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Draft Indian Standard

**ALUMINIUM CONDUCTOR FOR OVERHEAD
TRANSMISSION PURPOSES — SPECIFICATION**

**PART 2 ALUMINIUM CONDUCTORS — GALVANIZED STEEL — REINFORCED
FOR OVERHEAD TRANSMISSION LINES**

(Fourth Revision)

Conductors and Accessories for Overhead Lines
Sectional Committee, ETD 37

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FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Conductors and Accessories for Overhead Lines Sectional Committee had been approved by the Electrotechnical Division Council.

This standard has been prepared to cover the requirements of ACSR conductors for use on overhead transmission lines. This includes conductors for extra high voltages, wherein corona and radio interference attain great importance and special attention has to be paid to the finish of the conductor. Tests to ascertain conformity in this regard have also been stipulated in the standard:

IS-398 (Part 2) for ACSR conductors was originally published in 1953 and the first revision was brought out in 1961. The second revision of IS-398 (Part 2) was brought out in 1976 and third revision in 1996. IS 398(Part 5) for ACSR conductors for extra high voltage transmission lines was first published in 1982 and its first revision was published in 1992. At that time of first publish of IS 398 (Part 5), the development of EHV network was envisaged at 400 kV ac only. For this system after detailed techno-economic studies by CEA, 54/3. 53 mm Al+ 7/3.53 mm steel conductor in the form of horizontal twin conductor bundle with a sub conductor spacing of 450 mm was identified as the most suitable conductor. However, with the expansion of Indian transmission network comprising of 400 kV, +/-500kV HVDC, 765kV and +/-800kV HVDC lines and introduction of new voltage levels such as +/-320kV & +/-350 kV HVDC, use of various sizes of ACSR conductors in the country has been burgeoning significantly. Further, due to high capacity requirements in several instances, use of higher size of ACSR conductor has not been restricted to higher voltage levels and the same are also being used for lower voltage transmission lines on case-to-case basis. Also, with better mechanization, improved modern-day conductor manufacturing technologies and greater focus on quality, ACSR conductor for even lower voltage transmission lines are able to match the tolerance requirements and other quality parameters which in the past, used to be specified only for 400kV & above voltage level conductors. Hence, in this revision of IS-398 (Part 2), the existing provisions of IS-398 (Part 2) and IS-398 (Part 5) have been merged together into a common part i.e. revised IS-398 (Part 2). With this merger, apart from the three sizes of conductor specified earlier, this revision now includes even the smaller sizes of ACSR conductor that are used for transmission lines in the country. It is, however, not intended to restrict the standard to the parameters of these conductors only and requirements for any other conductors for the purpose of overhead transmission lines, will be added later as and when the need arises.

In the standard value adopted for resistivity of EC grade aluminium is 0.028264 ohm. mm²/m at 20°C which is the value adopted in the IEC Standard also.

This part deals with aluminium conductors galvanized steel reinforced for transmission lines and it forms Part 2 of the series.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off -in accordance with the latest amendment of IS 2 'Rules for rounding off numerical values'. The number of significant places retained in the rounded off value should be the same that of the specified value in this standard.

*Draft Indian Standard***ALUMINIUM CONDUCTORS FOR OVERHEAD
TRANSMISSION PURPOSES-SPECIFICATION****PART 2 ALUMINIUM CONDUCTORS — GALVANIZED STEEL — REINFORCED
FOR OVERHEAD TRANSMISSION LINES*****(Fourth Revision)*****1.0 SCOPE**

1.1 This standard (Part 2) covers the requirements and tests for aluminium conductors, galvanized steel-reinforced (ACSR) used for overhead transmission lines.

1.2 This standard specifies the requirement of aluminium conductors, galvanized steel-reinforced with specified dimensions and including number of wires, but can also be applied to other round-wire ACSR conductors having different sizes or number of constituent strands.

