height of the towers, but also to reach more ampacity than with a classical conductor operating to a maximum of 75°C according to Belgian regulation.

The designed conductor, by operating at a max temperature of 160°C, is capable of transmitting, in simplex configuration, the same current as a twin AAAC-Z 928 (2x1383 = 2766 A). The rest of the line is indeed equipped with twin bundle classic conductors; therefore, the purpose of using a HTLS solution was to avoid a bottleneck at the crossing.

2.1.2. Design of the conductor (Nexans)

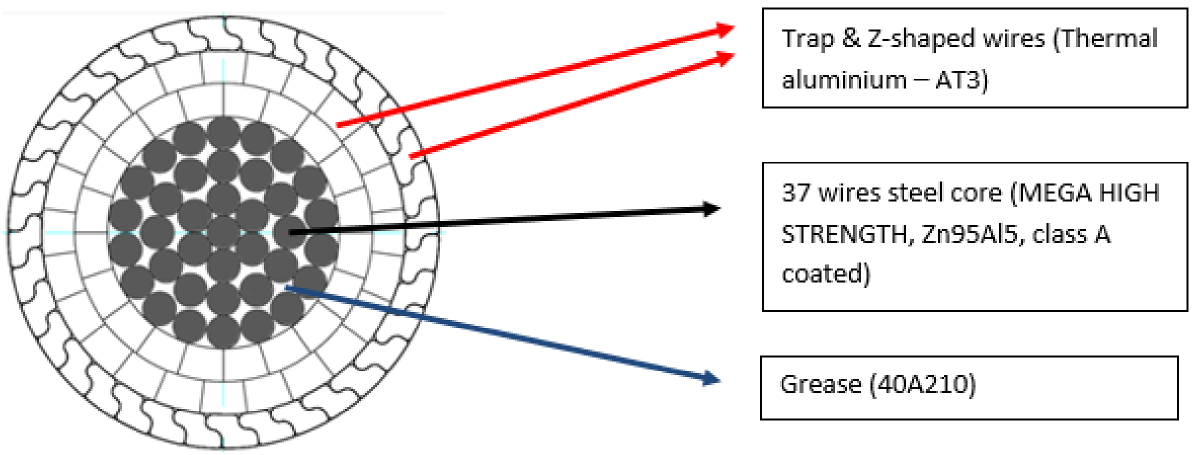
Based on the constraints imposed by Elia, Nexans designed a well-balanced solution, in terms of electrical (ampacity) and mechanical (breaking tensile strength) requirements.

A compact conductor with a diameter of 44 mm was considered to minimize, as much as possible, audible noise concerns and transversal loads, due to wind, transferred to the pylons.

As material for the conductive part of the conductor, thermal resistant alloy AT3 type as per IEC 62004, was used. The thermal limit of this alloy in continuous operation is 210 ºC (240 ºC in short term emergency conditions) versus 150 and 180 ºC respectively for AT1 type.

The cross-sectional area for the AT3 alloy is 989 mm^2, allowing this conductor to transmit 2766 A without surpassing the 160 ºC. In fact, this conductor could transmit 3460 A when operating at its thermal limit of 210 ºC.

The conductor is fully greased, except the outer layer, by using a high-performance grease (40A210 type, as per EN 50326) with a dropping point above 210 ºC and practically null oil migration.



The core is composed by 37 steel wires, 3,38 mm diameter. The steel wires are protected against corrosion by a Zn95Al5 alloy coating (see paragraph 2.1.3 for details concerning steel grade and advantages of this type of coating).

The combination of the following elements will provide an extra protection against galvanic corrosion problems. Life expectancy of this conductor is estimated in no less than 40 years.

- Coating of Zn95Al5 alloy for the steel wires

- Protective grease type 40A210, with null oil migration (determined by the oil separation test, as per EN 50326), and applied in all layers except the external one, and

Test name/clause	Test method	Specification	Result
Oil separation (6.6.2)	IP121 (modified) 1 hour at 210°C	<0.2%	0.0%

- a closed conductor design using Z-shaped strands in the outer layer, avoiding the entrance inside of pollutants and substances acting as electrolytes,

The rated breaking strength of the conductor is 730 kN. It is important to mention that, according to the sag and tension calculations, in the worst climatic conditions of the area, the conductor will never be submitted to a tensile load above 40 % of conductor RTS, resulting in a safety factor of 2,5.

