TYPE TEST REPORT

Test object:	Aluminium Conductor Steel Reinforced/Aluminium-clad Steel Core (ACSR/AW)	
Designation:	ACSR/AW LAPWING	
Manufacturer:	**EL SEWEDY CABLES COMPANY** Block No. 27 – First Service Sector – Fifth District New Cairo EGYPT	
Tested for:	**EL SEWEDY CABLES COMPANY**	
Date of tests:	20th February 2017 – 10th March 2017	
Project ID:	NAL-41/2016	
Order/Contract:	P.O No. 3/2016, 23rd November 2016	
Test specification:	**IEC 61089:1991**	**Round wire concentric lay overhead electrical stranded conductors**
	IEC 61232:1993	**Aluminium-clad steel wires for electrical purposes**
	IEC 60889:1987	**Hard-drawn aluminium wire for overhead line conductors**

Tests performed: The test object, constructed in accordance with the description, drawings and photographs incorporated in this report has been subjected to the following tests:

- Verification of construction
- Tests of aluminium wires
- Tests of aluminium-clad steel wires
- Stress-strain test
- Tensile breaking strength
- DC resistance measurement

Test results: **The test object fulfilled the requirements of the standard.**

This Type Test Report has been issued by VEIKI-VNL Electric Large Laboratories Ltd. Testing Laboratory in accordance with above mentioned specification.

The Report applies only to the test object. The responsibility for conformity of any product having the same designations with that tested rests with the Manufacturer.

This Report comprises 29 sheets in total (27 numbered pages, 2 drawings).

Budapest,
24th March, 2017

Lajos Tóth	Norbert Menyhért	Dr. László Varga pp
responsible for the test	supervised by	managing director

Laboratory accredited by NAH under No. NAH-1-1251/2015.
VEIKI-VNL Ltd. is an independent company, member of Short-circuit Testing Liaison (STL).

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TEST CERTIFICATES OR REPORTS ISSUED BY VEIKI-VNL ELECTRIC LARGE LABORATORIES LTD. TESTING LABORATORY

Type Test Certificate of Complete Type Test
This certificate provides the verification of all the rated characteristics of the equipment as assigned by the manufacturer, by means of the performance of all type tests specified by the standards.

Type Test Certificate of Dielectric Performance
This certificate provides the verification of all dielectric ratings, by means of the performance of the appropriate type tests specified by the standards.

Type Test Certificate of Temperature-Rise Performance
This certificate provides the verification of temperature-rise limits together with measurement of the main circuit resistance, by means of the performance of the appropriate type tests specified by the standards.

Type Test Certificate of Short-Circuit / Making and Breaking Performance
This certificate provides the verification of rated characteristics with respect short-circuit and/or making and breaking performance, by means of the performance of the appropriate type tests specified by the standards.

Type Test Certificate of Switching Performance
This certificate provides the verification of the switching ratings (e.g. capacitive current), by means of the performance of the appropriate type tests specified by the standards.

Prototype Test Report
Prototype tests are required to verify the suitability of the materials and method of manufacture for composite insulators defined by relevant ANSI standards.

Design Test Report

According to IEC standard: The design tests are intended to verify the suitability of the design, materials and method of manufacture (technology) of composite insulators.

According to ANSI standard: The design tests are intended to verify the insulators electrical and mechanical characteristics that depend on its size and shape.

Type Test Report
This report provides the verification of the rated characteristics of the equipment as assigned by the manufacturer, by means of the performance of the appropriate type tests specified by the standards, for type tests not indicated above.

Development Test Report
This report is issued when the test is intended only to provide the Client with information about the performance of the equipment. The tests are performed in accordance with relevant standards, but are not intended to verify compliance of the equipment.

Control Test Report
This report is issued for tests performed on equipment in service, or removed from service. Tests are performed, and compliance is evaluated in accordance with relevant standards.

Test Report
Test report is issued in all cases not listed above.

Ratings/characteristics assigned by the manufacturer:

Test object:	Aluminium Conductor Steel Reinforced/ Aluminium-clad Steel Core (ACSR/AW)	
Designation:	ACSR/AW LAPWING	
Manufacturer:	EL SEWEDY Cables Company	
Structure:		
Core:	1 × Ø 3.183 mm	Aluminium-clad Steel wire
Layer 1:	6 × Ø 3.183 mm	Aluminium-clad Steel wire
Layer 2:	9 × Ø 4.775 mm	Aluminium wire
Layer 3:	15 × Ø 4.775 mm	Aluminium wire
Layer 3:	21 × Ø 4.775 mm	Aluminium wire
Cross-sectional area:		
Aluminium-clad Steel wires:	55.7 mm^2	
Aluminium wires:	805.84 mm^2	
Complete conductor:	861.5 mm^2	
Overall diameter of conductor:	38.2 mm	
Rated Tensile Strength (RTS):	185.9 kN	
Nominal conductor mass:	2598 kg/km	
DC resistance at 20 °C:	0.0358 Ω/km	

The tests were carried out in accordance with the following standards:

IEC 61089:1991	Round wire concentric lay overhead electrical stranded conductors
IEC 61232:1993	Aluminium-clad steel wires for electrical purposes
IEC 60889:1987	Hard-drawn aluminium wire for overhead line conductors

Requirements of manufacturer or purchaser:

ASTM B230:2007 — Clause 7, Table 1 : Elongation Requirements

List of manufacturer's drawings for identification of the test object:

Conductor Data Sheet ACSR/AW LAPWING (2 pages)

Present at the test in charge of manufacturer or purchaser:

Mr. Sameh Ahmed Abdelrahman Elnagar	ELSEWEDY Electric
Mr. Adel Ahmed Mohamed ElFaraskoury	EEHC
Ms. Mona Ali Abdalla Haggag	EEHC

TESTS PERFORMED ON THE TEST OBJECT

No.	Description	Relevant clauses of the standard
1	Verification of construction	IEC 61089:1991, Clause 6.6.1 – 6.6.6
2	Tests of aluminium wires	IEC 60889:1987, Clause 7, 10.1, 10.2, 11, ASTM B230:2007
3	Tests of aluminium-clad steel wires	IEC 61232:1993, Clause 6.3.1 – 6.3.6
4	Stress-strain curves	IEC 61089:1991, Sub-Clause 6.5.1-6.5.2, Annex B
5	Tensile test of the conductor	IEC 61089:1991, Sub-Clause 6.5.3, Annex B
6	DC resistance of complete conductor	Client's requirement

DESCRIPTION OF THE TESTS

1. Verification of Construction

1.1. Test method and parameters

The following tests and measurements were performed according to the main parameters specified in the data sheet of the conductor. The tested conductor is shown on Photo 1.

- Surface condition of conductor: The conductor sample was checked visually. No crack, breakage, discoloration shall be observed on the surface and on individual wires in the outer layer. It shall free from all visible imperfections.
- Conductor diameter: A 6m long sample was cut from the complete conductor and straightened to a frame with a force to keep it straight. The diameter of the complete conductor sample was measured by a digital calliper in two different direction of the same point. The average of the measured values was the measured diameter of the conductor.
- Inertness: The inertness of the conductor was checked by cutting the conductor. The aluminium-clad steel wires of the core and aluminium wires shall lie naturally in their position and when the conductor was cut, the wire ends shall remain in position.
- Lay ratio and lay direction: A 6m long sample was cut from the complete conductor and straightened to a frame with a force to keep it straight. The direction was checked on the outer layer as right handed or left handed and recorded. The diameter was checked on the outer layer and the length of the lay is measured. The rate between the lay length and the diameter determine the lay ratio. The procedure was repeated in all layers after removing each layer until the core was reached.
- Number and types of wires: During the determination of the lay ratio, the number and type of wires were checked in each layer. By this way, the construction of the conductor can be approved.
- Mass per unit length: Mass per unit length of the conductor was measured on a sample cut out from the whole conductor. The length was 1m and adjusted to the upper limit of the high precision digital scale. The exact length of the sample was measured and recorded. The mass per unit length was calculated from the measured value, corrected by the ratio between 1000 mm and the measured length.

1.2. Test results

Specified and measured values are listed in Table 1.

Table 1: Conductor parameters

Parameter	Specified values	Measured values
Surface condition	The surface of the conductor shall be free from all visible imperfections.	Complies
Inertness	The individual wires of the aluminium-clad steel core and aluminium wires shall lie naturally in their position and after cut the wire ends shall remain in position.	Complies
Type/ Designation of wires	Aluminium-clad steel wires of the core and aluminium wires	Complies
Number and diameter of aluminium-clad steel wires	(1+6) x 3.183±0.05 mm (3.133-3.233mm)	(1+6) x 3.19 – 3.199 mm
Number and diameter of aluminium wires	(9+15+21) x 4.775±0.03 (4.745–4.805 mm)	(9+15+21) x 4.783 – 4.800 mm
Outer diameter	38.2 mm ±1% (37.82–38.58 mm)	38.470 mm
Cross sectional area of aluminium layers	806 mm^2 ±2% (789.88 – 822.12 mm^2)	811.43 mm^2
Lay direction		
- Steel layer (6)	S (left)	S (left)
- Inner AL layer (9)	Z (right)	Z (right)
- Middle AL layer (15)	S (left)	S (left)
- Outer AL layer (21)	Z (right)	Z (right)
Lay ratio		
- Steel layer (6)	16-26 (153-243 mm)	18.46 (177 mm)
- Inner AL layer (9)	10-16 (191-306 mm)	14.77 (282 mm)
- Middle AL layer (15)	10-16 (287-458 mm)	12.26 (352 mm)
- Outer AL layer (21)	10-14 (382-535 mm)	11.00 (423 mm)
Mass of conductor	2598 kg/km ± 2% (2546 - 2649 kg/km)	2631 kg/km
DC Resistance at 20°C	Max: 0.0358 Ω/km	0.0343 Ω/km

The measured values are in correspondence with the manufacturer's specification given in the data sheet of the conductor.