2.0 REFERENCES

The standards listed below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below

IS No	Title
398 (Part 4)	Aluminium conductors for overhead transmission purposes. Part 4 Aluminum alloy stranded conductors (aluminum-magnesium-silicon type) — Specification
398 (Part 6)	Aluminium conductors for overhead transmission purposes Part 6 High Conductivity Aluminum alloy stranded conductors— Specification
1778	Reels and drums for bare Conductor
15976	Steel Reels and Drums for Bare Conductors
5484	EC grade aluminium rods produced by continuous casting and rolling

3.0 TERMINOLOGY

For the purpose of this standard, the following definitions in addition to those given in IS 1885 (Part 32) shall apply.

3.1 Concentric Lay Stranded Conductor

Conductors composed of a central core surrounded by one or more adjacent layers of wires being laid helically in opposite directions.

3.2 Aluminum Conductor, Galvanized Steel-Reinforced

Conductor consisting of seven or more aluminum and galvanized steel wires built up in concentric layers. The central wire or wires are of galvanized steel and the outer layer or layers of aluminum.

3.3 Diameter

The mean of two measurements at right angles taken at the same cross-section.

3.4 Direction of Lay

The direction of lay is defined as right-hand or Left-hand. With right -hand lay, the wires conform to the

direction of the central part of the letter 'Z' When the conductor is held vertically. With left-hand lay, the wires conform to the direction of the central part of the letter 'S' when the conductor is held vertically.

3.5 **Lay Ratio**

Ratio of the axial length of a complete turn of the helix formed by an individual wire in a stranded conductor to the external diameter of the helix

3.6 **Conductor Bundle**

The combination of more than one conductor per phase in parallel suitably spaced from each other used in overhead transmission lines.

3.7 **Sub conductor**

The individual conductor in a bundle defined in 3.6.

4.0 **PHYSICAL CONSTANTS FOR HARD DRAWN ALUMINIUM**

4.1 **Resistivity**

The resistivity of aluminium depends upon its purity and its physical condition. For the purpose of this standard, the maximum value permitted is 0.028264 ohm.mm²/m at 20 °C and this value has been used for calculation of the maximum permissible value of DC resistance.

NOTE – It is not intended to check the resistivity from the measured value of DC resistance

4.2 **Density**

At a temperature of 20°C, the density of hard drawn aluminium has been taken as 2.703 g/cm³

4.3 **Constant -Mass Temperature Co- efficient of Resistance**

At a temperature of 20°C, the constant-mass temperature co-efficient of resistance of hard drawn aluminium, measured between two potential points rigidly fixed to the wire, the metal being allowed to expand freely, has been taken as 0.00403/°C.

4.4 **Co-efficient of Linear Expansion**

The co-efficient of linear expansion of hard drawn aluminium at 0°C has been taken as 23×10^{-6} per degree Celsius. This value holds good for all practical purposes over the range of temperature from 0°C to the highest safe operating temperature.

5.0 **PHYSICAL CONSTANTS FOR GALVANIZED STEEL WIRES**

5.1 **Density**

At a temperature of 20°C, the density of galvanized steel wire is to be taken as 7.80 g/cm³.

5.2 **Co-efficient of Linear Expansion**

In order to obtain uniformity in calculation, a value of 11.5×10^{-6} /°C may be taken as the value for the coefficient of linear expansion of galvanized steel wires used for the cores of steel-reinforced aluminum conductors.

6.0 **MATERIAL**

6.1 The conductors shall be constructed from EC grade aluminium rods suitably hard-drawn on wire drawing machine (IS 5484 can be referred for the aluminium rod specifications). The mechanical and electrical properties of aluminum wire shall comply with the requirements given in Table 1.

6.1.1 Galvanized steel wire should be drawn from high carbon steel rods produced by either acid or basic open hearth process, electric furnace process or basic oxygen process. The mechanical and electrical properties of wire shall comply with the requirements given in Table 2. The chemical composition of high carbon steel wire is given in Annex A for the purpose of guidance.

6.2 The zinc used for galvanizing shall be electrolytic high grade zinc not less than 99.95 percent purity. It shall conform to and satisfy all the requirements of IS 209. Galvanizing may be done either by hot process or

electrolytic process. When specified by the purchaser, neutral grease may also be applied (in addition to galvanizing of steel wires) between the layers of wires.