This paper also compares both Scheldt crossing conductors in terms of design, expected performance and technical challenges.

	1st Scheldt crossing	2nd Scheldt crossing
Year	1974	2019
Total Section (mm^2)	1640	1320
Diameter (mm)	51,9	44,0
Steel section (mm^2)	246,3	332
Weight (kg/m)	6,037	5,457
Type of conductor	AACSR-Z	ZTACSR-Z
Max operating t°(°C)	75	160
UTS (kN)	850	730
Max ampacity (A)	1840	2766
Central span (m)	1170	912
Minimum clearance to be respected (m)	70	114

2.1.3. Core design (Bekaert)

It is mainly the core of this conductor that is very innovative as Bekaert specifically developed the new special steel grades, designated as MEGA and GIGA High Strength (**not yet standardized)** for such specific solutions: large river crossings, heavy ice loads or new steel core designs reducing the diameter, still keeping the same breaking load.

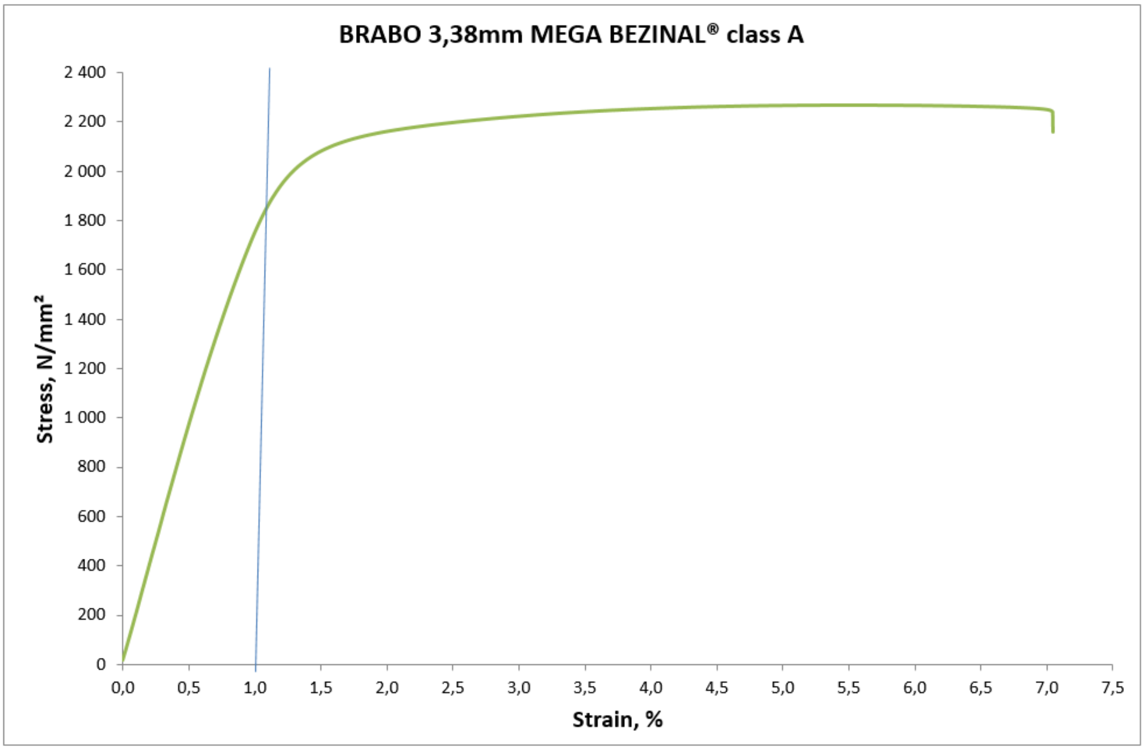
Both steel grades are included in the future IEC 63248 (still in draft CD) “Conductors for overhead lines - Coated or cladded metallic wire for concentric lay stranded conductors”. [4]

For this project, MEGA High Strength steel wires were considered, which main tensile properties are:

- Breaking tensile strength ≥ 2150 MPa
- Stress at 1 % elongation ≥ 1720 MPa

A typical stress-strain curve of the single wire used for the Brabo project is shown in graph 1.