2. Tests of aluminium wires

2.1 Test method and parameters

The following tests were performed on the wire samples removed from the conductor:

- Appearance and surface condition of wires and dimensional check: The wires were checked visually and the diameter was measured. The wires shall be smooth and free from imperfection.
- Tensile stress test with measurement of elongation at break: The wire was held in the tensile test machine and the force was increased until break of wire occurred (Photo 7). The force was recorded with the data logger of the tensile test machine. Elongation was determined by measurement of distance between markings on samples with broken ends fitted. Marking were originally 250 mm apart. Elongation values measured only on non-stranded wires.
- Resistivity measurement: The resistance of one-meter long sample was measured at room temperature and the value was calculated to 20 °C. The cross-sectional area of the aluminium wires calculated from diameter measured at both end and middle position. In every position two measurement were taken, perpendicular to each other. The resistivity was calculated from resistance and the cross-sectional area. The temperature is recorded by a T-type thermocouple temporarily attached to wire.
- Wrapping test: The wire was wrapped around a mandrel of diameter equal the wire diameter, eight times with a speed lower than 60 rev/min. Six turns were unwrapped and then the sample visually checked.
- Welding of aluminium: Tensile tests were made on welded aluminium joint sampled. The tensile strength must be higher than 130N/mm^2.

2.2 Test results

Table 2: Appearance, surface condition and dimensional check on aluminium wires after stranding

Wire	**Appearance and surface condition of wire [Smooth and shall be free from imperfections]**	**Diameter [mm] 4.775±0.03mm (4.745 – 4.805mm)**
Outer 1	Complies	4.797
Outer 2	Complies	4.794
Outer 3	Complies	4.797
Outer 4	Complies	4.792
Outer 5	Complies	4.792
Outer 6	Complies	4.800
Outer 7	Complies	4.789
Outer 8	Complies	4.792
Outer 9	Complies	4.796
Outer 10	Complies	4.786
Outer 11	Complies	4.787
Outer 12	Complies	4.783
Outer 13	Complies	4.793
Outer 14	Complies	4.794
Outer 15	Complies	4.794
Outer 16	Complies	4.797
Outer 17	Complies	4.793
Outer 18	Complies	4.789
Outer 19	Complies	4.794
Outer 20	Complies	4.797
Outer 21	Complies	4.790

Continued on next page

Table 2 (continued):

Wire	Appearance and surface condition of wire [Smooth and shall be free from imperfections]	Diameter [mm] 4.775±0.03mm (4.745 – 4.805mm)
Middle 1	Complies	4.789
Middle 2	Complies	4.786
Middle 3	Complies	4.793
Middle 4	Complies	4.785
Middle 5	Complies	4.795
Middle 6	Complies	4.789
Middle 7	Complies	4.790
Middle 8	Complies	4.790
Middle 9	Complies	4.790
Middle 10	Complies	4.795
Middle 11	Complies	4.789
Middle 12	Complies	4.793
Middle 13	Complies	4.787
Middle 14	Complies	4.791
Middle 15	Complies	4.793
Inner 1	Complies	4.791
Inner 2	Complies	4.798
Inner 3	Complies	4.791
Inner 4	Complies	4.791
Inner 5	Complies	4.793
Inner 6	Complies	4.790
Inner 7	Complies	4.788
Inner 8	Complies	4.792
Inner 9	Complies	4.792

The surface of the wires is smooth and free from imperfections and the diameter of the wires is within tolerance; therefore the aluminium wires met the requirements.

Table 3: Resistivity of aluminium wires after stranding:

Wire	Cross-section [mm²]	T (°C)	R [mΩ/m]	R_{20} [mΩ/m]	Resistivity [nΩ×m]
Outer 1	18.072	22.6	1.5619	1.54572	27.935
Outer 2	18.050	23.2	1.5608	1.54088	27.813
Outer 3	18.072	23.3	1.5650	1.54444	27.912
Outer 4	18.037	22.6	1.5708	1.55449	28.039
Outer 5	18.031	22.5	1.5678	1.55211	27.986
Outer 6	18.095	22.6	1.5569	1.54071	27.879
Outer 7	18.008	22.5	1.5647	1.54910	27.897
Outer 8	18.032	22.6	1.5618	1.54563	27.871
Outer 9	18.065	22.6	1.5632	1.54702	27.947
Outer 10	17.986	22.4	1.5653	1.55031	27.884
Outer 11	18.000	22.5	1.5682	1.55259	27.946
Outer 12	17.965	22.5	1.5692	1.55352	27.908
Outer 13	18.045	23.0	1.5674	1.54871	27.946
Outer 14	18.050	22.9	1.5613	1.54322	27.855
Outer 15	18.050	22.6	1.5581	1.54191	27.831
Outer 16	18.069	22.7	1.5616	1.54481	27.913
Outer 17	18.044	23.4	1.5676	1.54638	27.902
Outer 18	18.013	22.8	1.5692	1.55168	27.951
Outer 19	18.050	22.8	1.5645	1.54704	27.924
Outer 20	18.072	22.6	1.5598	1.54363	27.897
Outer 21	18.016	22.4	1.5614	1.54644	27.861

Continued on next page

Table 3 (continued):

Wire	Cross-section [mm^2]	T (°C)	R [mΩ/m]	R_{20} [mΩ/m]	Resistivity [nΩ×m]
Middle 1	18.010	22.7	1.5692	1.55228	27.956
Middle 2	17.992	23.1	1.5746	1.55520	27.981
Middle 3	18.044	23.3	1.5742	1.55352	28.031
Middle 4	17.981	23.3	1.5783	1.55757	28.006
Middle 5	18.054	23.6	1.5718	1.54935	27.971
Middle 6	18.012	23.3	1.5741	1.55345	27.981
Middle 7	18.020	22.9	1.5707	1.55257	27.977
Middle 8	18.017	23.7	1.5753	1.55214	27.965
Middle 9	18.021	22.9	1.5716	1.55346	27.995
Middle 10	18.056	22.9	1.5683	1.55017	27.990
Middle 11	18.013	22.8	1.5712	1.55370	27.987
Middle 12	18.039	22.7	1.5687	1.55183	27.993
Middle 13	17.996	22.8	1.5693	1.55180	27.926
Middle 14	18.023	22.9	1.5689	1.55080	27.951
Middle 15	18.040	22.7	1.5658	1.54892	27.942
Inner 1	18.030	24.3	1.5740	1.54722	27.896
Inner 2	18.077	22.5	1.5509	1.53540	27.756
Inner 3	18.029	22.2	1.5611	1.54736	27.897
Inner 4	18.027	24.6	1.5750	1.54631	27.876
Inner 5	18.039	22.4	1.5597	1.54472	27.864
Inner 6	18.021	22.4	1.5609	1.54591	27.859
Inner 7	18.006	22.1	1.5622	1.54908	27.893
Inner 8	18.031	22.0	1.5643	1.55175	27.980
Inner 9	18.035	22.2	1.5612	1.54745	27.908
Max.					**28.039**

The resistivity was lower than the specified 28.264 nΩ×m; therefore the aluminium wires met the requirements.

Table 4: Tensile break test and of aluminium wires before stranding

Wire [Bound/Sample]	Cross-section [mm²]	Tensile force [N]	Tensile stress [N/mm²]	Elongation at break [mm]	Elongation at break [%]
BS1-1	18.133	3227.2	178.64	-	-
BS1-2	17.683	3136.5	174.20	6	2.4
BS1-3	18.065	3135.8	174.09	6	2.4
BS2-1	18.005	3233.3	179.28	-	-
BS2-2	18.013	3204.1	177.21	-	-
BS2-3	18.035	3190.9	176.19	5.5	2.2
BS3-1	18.080	3139.8	173.44	5.5	2.2
BS3-2	18.111	3202.1	177.25	-	-
BS3-3	18.103	3164.5	175.75	-	-
BS4-1	18.065	3259.8	181.20	-	-
BS4-2	18.005	3307.2	183.37	-	-
BS4-3	17.990	3201.6	176.78	6	2.4
BS5-1	18.035	3231.1	179.68	-	-
BS5-2	18.111	3173.0	176.37	-	-
BS5-3	17.983	3233.3	179.20	6	2.4

Table 5: Tensile break test of welded aluminium joints

Wire [Bound/Sample]	Tensile force [N]	Tensile stress [N/mm²]
long1	3093.2	171.29
long	3138.1	173.78
long3	3069.3	169.97
long4	3104.0	171.89
long5	3135.3	173.62
short1	3096.4	171.47
short2	3068.6	169.93

The measured tensile stress values are greater than the value of 130 N/mm^2 therefore the aluminium wires met the requirements.