NOTE: Lithium soap grease corresponding to Grade II of IS 7623 having minimum drop point not less than 180°C is suitable for such application

7.0 FREEDOM FROM DEFECTS

7.1 The wires used for standard conductors shall be smooth and free from all imperfections not consistent with good commercial practice, for example, spills and splits.

8.0 STANDARD SIZES

8.1 Wires

8.1.1 Nominal Sizes

The aluminium and galvanized steel wires for the standard constructions covered by this standard shall have the diameter specified in Tables 1 and 2. The diameter of the galvanized steel wire shall be measured over the zinc coating

8.1.2 Tolerances on Nominal Sizes

8.1.2.1 Aluminum wires

A tolerance of ± 0.02 mm shall be permitted on the nominal diameters upto & including 4mm and a tolerance of ± 0.5 percent shall be permitted on the nominal diameters above 4mm as specified in Table 1 (rounded off).

8.1.2.2 Galvanized steel wire

A tolerance of ± 2 percent shall be permitted on the normal diameter specified in Table 2 (rounded off).

8.2 Aluminum Conductors, Galvanized Steel-Reinforced

8.2.1 The standard sizes and properties of ACSR conductors shall be as given in Table 3.

8.2.2 Tolerances on size/ mass shall be as follows:

- a) Outer diameter of conductor : ± 1 percent,; and
- b) Overall Mass of conductor : ± 2 percent..

9.0 JOINT IN WIRES

9.1 The wires shall be drawn in continuous length, without joints, except those made in wire rod or before drawing operation

9.2 Aluminium Wires

9.2.1 During stranding in aluminium wire no welds shall be made for the purpose of achieving the required conductor length.

9.2.2 No joint shall be permitted in the aluminium wires in the outermost layer of the ACSR conductor and in any wire of stranded conductor containing seven wires. Joints in the individual aluminium wires are permitted in any layer except the outermost layer, in addition to those made in the base rod or wire before final drawing. Joints are permitted in wire broken during stranding provided such breaks are not associated with either inherently defective wire or with those of short lengths of aluminium wires. Joints shall be dressed smoothly with a diameter equal to that of parent wires and shall not be kinked. No two joints other than those in wires before stranding permitted under 9.1 occur at points in the stranded conductors nearer than 15 m.

9.2.3 Joints shall be made by electric butt welding, electric butt cold upset welding or cold pressure welding. These joints shall be made in accordance with good commercial practice. Electric butt welding shall be annealed for approximately 250 mm on both sides of the welds.

9.2.4 While the joints specified are not required to meet the requirements of unjointed wires, they shall be

withstanding a stress of not less than 75 MPa for annealed electric butt welded joints and not less than 130 MPa for cold pressure and electric butt cold upset welded joints. The manufacturer shall demonstrate that the proposed welding method is capable of meeting the specified strength requirements.

9.3 Galvanized Steel Wires

No joints of any kind shall be made in the finished coated steel wires.

Table 1 Aluminium Wires Used in the Construction of Aluminium Conductors, Galvanized Steel-Reinforced for overhead transmission lines (Clauses 6.1, 8.1.1, 8.1.2.1, 13.6, 13.9 and 13.13)