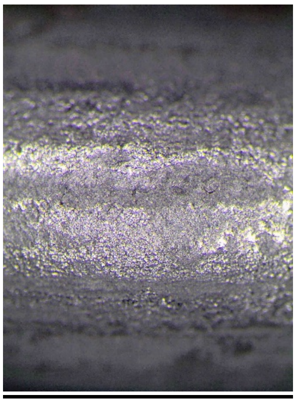
Graph 1 : typical stress-strain curve 3.38mm MEGA tensile - BRABO



The steel composition used is a high carbon Chromium Vanadium micro-alloy on which an additional heat treatment has been applied in order to obtain the desired mechanical properties. Bekaert has extensive experience with this steel composition mainly in the offshore industry where the same steel grade is used for mooring lines for oil production platforms.

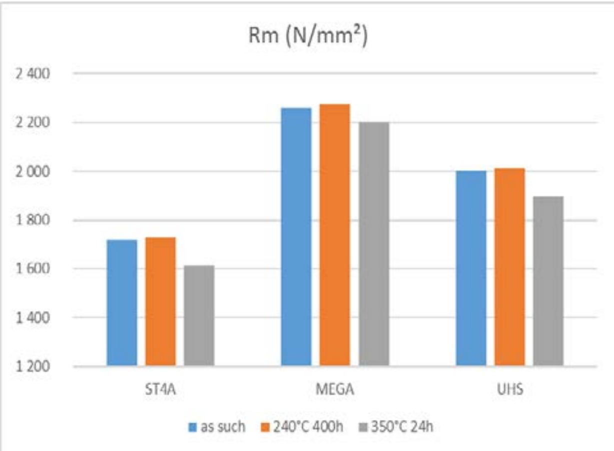
In addition, a Zn95Al5 advanced metallic coating was used to enhance corrosion resistance performance of the steel wires for long-term life expectancy. This alloy also guarantees a better thermal resistance than traditional galvanizing.

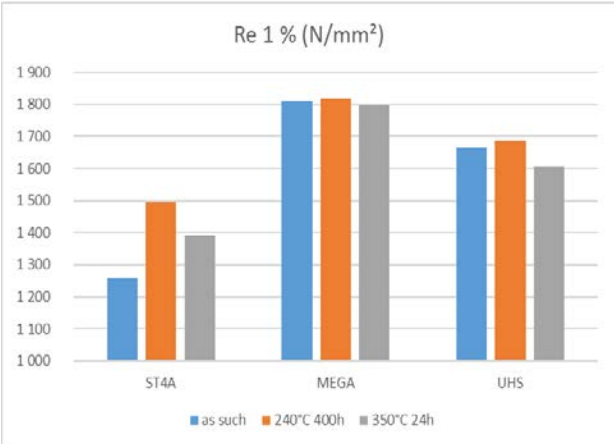
Picture 1: wrapping test performed on a MEGA tensile wire with coating after heat exposure

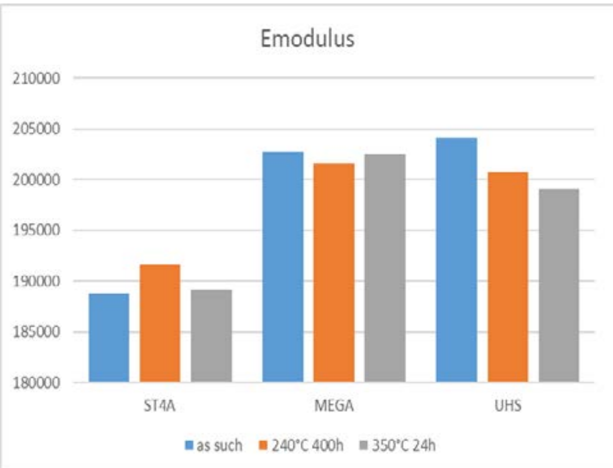
		MEGA BEZINAL® Wrapping test (mandrel = 2xD) heat exposure 240°C 400h