Table 6: Tensile break test and wrap test results of aluminium wires after stranding:

Wire	Cross-section [mm²]	Tensile force [N]	Tensile stress [N/mm²]	Elongation at break [mm]	Elongation at break [%]	Wrap test result
Outer 1	18.072	3190.6	176.55	n/a	n/a	Complies
Outer 4	18.037	3111.3	172.50	n/a	n/a	Complies
Outer 5	18.031	3150.7	174.74	n/a	n/a	Complies
Outer 7	18.008	2964.9	164.64	5.5	2.2	Complies
Outer 8	18.032	3025.6	167.79	n/a	n/a	Complies
Outer 10	17.986	3050.2	169.59	n/a	n/a	Complies
Outer 11	18.000	2946.9	163.72	n/a	n/a	Complies
Outer 13	18.045	3103.3	171.98	n/a	n/a	Complies
Outer 17	18.044	2970.5	164.63	n/a	n/a	Complies
Outer 21	18.016	3085.1	171.24	n/a	n/a	Complies
Middle 2	17.992	3010.2	167.31	n/a	n/a	Complies
Middle 4	17.981	2915.8	162.16	n/a	n/a	Complies
Middle 6	18.012	2977.5	165.31	n/a	n/a	Complies
Middle 7	18.020	3137.8	174.13	n/a	n/a	Complies
Middle 8	18.017	3038.2	168.63	n/a	n/a	Complies
Middle 10	18.056	3083.0	170.75	n/a	n/a	Complies
Middle 11	18.013	3044.3	169.01	n/a	n/a	Complies
Middle 12	18.039	2998.0	166.20	n/a	n/a	Complies
Middle 13	17.996	2990.0	166.15	n/a	n/a	Complies
Middle 15	18.040	3124.3	173.19	4	2	Complies
Inner 1	18.030	3093.2	171.56	n/a	n/a	Complies
Inner 2	18.077	3138.1	173.60	n/a	n/a	Complies
Inner 3	18.029	3069.3	170.24	n/a	n/a	Complies
Inner 4	18.027	3104.0	172.19	n/a	n/a	Complies
Inner 5	18.039	3135.3	173.81	n/a	n/a	Complies
Inner 6	18.021	3096.4	171.82	n/a	n/a	Complies
Inner 7	18.006	3068.6	170.42	n/a	n/a	Complies
Inner 8	18.031	3053.7	169.36	n/a	n/a	Complies
Inner 9	18.035	3079.3	170.74	n/a	n/a	Complies
Min:			**162.16**			

The measured tensile stress values are greater than the specified value of 152 N/mm^2 therefore the aluminium wires met the requirements of tensile strength.

The average of elongation values is 2.1% and the minimum value is 2% therefore the aluminium wires met the requirements of elongation according to standard ASTM B230:2007.

3. Tests of aluminium-clad steel wires

3.1. Test method and parameters

The tests were carried out on individual steel wires removed from the conductor:

- *Tensile stress test with measurement of elongation at break:* The wires were held in the tensile test machine and the force was increased until break of wire occurred. The force was recorded with the data logger of the tensile test machine. Elongation at break was determined by measurement of distance between markings on samples with broken ends fitted. Markings were originally 250 mm apart. Elongation at break only measured on samples before stranding.
- *Stress at 1% extension:* The steel wires were held in a tensile test machine. An initial load equivalent to the initial stress of 300 N/mm^2 was applied to the test samples. An extensometer was applied to the samples on a gauge length of 250 mm. The initial setting of extensometer was 0.25mm. The initial load was increased until the extensometer indicated an extension of 1% of the original gauge length. The values were recorded and the stress was calculated.
- *Torsion test*
  A specimen bended to "C" shape and it was gripped to twisting machine. The active part length was 318mm, 100 times of the diameter. The machine keeps the axial forces lower than 30N. The wire was twisted until break occurs. The number of revolutions are shown on a digital counter attached to drivetrain.
- *Thickness of aluminium*
  The specimens are fixed using resin casting and the surface polished. The measurement performed by electron microscope.
- *Resistivity test*
  The resistance of one-meter long sample was measured at room temperature and the value was calculated to 20 °C. The cross-sectional area of the aluminium-coated steel wires calculated from diameter measured at both end and middle position. In every position two measurement were taken, perpendicular to each other. The resistivity was calculated from resistance and the cross-sectional area. The temperature is recorded by a T-type thermocouple temporarily attached to wire. The test is shown on Photo 8.

3.2. Test results

- *Tensile stress test:* The calculated tensile stress values from the measured tensile force were higher than the specified 1275 N/mm^2, the calculated elongation values were 1.6% which are higher than the standard's requirement 1.5%; therefore the aluminium-coated steel wires met the requirements of EN 61232 standard and the data sheet of the conductor. The measured and calculated values are shown in Table 8. The measurement is shown on Photo 8.
- *Stress at 1% extension:* The measured values were higher than the specified 1137 N/mm^2 and the standard's requirement 1200N/mm^2 therefore the steel wires met the requirements of the standard and the data sheet of the conductor. The measured values are shown in Table 9.
- *Thickness of aluminium*
  The values of AL thickness are higher than 0.159mm (10% of radius), which is the minimum requirement according to Table 3 of standard IEC61232. The measured values are shown in Table 6. The prepared sample is shown on Photo 9.
- *Torsion test*
  The required minimum value of turns is 20 according to Clause 4.9 of the standard IEC61232. The test results are shown on Table 7. The wires fulfilled the requirements of standard.
- *Resistivity test*
  The resistivity values are shown in Table 10. The values were lower than acceptance criteria 84.8 n$\Omega\times$m. The wires fulfilled the requirements.

Table 7: Test result of torsion test, and thickness of aluminium

Test Sample	Number of twists	Thickness of Al [mm]
Steel core	39	0.220
Steel 1	40	0.189
Steel 2	39	0.207
Steel 3	39	0.196
Steel 4	42	0.211
Steel 5	40	0.202
Steel 6	41	0.205

Table 8: Test result of the tensile stress test and measurement of elongation at break

Test Sample	Diameter [mm]	Cross-section [mm2]	Tensile force [N]	Tensile stress [N/mm2]	Elongation at break [mm]	Elongation at break [%]
Steel core	3.189	7.987	12289.4	1539	-	-
Steel 1	3.198	8.032	12201.6	1519	-	-
Steel 2	3.192	8.002	12007.4	1500	-	-
Steel 3	3.194	8.012	12542.8	1565	4	1.6
Steel 4	3.198	8.032	12343.7	1537	-	-
Steel 5	3.204	8.063	12800.0	1588	4	1.6
Steel 6	3.195	8.017	12347.5	1540	-	-

Table 9: Test result of stress at 1% elongation

Test Sample	Diameter [mm]	Cross-section [mm2]	Force at 1% elongation [kN]	Stress at 1% elongation [N/mm2]
Steel core	3.189	7.987	10.543	1320
Steel 1	3.198	8.032	10.438	1299
Steel 2	3.192	8.002	9.630	1203
Steel 3	3.194	8.012	10.000	1248
Steel 4	3.198	8.032	10.604	1320
Steel 5	3.204	8.063	10.053	1247
Steel 6	3.195	8.017	9.730	1214

Table 10: Test result of resistivity measurement

Wire	Cross-section [mm^2]	T (°C)	R [mΩ/m]	R_{20} [mΩ/m]	Resistivity [nΩ×m]
Steel core	8.008	22.5	9.9687	9.86923	79.116
Steel 1	8.035	23.0	9.9853	9.86599	79.371
Steel 2	8.024	22.4	9.9724	9.87684	79.331
Steel 3	8.017	22.7	9.9912	9.88368	79.330
Steel 4	8.020	22.8	10.0490	9.93687	79.793
Steel 5	8.024	23.0	10.0600	9.93983	79.857
Steel 6	8.012	22.5	9.9745	9.87496	79.204

The resistivity was lower than the specified 84.8 nΩ×m; therefore the aluminium wires met the requirements.

4. Stress-strain curves

4.1. Test method and parameters

Stress–strain test was carried out on overhead line conductor type ACSR/AW Lapwing in accordance with standard IEC 61089:1991 Clause 6.5.1-6.5.2 and Annex B. The ends of the conductor specimens were terminated with epoxy-resin dead-end and fixed in the end fittings (Photo 2). The test was performed in a tensile machine; with gauge length of 11.612 m. The conductor was tensioned according to the following table:

Table 11: Loading schedule for stress-strain test

Initial load (2% of RTS):	3.7 kN	to straighten the conductor and set the strain gauges to zero.
Load (30% of RTS):	55.8 kN	30 min, then released to initial load
Load (50% of RTS):	93.0 kN	60 min, then released to initial load
Load (70% of RTS):	130.1 kN	60 min, then released to initial load
Load (85% of RTS):	158.0 kN	60 min, then released to initial load

During the test the conductor sample was supported along its length to keep the conductor straight and minimize the sag. The test set-up for the stress-strain test is shown in Figure 1 and on Photo 3. The test was carried out in a temperature-controlled laboratory at 20°C±2°C.

The stress-strain test on the steel core was also performed according to Clause 6.5.1-6.5.2 and Annex B of the IEC 61089:1991 standard. The procedure was similar as for the whole conductor except the tension levels for the steel core were determined by the elongation at the beginning of each hold period obtained on the whole conductor at 30%, 50%, 70% and 85% RTS, respectively. The gauge length was 11.586 m.