Diameter			Cross Sectional Area of Nominal Diameter Wire	Mass	DC Resistance at 20°C Max	Minimum Breaking Load	
Nom	Min	Max				Before Stranding	After Stranding
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mm	mm	mm	mm ²	Kg/Km	Ω/Km	KN	KN
1.50	1.48	1.52	1.767	4.78	16.429	0.34	0.32
1.96	1.94	1.98	3.017	8.16	9.562	0.56	0.53
2.11	2.09	2.13	3.497	9.45	8.239	0.63	0.60
2.54	2.52	2.56	5.067	13.7	5.667	0.86	0.82
2.59	2.57	2.61	5.269	14.24	5.449	0.90	0.86
2.79	2.77	2.81	6.114	16.53	4.690	1.04	0.99
3.00	2.98	3.02	7.069	19.11	4.052	1.20	1.14
3.18	3.16	3.20	7.942	21.47	3.604	1.31	1.24
3.35	3.33	3.37	8.814	23.82	3.245	1.45	1.38
3.50	3.48	3.52	9.621	26.01	2.972	1.59	1.51
3.53	3.51	3.55	9.787	26.45	2.921	1.57	1.49
3.80	3.78	3.82	11.341	30.66	2.519	1.81	1.72
3.99	3.97	4.01	12.504	33.80	2.283	2.00	1.90
4.09	4.07	4.11	13.138	35.51	2.172	2.10	2.00
4.13	4.11	4.15	13.396	36.21	2.130	2.14	2.03
4.44	4.42	4.46	15.483	41.85	1.842	2.48	2.36
4.57	4.55	4.59	16.403	44.34	1.738	2.62	2.49
4.72	4.70	4.74	17.497	47.30	1.629	2.80	2.66
4.78	4.76	4.80	17.945	48.51	1.588	2.87	2.73

NOTES

- 1 The resistance has been calculated from the cross-sectional area based on minimum diameter and a resistivity of 0.028 264 ohm. mm²/m.
2. The resistance of individual wires shall be such that the completed stranded conductor meets the requirements of the maximum resistance specified in col 8 of Table 3.
3. Minimum breaking load of individual wires (before stranding) have been calculated considering nominal diameter of each wire. After stranding values have been kept as 95% of the before stranding values.

Table 2 Steel Wires Used in the Construction of Aluminium Conductors, Galvanized Steel-Reinforced for overhead transmission lines (Clauses 6.1, 8.1.1, 8.1.2.2, 13.6 and 13.13)

Diameter	Cross Sectional Area	Mass	Minimum Breaking Load
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Nom	Min	Max	of Nominal Diameter Wire		Before Stranding	After Stranding
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mm	Mm	mm	mm ²	Kg/Km	KN	KN
1.50	1.47	1.53	1.767	13.78	2.46	2.34
1.57	1.54	1.60	1.936	15.10	2.70	2.57
1.91	1.87	1.95	2.865	22.35	3.99	3.79
1.96	1.92	2.00	3.017	23.53	4.20	3.99
2.11	2.07	2.15	3.497	27.27	4.59	4.36
2.21	2.17	2.25	3.836	29.92	5.04	4.79
2.30	2.25	2.35	4.155	32.41	5.46	5.19
2.54	2.49	2.59	5.067	39.52	6.66	6.33
2.59	2.54	2.64	5.269	41.09	6.92	6.57
2.79	2.73	2.85	6.114	47.69	8.03	7.63
3.00	2.94	3.06	7.069	55.13	9.29	8.83
3.18	3.12	3.24	7.942	61.95	10.44	9.92
3.35	3.28	3.42	8.814	68.75	11.58	11.00
3.45	3.38	3.52	9.348	72.92	12.28	11.67
3.53	3.46	3.60	9.787	76.34	12.86	12.22
4.09	4.01	4.17	13.138	102.48	17.26	16.40

Table 3 : Aluminium Conductors, Galvanized Steel-Reinforced for overhead transmission lines
(Clauses 8.2.1 and 8.2.2)