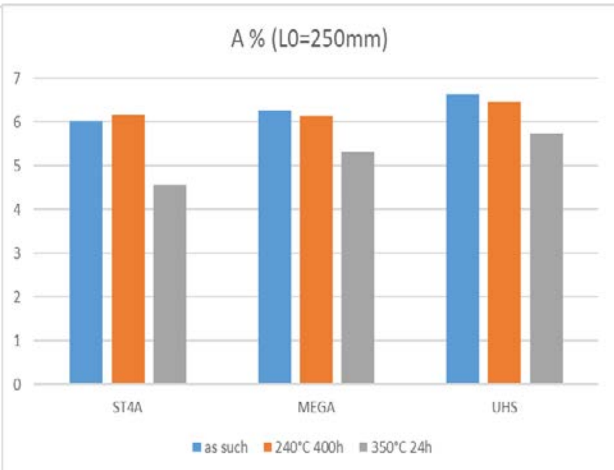
Additional heat exposure trials have been conducted to evaluate the impact on mechanical properties and coating adherence on these new steel grades. Bekaert compared different grades, ST4A, UHS, MEGA as such (not aged) and exposed to 240°C for 400 hours and 350°C for 24 hours.

The following mechanical properties were evaluated not aged (as such) and after heat exposure in the following graphs: ultimate tensile strength (Rm), stress at 1% extension (Re 1%), E-modulus, elongation (A%), coating adherence and ductility wrap on picture 1.









As conclusion, the behavior of the high tensile grades was comparable with current standard grades and showed a satisfactory stability after the different heat exposure conditions.

2.1.4. Manufacturing of the conductor (Bekaert / Nexans)

Manufacturing the core and the complete conductors was not easy and encountered some problems.

All layers from the steel core were pre-formed in order to obtain an inert core. Due to the high tensile strength, it is more difficult to plastically deform the wires. All layers were also fully greased.

The aluminium part was stranded in 2 passes, first one for inner and intermediate AT3 layers, composed both by trapezoidal strands and a second stranding pass for the 36 Z-shaped strands of the outer layer. For this purpose, special Nylon guides were used in the stranding machine to correctly position all the shaped wires.

2.1.5. Testing of the system conductor / fitting (Nexans / Dervaux)

The paper includes the results of the type testing on the conductor and the fittings. Elia always allocates the full HTLS system, from design to qualification, to one contractor in order to have clear responsibilities.

Accessories for both phase conductors and earth wires were produced by Dervaux/SICAME. The whole system conductor/accessories were type tested to guaranty the proper compatibility.

No suspension clamps were used in this project.

Phase conductor, earth wire, dead-end clamps, full tension joints and dampers were submitted to the following type tests:

- Stress/strain curves for both phase and earth wire to determine, in a precise way, the polynomial coefficients and final modulus of elasticity to properly calculate sag & tensions by using PLS_CADD software.
- Breaking tensile strength for the complete system conductor-dead end-full tension joint-dead-end.
- Self-damping characteristics tests for both phase and earth wire. The information obtained from these tests was used for the damping study which determined the number and position of the Stockbridge dampers.
- Slippage test on system conductor-wedge grips (at 20 and 40 % RTS of the conductor)
- Damper fatigue test
- RIV and Corona test on Stockbridge damper.

2.1.6. Installation of the conductors (Elia / Eiffage / Nexans)

This conductor has been strung at a parameter at 15 ºC ≤ 3000 m to guarantee clearances imposed by the local authority of Antwerp port and the Belgian regulations. This high parameter requested also special vibration study due to the installation of beacons and bird spheres on this span installed near nature reserves.

The installation of the phase conductors was a major challenge due to the difficulties of this project:

- specific procedure to install the pilot pulling ropes avoiding the interruption of the traffic by the river,
- pulley blocks placed at more than 166 m height,
- distance limitations to place the tensioner machine resulting in severe angles at the entrance of the conductor in the pulleys,
- necessity to respect a proper sequence of pulling to avoid excessive unbalance loads on the pylons,
- high pulling and regulation forces,
- installation of beacons/bird diverters and Stockbridge dampers all along the central span in extremely difficult conditions,..