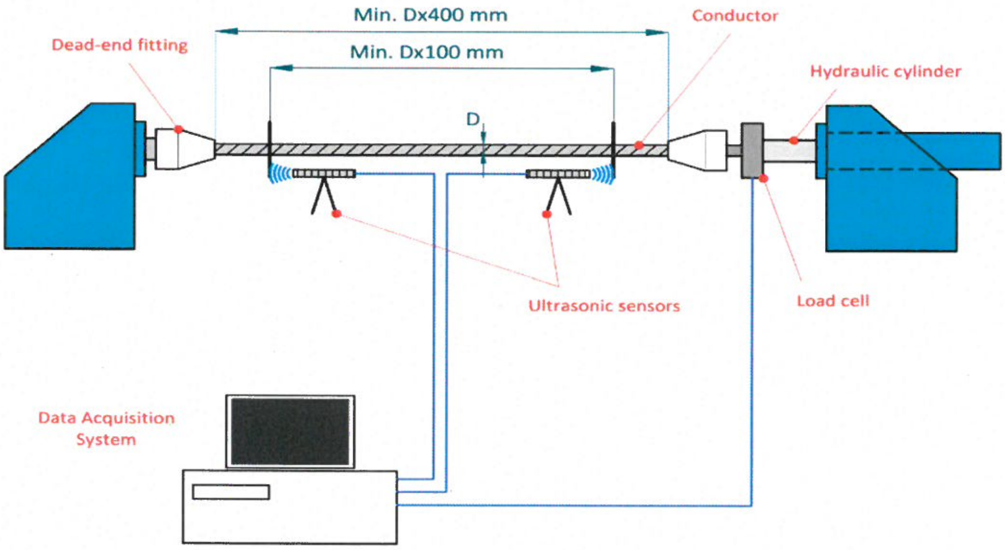


Figure 1
Test arrangement

4.2. Test results

The modulus of elasticity of the conductor was determined from the Force-Elongation curve by simple linear regression. Figure 2 shows the lines of best fit placed on the unloading segments of the curve.

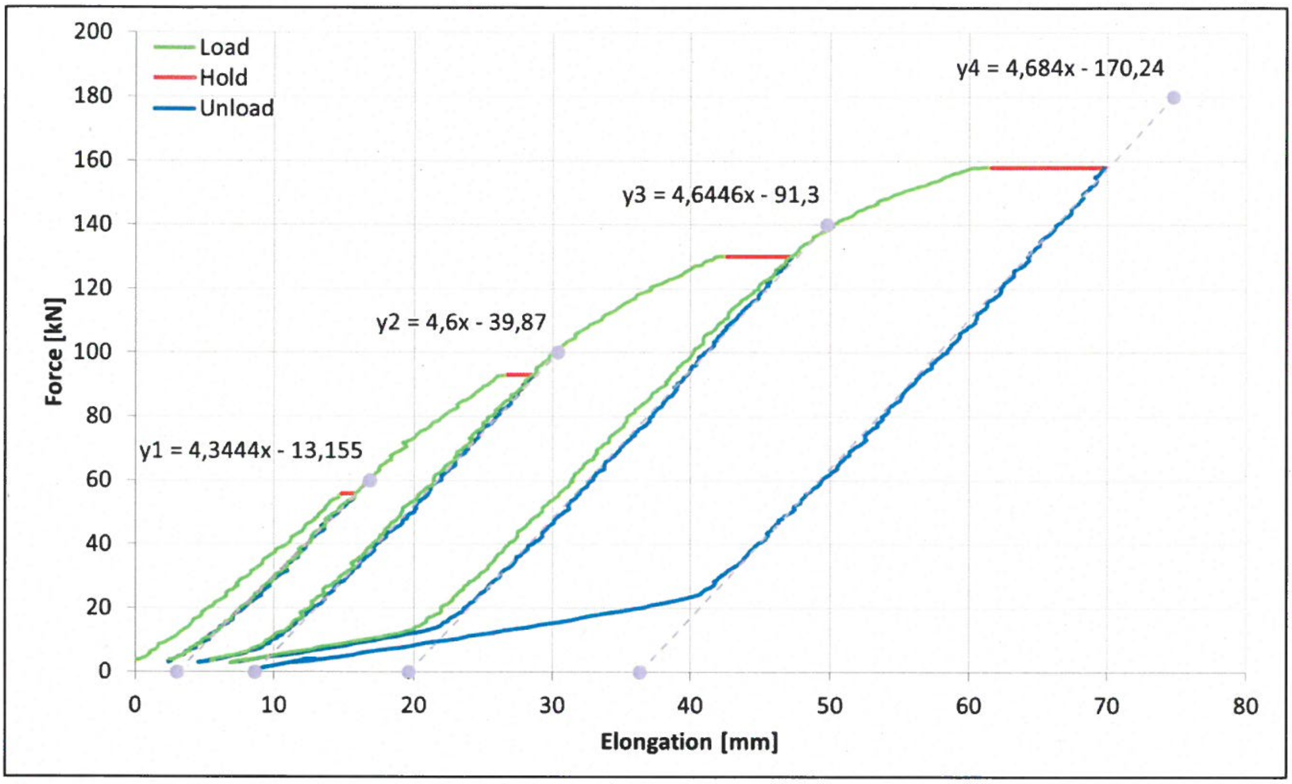


Figure 2
Lines of best fit placed on the unloading segments

The Modulus of Elasticity obtained at 30, 50, 70 and 85% RTS are summarised in Table 10.

Table 12: Modulus of elasticity

Load	**Line of best fit** $(y = m \cdot x + b)$	**Slope** (m)	**Modulus of Elasticity** $(E = m \cdot \frac{l_0}{A})$
30% RTS	$y_1 = 4.3444 \cdot x - 13.155$	4.3444	$58.56\ \frac{kN}{mm^2}$
50% RTS	$y_2 = 4.6 \cdot x - 39.87$	4.6	$62.00\ \frac{kN}{mm^2}$
70% RTS	$y_3 = 4.6446 \cdot x - 91.3$	4.6446	$62.60\ \frac{kN}{mm^2}$
85% RTS	$y_4 = 4.684 \cdot x - 170.24$	4.684	$63.13\ \frac{kN}{mm^2}$

The measured curves were corrected to cross zero by 0.0062% strain for the conductor, and 0.0333% strain for the steel core. The corrected Stress-Strain curves of the conductor and the core are plotted in Figures 3-4.

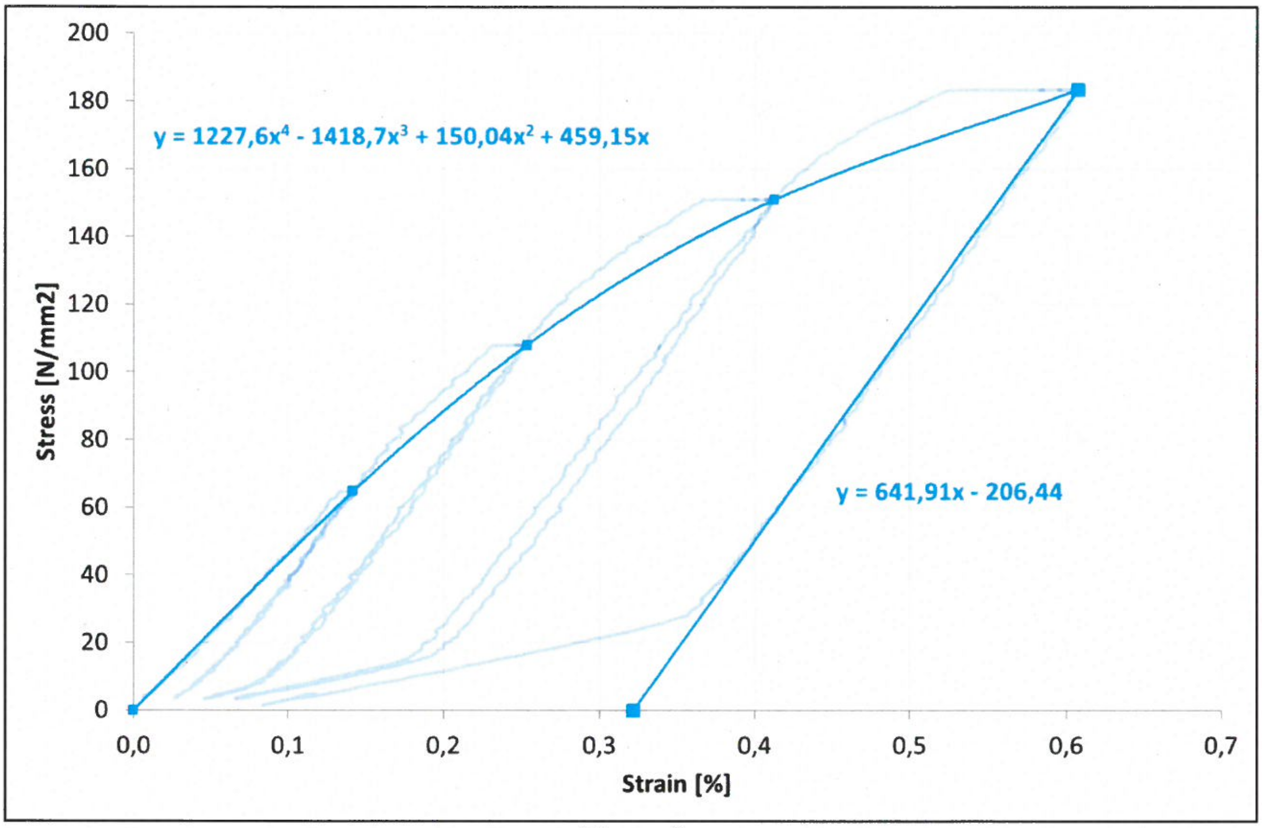


Figure 3
Stress-Strain curve (Complete conductor)