Nominal Aluminium	Stranding and Wire Diameter		Sectional Area of Aluminium	Total Sectional Area	Approx. Diameter	Approx. Mass	Calculated DC Resistance at 20°C Max	Approx calculated Breaking Load Min
	Aluminium	Steel						
(1) mm ²	(2) mm	(3) mm	(4) mm	(5) mm ²	(6) mm	(7) kg/km	(8) ohm/km	(9) KN
10	6/1.50	1/1.50	10.60	12.40	4.50	43	2.707	4.09
18	6/1.96	1/1.96	18.12	21.12	5.88	73	1.584	6.86
20	6/2.11	1/2.11	21.00	24.50	6.33	85	1.366	7.61
30	6/2.59	1/2.59	31.62	36.92	7.77	128	0.9075	11.17
50	6/3.35	1/3.35	52.86	61.66	10.05	214	0.5428	18.37
80	6/4.09	1/4.09	78.84	91.94	12.27	319	0.3640	27.02
100	6/4.72	7/1.57	105.00	118.60	14.15	394	0.2733	32.53
130	26/2.54	7/1.91	131.82	151.92	15.89	529	0.2190	45.65
150	30/2.59	7/2.59	158.10	195.00	18.13	726	0.1828	67.63
180	30/2.79	7/2.79	183.30	226.10	19.53	842	0.1577	78.35
200	30/3.00	7/3.00	212.10	261.60	21.00	974	0.1362	90.56
400	26/4.44	7/3.45	402.48	467.98	28.11	1624	0.07174	136.26
400	42/3.50	7/1.96	404.04	425.14	26.88	1286	0.07171	90.43
420	54/3.18	7/3.18	428.76	484.36	28.62	1627	0.06767	131.44
520	42/3.99	7/2.21	525.00	551.90	30.57	1666	0.05518	112.31
530	54/3.53	7/3.53	528.66	597.16	31.77	2004	0.05488	159.60
560	42/4.13	7/2.30	562.80	591.90	31.68	1787	0.05063	120.57
690	42/4.57	7/2.54	688.80	724.30	35.04	2187	0.04137	147.47
810	45/4.78	7/3.18	807.75	863.35	38.22	2668	0.03577	188.69

NOTE — In order to maintain the circularity of the wires the tolerances allowed in 8.1.2.1 and 8.1.2.2 shall apply to both the measurements at right angles taken at the same cross-section as per 3.3 of IS 398 (Part 2)

Table 4 Lay Ratio of Aluminium Conductors Galvanized Steel-Reinforced
(Clauses 10.2, 10.3 and 13.5)

Number of Wires in Conductor		Lay Ratios for Aluminium Wire							
		Lay Ratios for Steel Core (6 Wire Layer)		Outside Layer		Layer Immediately Beneath outside Layer.		Innermost Layer of Conductors with 3 Aluminium Wire Layers	
Aluminium	Steel	Min	Max	Min	Max	Min	Max	Min	Max
(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6	1	-	-	10	14	-	-	-	-
6	7	13	28	10	14	-	-	-	-
26	7	13	28	10	14	10	16	-	-
30	7	13	28	10	14	10	16	-	-
42	7	16	18	10	12	11	13	12	14
45	7	16	18	10	12	11	13	12	14
54	7	16	18	10	12	11	13	12	14

NOTE:

For the purpose of calculation, the mean lay ratio shall be taken as the arithmetic mean of the relevant minimum and maximum values given in this table:

Table 5 : Stranding Constant for Aluminium Conductors, Galvanized Steel-Reinforced for overhead transmission lines(Clause 10.5)

No. of Wires in Conductor		Stranding Constant		
		Mass		Electrical Resistance (5)
Aluminium (1)	Steel (2)	Aluminium (3)	Steel (4)	
6	1	6.091	1	0.1692
6	7	6.091	7.032	0.1692
26	7	26.562	7.032	0.03929
30	7	30.670	7.032	0.03408
42	7	43.053	7.045	0.024406
45	7	46.004	7.045	0.022718
54	7	55.430	7.045	0.019009

10.0 STRANDING

10.1 The wires used in the construction of a galvanized steel-reinforced aluminium conductor shall, before and after stranding, satisfy all the relevant requirements of this standard.

10.2 The lay ratio of the different layers shall be within the limits given in Table 4.

10.3 The ratio of the nominal diameter of the aluminium wires to the nominal diameter of the galvanized steel wires in any particular construction of galvanized steel-reinforced aluminium conductor, shall conform to the appropriate value given in Table 4.

10.4 In all constructions, the successive layers shall have opposite directions of lay, the outermost layer being right-handed. The wires in each layer shall be evenly and closely stranded.

10.5 In conductors having multiple layers of aluminium wires, the lay ratio of any aluminium layer shall be not greater than the lay ratio of the aluminium layer immediately beneath it.

10.6 Steel wires shall be formed during stranding so that they remain intact when conductor is cut for jointing operation.