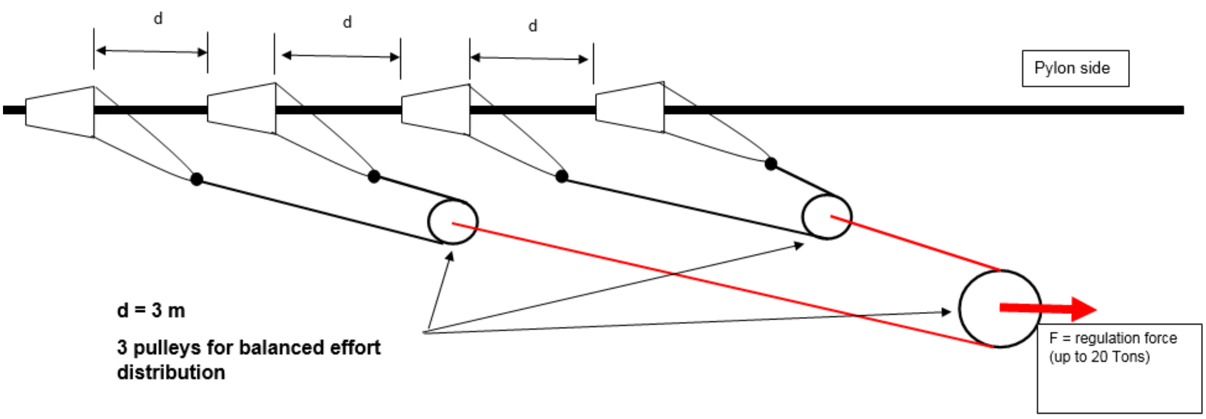
Picture 2 : detail of the perspective pylon-tensioner machine during pulling of one of the lower conductor phases

For pulling purposes, it was necessary to use a compression pulling clamp, similar in appearance to the dead-end clamp to attach the conductors on the insulator chains but without jumper lug (see picture 3). The link in between the pulling clamp and the swivel joint was carried out by using a flexible steel rope.

Picture 3: details of the whole compression pulling clamp-steel rope-swivel joint

During sagging, the conductor was supported by 4 wedge type grips, disposed in a double tandem configuration as show in picture 4.

Picture 4: Configuration of wedge grips to sustain the conductor and for regulation operations



Another important difficulty was the installation of the beacons and Stockbridge dampers. The damping study resulted in a big number of dampers to be installed all along the long central span. In picture 5, a detail of the arrangement of beacons and dampers is shown.

Picture 5: Dampers and bird beacons arrangement in long central span (between pylon 2 & pylon 3)

3 Conclusion

These available new steel grades are an interesting alternative for designing optimized overhead conductors, helping to reduce diameter, weight and steel section for a same tensile strength. Therefore, they are ideal for projects with special difficulties such as the described Scheldt river crossing.

The lessons learnt from this project are mainly the following ones :

- Specific vibration study for this kind of project should be performed as soon as possible as it might impact severely the installation methodology and tools to be used by the contractor ;
- Attention should be put on subcontracted parts (wedge type grips e.g.) which quality issues could affect installation lead time and safety ;
- Specific installation manuals should be developed in an early stage between the supplier of the conductor and the installator for this kind of projects.

This project demonstrates once again that Elia is carving out a position in the field of technological excellence where research and development with solid partners is essential.

By building this 2nd Scheldt crossing as part of Brabo II project, Elia increases the security of supply of Belgium by enhancing the import capacity on the Northern border with the Netherlands.

BIBLIOGRAPHY

[1] https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/brabo
[2] Caractéristiques aérodynamiques de nouveaux conducteurs pour grandes portées aériennes, Cigré Session 1976, paper 22-06
[3] Conception of very high towers for crossing the river Scheldt, Cigré session 2018, paper B2-213
[4] IEC 63248 (still in draft CD) "Conductors for overhead lines - Coated or cladded metallic wire for concentric lay stranded conductors"