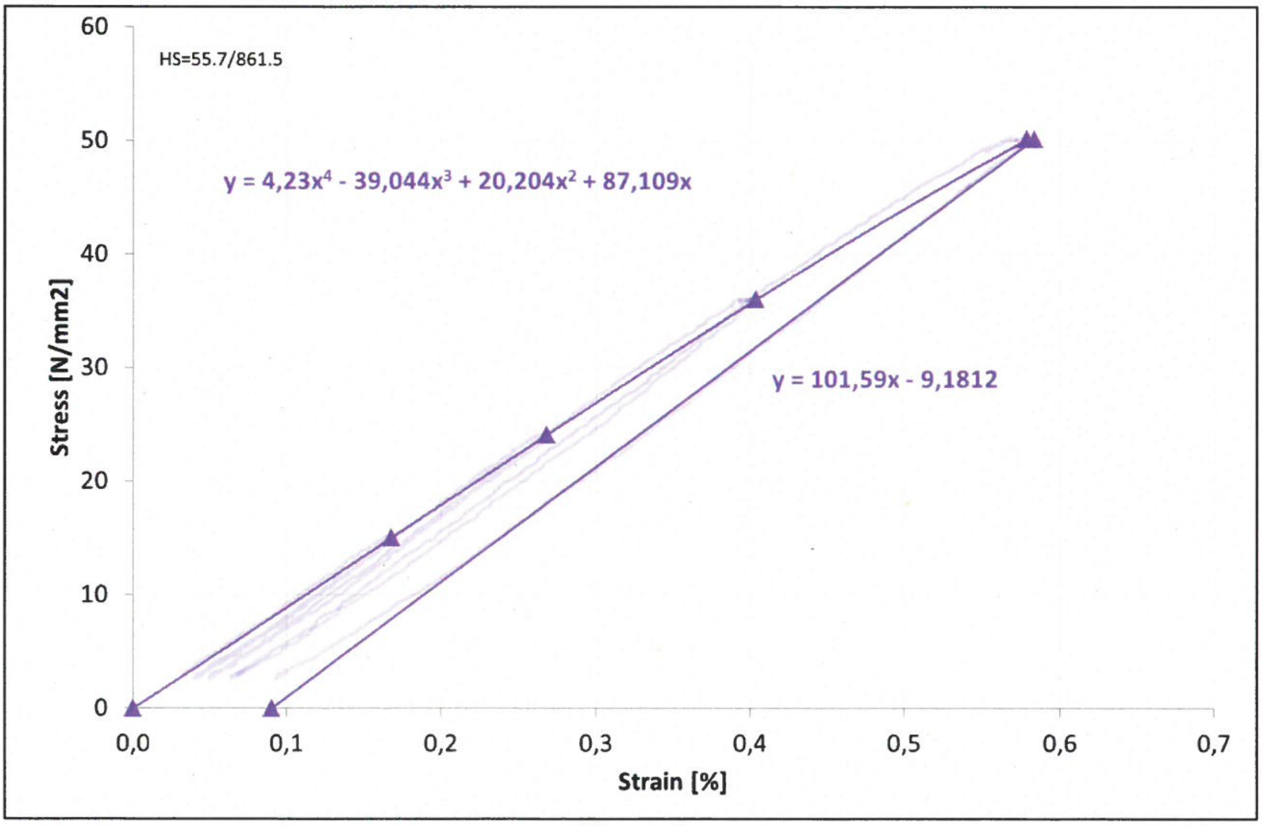


Figure 4
Stress-Strain curve (Steel Core)

The stress-strain values obtained at the end of each hold period are summarized in Table 13. The stress of the aluminium layers is calculated by subtracting the corresponding data points of the steel core from the whole conductor. The stress values of the core and aluminium layers are calculated with the cross-sectional area of the whole conductor. It is equivalent with calculating the stress using own cross-sectional area of the steel core and aluminium layers, and then multiplying with the corresponding cross-sectional area ratio ($HS = 55.7/861.5$ and $HA = 805.84/861.5$).

Table 13: Stress and strain of the conductor, steel core and aluminium layers

Load	Strain [%]	Stress of Conductor [N/mm^2]	Stress of Steel Core [N/mm^2]	Stress of Aluminium Layers [N/mm^2]
30% RTS	0.14	64.78	12.69	52.09
50% RTS	0.25	107.95	22.75	85.20
70% RTS	0.41	150.93	36.77	114.16
85% RTS	0.61	183.40	52.18	131.22

The measured curves and also the polynomial curves cross the origin of the coordinate system therefore the constant term of the polynomials are zero.

The initial curves were obtained by fitting 4th order polynomial curves to above points. The coefficients are as follows:

- Complete conductor: $y = 1227.6x^4 - 1418.7x^3 + 150.04x^2 + 459.15x$
- Aluminium-clad steel core: $y = 4.23x^4 - 39.044x^3 + 20.204x^2 + 87.109x$
- Aluminium layers: $y = 1223.4x^4 - 1379.7x^3 + 129.84x^2 + 372.04x$

where:
x: strain [%]
y: stress [N/mm^2], calculated with the cross-sectional area of the whole conductor

The coefficients of the regression lines fitted to the unloading segments on the stress-strain curves are as follows:

- Complete conductor: $y = 641.91x - 206.44$
- Aluminium-clad steel core: $y = 101.59x - 9.1812$
- Aluminium layers: $y = 540.32x - 197.26$

where:
x: strain [%]
y: stress [N/mm^2], calculated with the cross-sectional area of the whole conductor

The composite Stress-Strain curves are plotted in Figure 5.

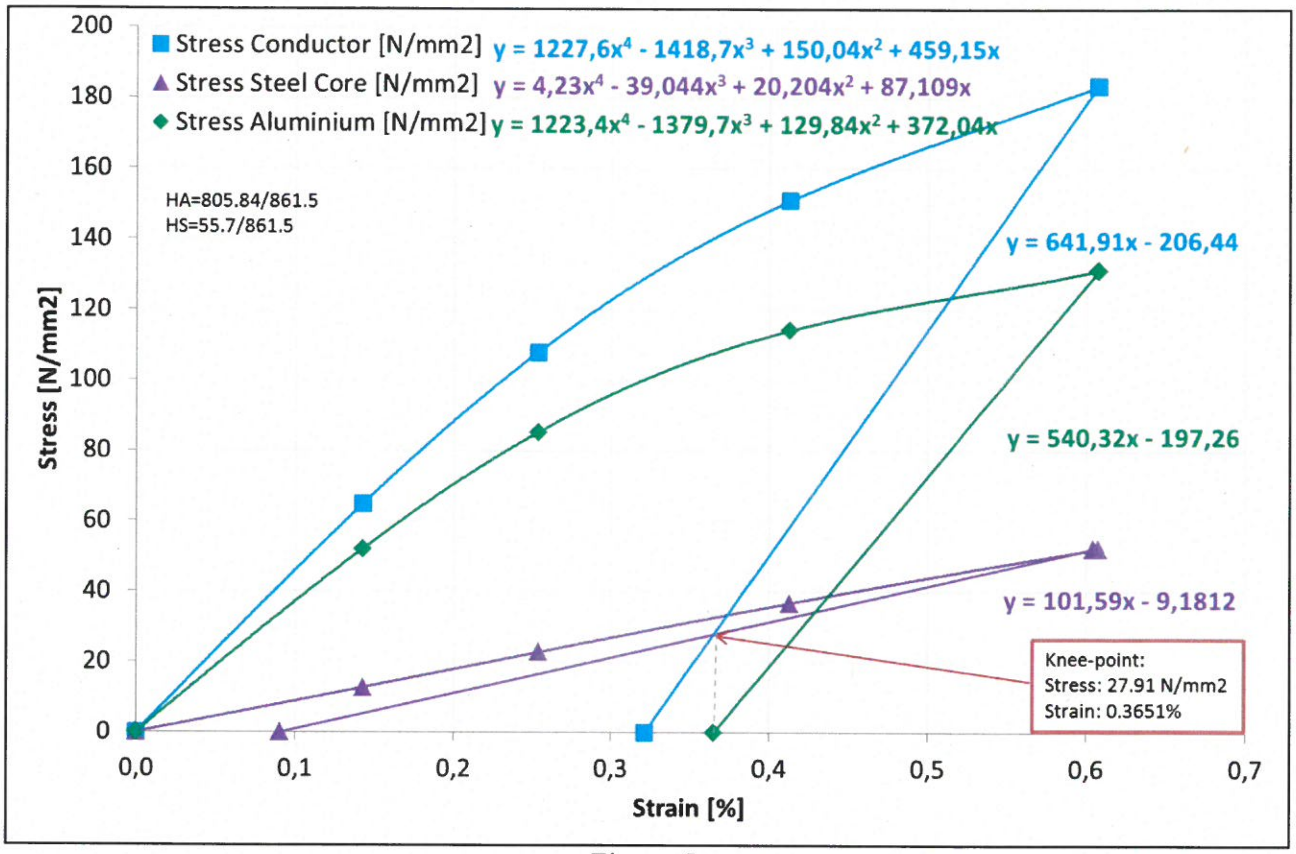


Figure 5
Composite Stress-Strain curves

5. Tensile test of the conductor

5.1. Test method and parameters

The verification of tensile breaking strength was carried out on overhead line conductor type ACSR/AW Lapwing in accordance with standard IEC 61089:1991 Clause 6.5.3 and Annex B. The tensile breaking strength test was performed on two conductor specimens.

5.2. Test results

The test results were the following:

- Sample 1: the tensile specimen broke at the load of 180.80 kN.
- Sample 2: the tensile specimen broke at the load of 180.79 kN.

The tensile loads were higher than 176.6 kN (95 % of the 185.9 kN RTS), which is the acceptance criterion of the standard. Based on the test results; the overhead line conductor type ACSR/AW Lapwing fulfilled the requirements of tensile breaking strength.

The obtained Force-Elongation curves are shown in Figures 6-7. The fractured wires are shown on Photos 4-5.

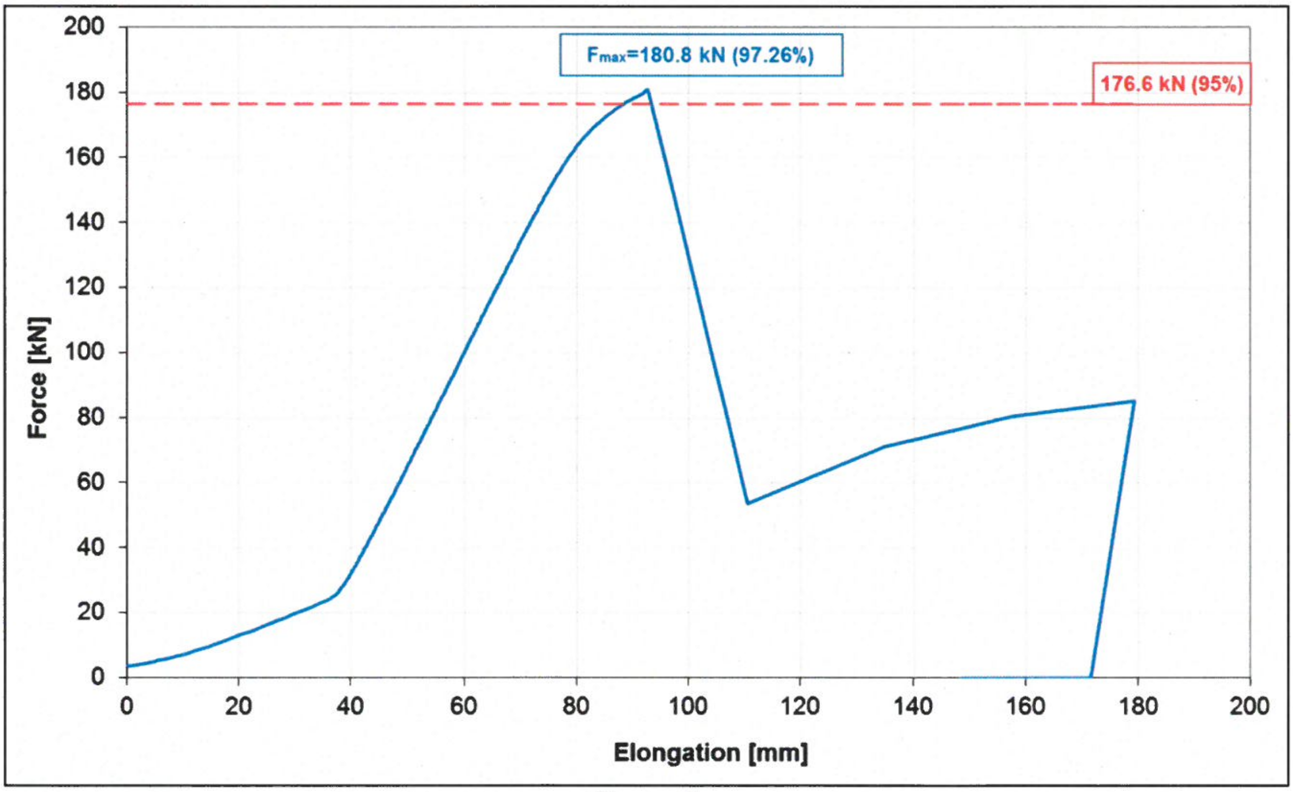


Figure 6
Tensile breaking test (Sample 1)

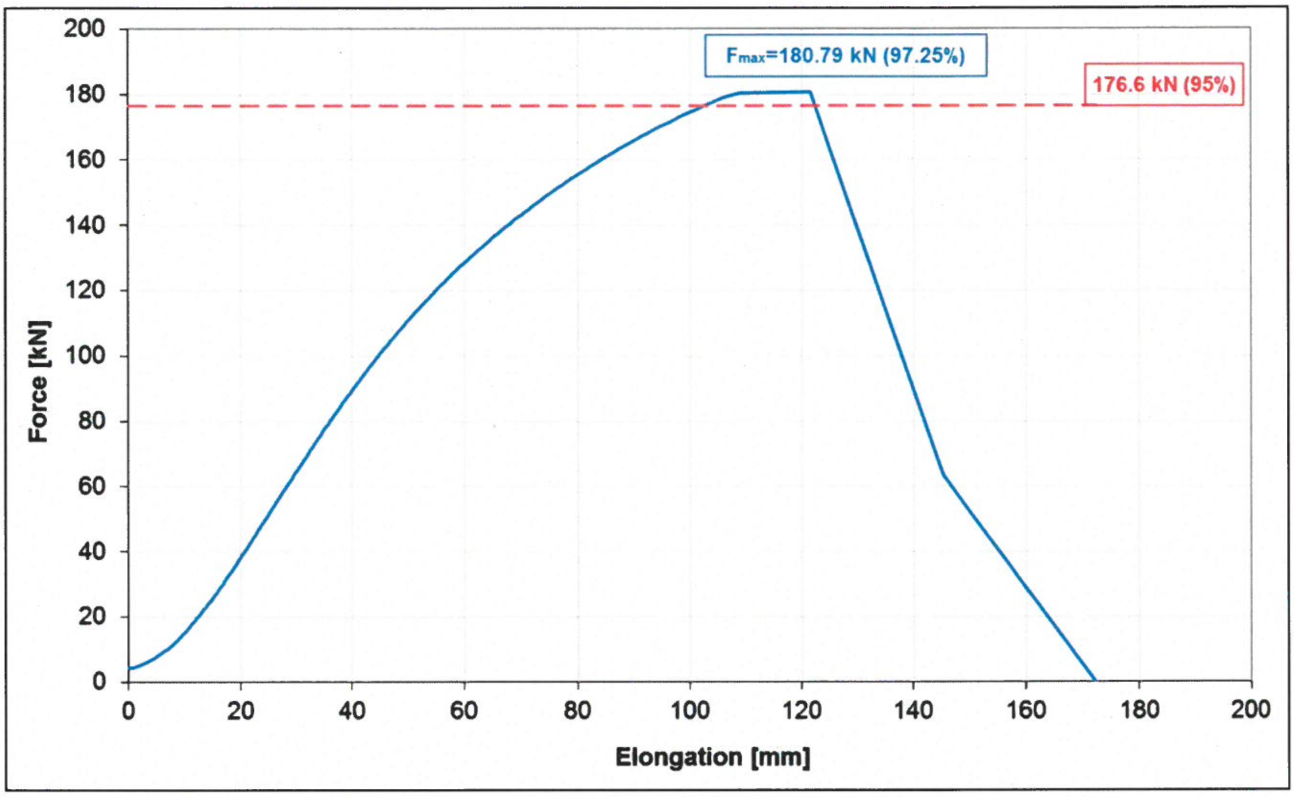


Figure 7
Tensile breaking test (Sample 2)

6. DC resistance measurement

6.1. Test method and parameters

The DC resistance measurement was carried out on overhead line conductor type ACSR/AW Lapwing according to the test procedure agreed with Client.

The conductor was placed in a 6 m long test span. The conductor was fixed by electrically and thermally isolated fittings; the applied force was 18.6 kN (10% of RTS). The average conductor temperature was measured by three thermocouples installed on the outer layer of the conductor. All resistance measurements were made by using 4-wire digital micro-ohm meter with an internal 200 A DC current supply. The voltage drop was measured in a 3m long conductor section. The test arrangement is shown in Figure 8 and on Photo 6.

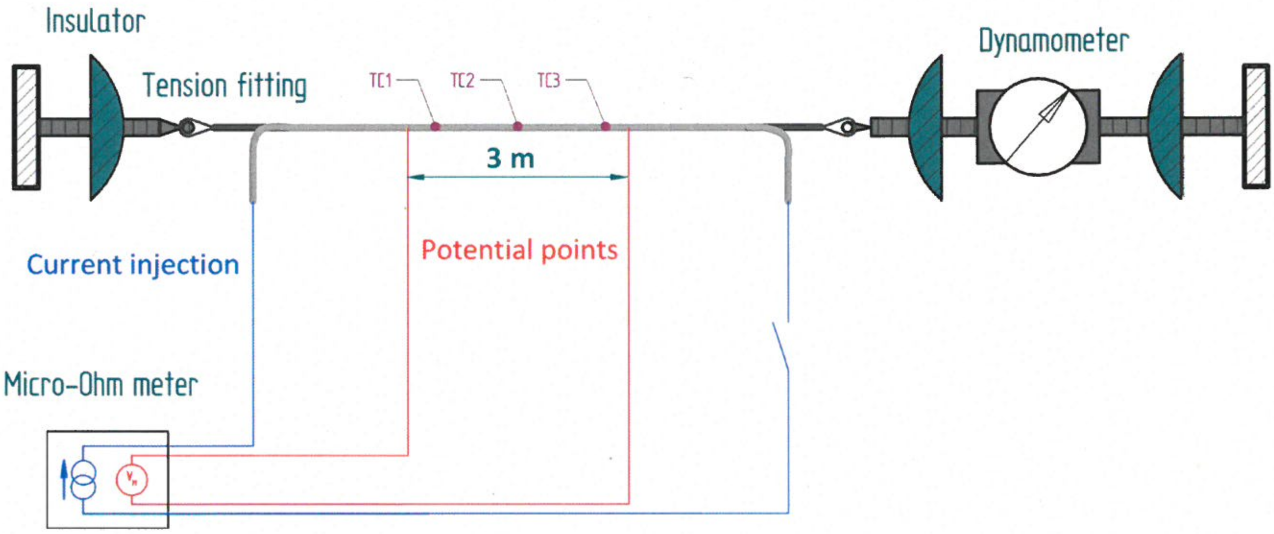


Figure 8
Test circuit diagram for DC resistance measurement

The electrical resistance of the test specimen was measured at ambient temperature. The measured resistance values were corrected to 20°C by means of the formula:

$$R_{20} = \frac{R_\theta}{1+\alpha_{20}\left(\theta-20\right)}$$

where

R_θ	is the measured resistance
θ	is the temperature in degree Celsius
α_{20}	is the thermal coefficient of resistance ($\alpha_{20} = 4\times10^{-3}$)

6.2. Test results

Table 14 indicates the results of the DC resistance measurement

Table 14: DC resistance of ACSR/AW Lapwing conductor

Measurement	$R_{\theta\ 3m}$ [µΩ]	R_{θ} [µΩ/m]	Θ [°C]	R_{20} [Ω/km]
1	102.270	34.090	18.0	0.0344
2	102.269	34.090	18.1	0.0344
3	102.270	34.090	18.1	0.0344
4	102.269	34.090	18.1	0.0344
5	102.276	34.092	18.1	0.0344
6	102.220	34.073	18.1	0.0343
7	102.234	34.078	18.1	0.0343
8	102.241	34.080	18.1	0.0343
9	102.256	34.085	18.1	0.0343
10	102.268	34.089	18.1	0.0344
				0.0343

The measured resistance of the conductor (0.0343 Ω/km) was lower than the specified maximum 0.0358 Ω/km; therefore the conductor met the DC resistance requirement of the data sheet.

Uncertainty of measurements

Wire resistance: ±0.5%
Conductor DC resistance: ±0.2%
Conductor temperature: ±1°C
Length (<120 mm): ±0.05mm
Length (>120 mm): ±1mm
Wire diameter: ±0.003 mm
Force measurement: ±1.5%
Mass of wires: ±20 mg

The uncertainty values given in this report are the standard deviation values multiplied by k=2. Measurement uncertainty was estimated according to the method described in the EA-4/02 document.

Measuring devices used for the tests:

Designation	Manufacturer	Type	S/N:
Data Logger	FLUKE	2620A	8745002
DC Microohm-meter	VEIKI-VNL Ltd.	MO-3	MO-3-03/2015
Measuring tape	MODECO	-	-
Load Cell	A.S.T GmbH	KAP-S/20kN	1605451
Tensile test machine (50 kN) Extensometer	Métisz-Q Kft. VEIKI-VNL Ltd.	ZD10-90 LVDT	263/1111/DSZ 2/2014
Tensile test machine (300 kN)	BARABÁS Mérnökiroda	KSZ	001/2011
Digital micrometer	Mitutoyo	MDC-25SX	293-821-30
Laser distance meter	Bosch	DLE 70	417373104
Thermocouples	Omega	"T" type, precision grade	---

PHOTOS

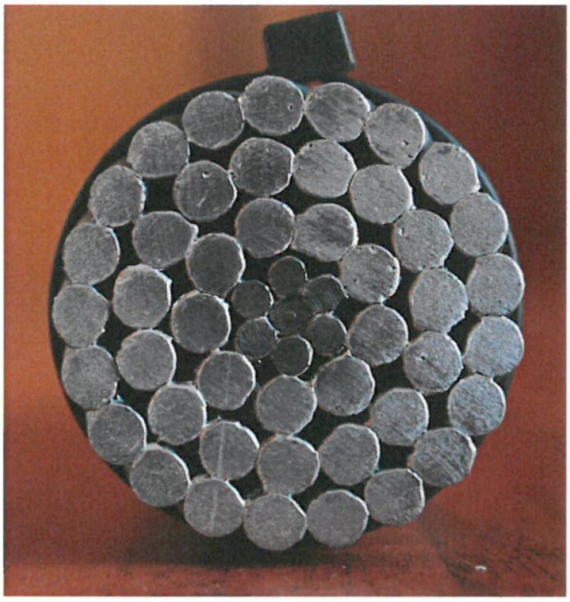
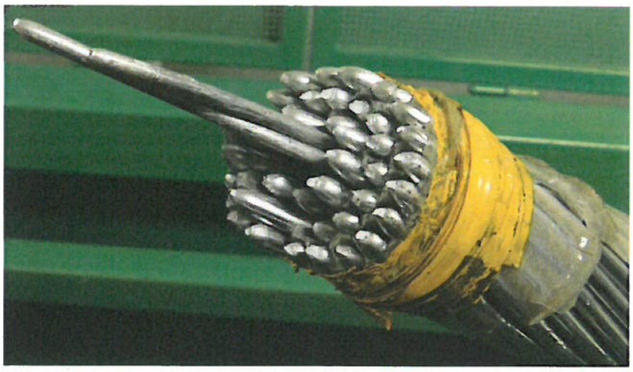


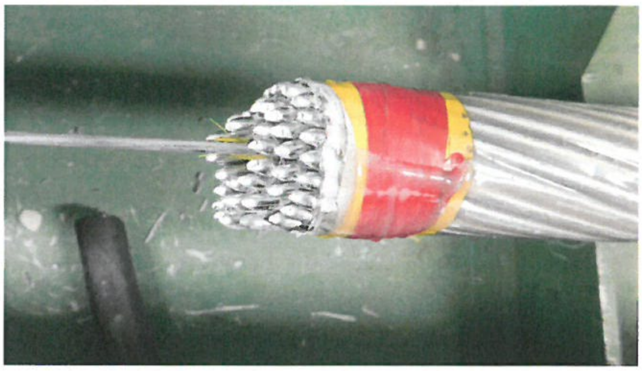
Photo 1
Cross-sectional view of the tested conductor

Photo 2
Conical epoxy resin end fitting used for the mechanical tests

Photo 3
Stress-strain and tensile breaking test arrangement



Sample 1



Sample 2

Photos 4-5
Broken conductor after the tensile break test

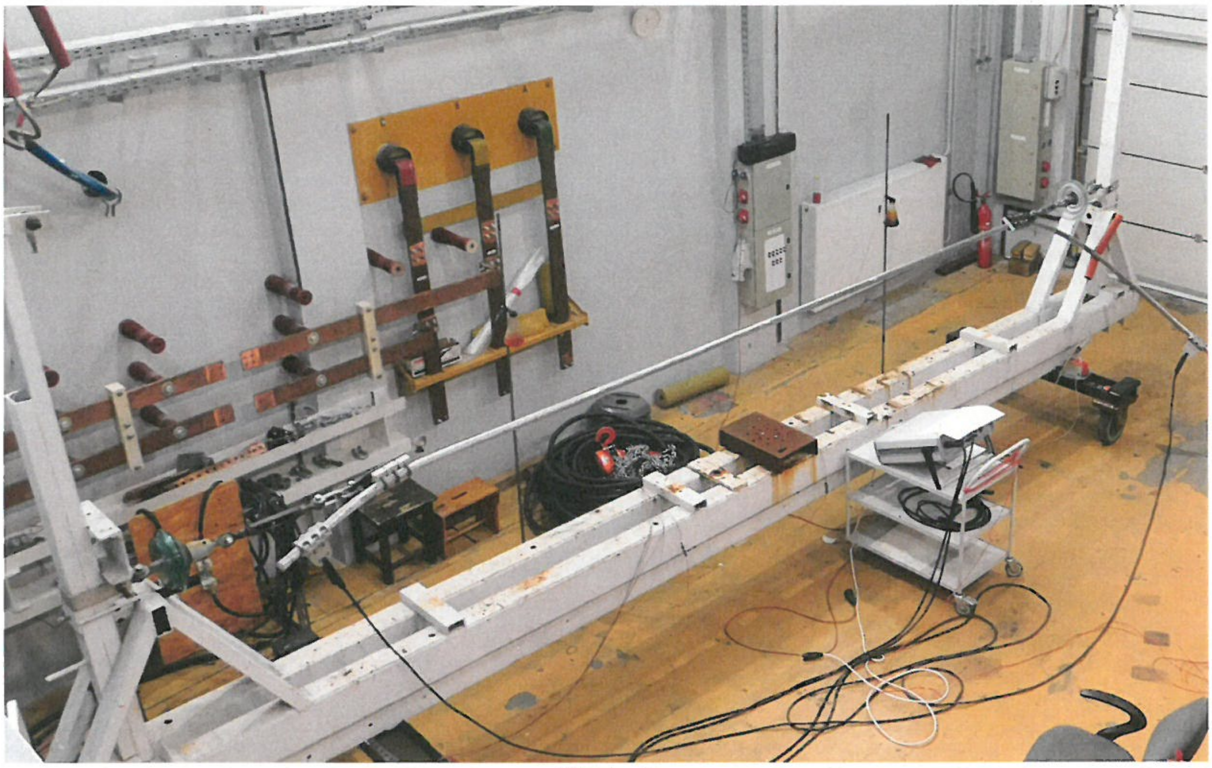


Photo 6
Test arrangement of DC resistance measurement

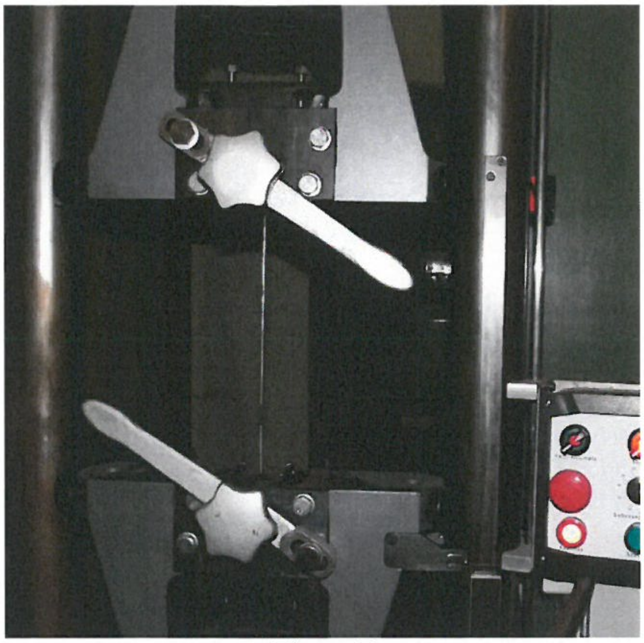


Photo 7
Broken individual wire after the tensile test

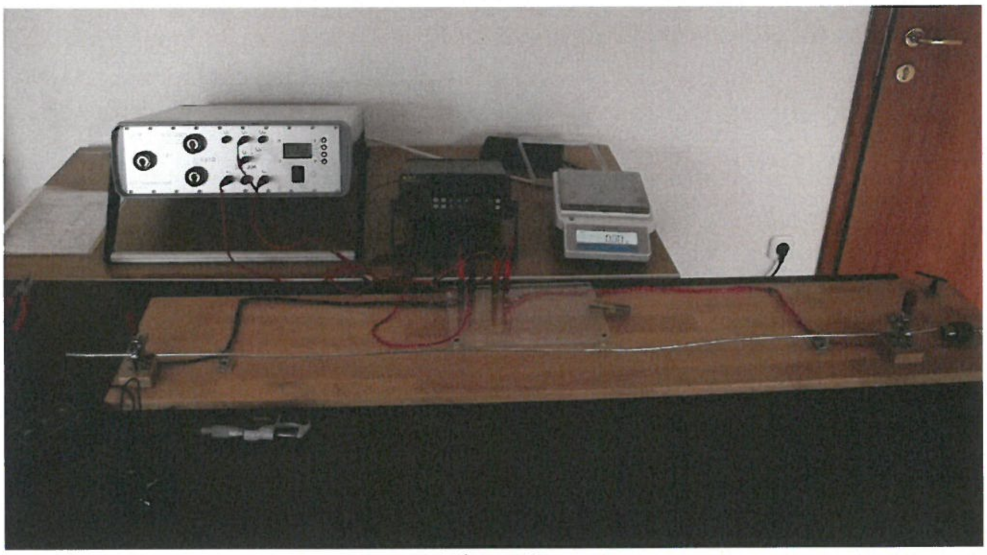


Photo 8
Test arrangement of resistance measurement

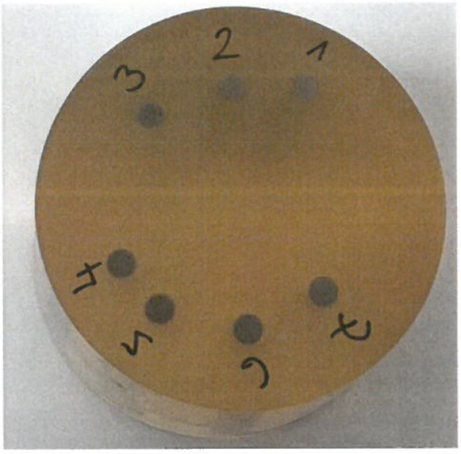


Photo 9
Sample prepared for Al thickness measurement

ELSEWEDY CABLES

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Tóth Lajos

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DATA TABLE

A - Complete Conductor:

- Maker's name :	EL SEWEDY CABLES	
- Type:	ACSR/AW (Lapwing)	
- Construction:	45x4.775, 7x3.183	
- Standards applied :	IEC 61089, 60889, 61232	
- Overall diameter of conductor :	38.2 ± 1%	mm
- Maximum D.C. resistance of conductor at 20° C :	0.0358	Ω/Km
- Grease application [Y / N] :	No	
-Rated tensile strength of conductor :	185.9	KN
- Conductor mass:	2598 ± 2%	Kg/Km
- Outer layer direction	R.H.	
- Lay Ratio:		
• 1st layer for Al Clad steel	16-26	
• 2nd layer for Aluminum	10-16	
• 3rd layer for Aluminum	10-16	
• 4th layer for Aluminum	10-14	

B - Aluminum Wire:

- Cross-section of aluminum wire	806	mm2
- Diameter of aluminum wire :	4.775 ± 0.03	mm
- Number of aluminum wires :	45	
- Minimum ultimate tensile strength of aluminum wire after stranding :	15.5	Kg/mm2
- Density of aluminum wire material :	2.703	Kg/dm3
- Resistivity:	28.264	nΩm
- Conductivity:	61% IACS	

C - Aluminum Clad Steel Wire (20SA):

- Cross-section of Al Clad steel wire	55.6	mm2
- Diameter of Al Clad steel wire :	3.183± 0.05	mm
- Number of Al Clad steel wires :	7	
- Minimum ultimate tensile strength of Al Clad steel wire after stranding :	130	Kg/mm2
-Stress at 1%:	116	Kg/m2
- Density of Al Clad steel wire material :	6.59	Kg/dm3
- Resistivity:	84.8	nΩm
- Conductivity:	20.3% IACS	
- Minimum Aluminum Cladding Thickness:	0.159	mm

Prepared by: Eng. Mohamed Samy

Approved by: Eng. Mohamed Mansor

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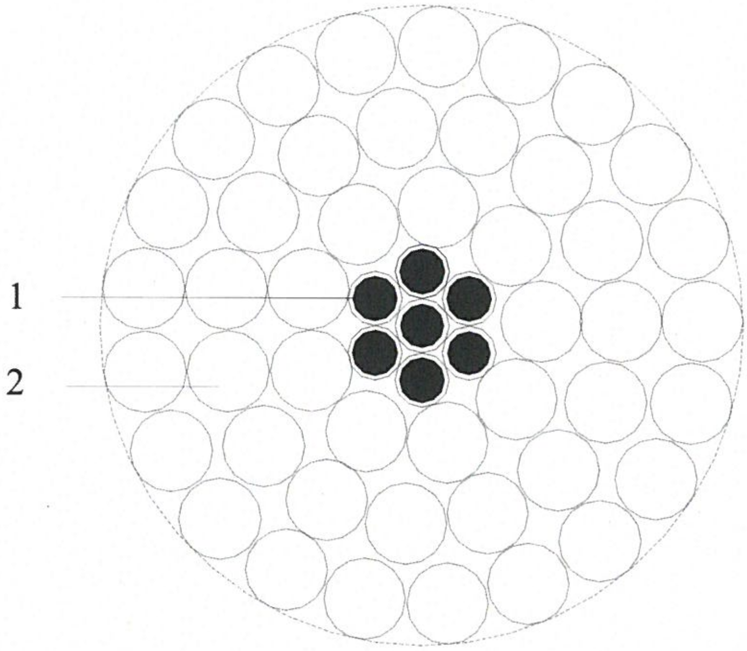

Size :	**805.7 (Lapwing)** *mm²*	*Type* : **ACSR/AW**	
		Standard: **IEC 61089,60889,61232**	
Code :	**AC0-T001-U(Lapwing)**	***EL-SEWEDY CABLES***	
Sr.	Description		
1.	***Aluminum Clad Steel*** *Wire (7 Wires)*		
2.	**Aluminum** *Wire* ***(45 Wires)***		
Not to Scale	*Drawn by* *Mr. Nabil Abdallah*	*Approved by* ***Eng. Mohamed Samy***	