10.7 For the purpose of calculation of mass and resistance, stranding constants given in Table 5 are to be used.

11.0 LENGTHS AND VARIATIONS IN LENGTHS

11.1 Standard Length

Unless otherwise agreed to between the purchaser and the manufacturer, galvanized steel reinforced aluminium conductor shall be supplied in the manufacturer's usual production and with a permitted variation of ± 5 percent in the length of any one conductor length.

11.2 Random Lengths

Unless otherwise agreed to between the purchaser and the supplier, it shall be permissible to supply not more than 10 percent of the length on any one order in random lengths; none of them shall be shorter than 70% of the nominal length.

12.0 PACKING AND MARKING

12.1 The conductor shall be wound on reels or drums and marked with the following minimum details:-

- a) Contract/specification number;
- b) Name and address of the consignee;
- c) Manufacturer's name & address;
- d) Drum number;
- e) Size & type of the conductor;
- f) Length of the conductor;
- g) Gross weight of the drum with protective lagging including conductor;
- h) Weight of empty drum with protective lagging;
- j) Net weight of the conductor;
- k) Arrow marking for unwinding; and
- m) Position of the conductor end.

12.2 Material of drum and packaging shall be as agreed between the purchaser and the manufacturer.

BIS Certification Marking:

12.3 The product(s) conforming to the requirements of this standard may be certified as per the conformity assessment schemes under the provisions of the Bureau of Indian Standards Act, 2016 and the Rules and Regulations framed thereunder, and the products may be marked with the Standard Mark.

13.0 TESTS

13.1 Classification of Tests

Type tests are intended to verify the main characteristics of a conductor which depend mainly on its design. These tests are normally performed only once for a given conductor construction and shall be carried out if agreed between the purchaser and the manufacturer. Acceptance and Routine tests are intended to guarantee the quality of conductors and compliance with the requirements of this standard. Type tests shall be carried out only on a conductor which meets the requirements of all the relevant acceptance tests. Type tests, acceptance and routine tests are listed as below:

	Type test	Acceptance and Routine Tests	Clause
Visual examination	x	x	13.3

Conductor	Measurement of lay ratio/ Direction of lay	x	x	13.5
	DC Resistance Test on Stranded Conductor	x	-	13.12
	Ultimate tensile strength test on Stranded Conductor	x	-	13.14
	Surface Condition Test on stranded conductor	x	-	13.13
	Corona test (for 400kV & above voltage level)	x	-	13.15
	Radio interference voltage test (for 400kV & above voltage level)	x	-	13.16
Aluminium wires	Measurement of diameter	x	x	13.4
	Breaking load test	x	x	13.6
	Wrapping test	x	x	13.8
	DC Resistance test	x	x	13.9
	Procedure qualification test on welded joint of Aluminium strands	x	x	13.11
Steel wires	Measurement of diameter	x	x	13.4
	Breaking load test	x	x	13.6
	Ductility test	x	x	13.7
	Wrapping test	x	x	13.8
	Galvanizing test	x	x	13.10

13.2 Selections of Test Samples for Routine Test, Acceptance Test and Type test

13.2.1 Routine Tests

The routine tests shall be same as acceptance tests and shall be carried out on each coil, before stranding.

13.2.2 Selection of Test Samples for Acceptance Tests

For the purpose of acceptance tests, samples of individual wires shall normally be taken by the manufacturer before stranding, from the outer ends of not less than 10 percent of wire coils and subjected to the acceptance tests specified in 13.1

Alternatively, if desired by the purchaser at the time of placing an order that the tests be made in the presence of his representative, samples of wire shall be taken from lengths of stranded conductors. Samples shall then be obtained by cutting 2 m from the outer end of the finished conductor from not more than 10 percent of the finished reels or drums. If there is more than one length on any reel or drum, the sample shall be taken from the outer length.

Coils offered for inspection shall be divided (this may be done physically or on the basis of identification numbers of the coils offered for supply) into equal lots, the number of lots being equal to the number of samples to be selected, a fraction of a lot being counted as a complete lot. One sample coil shall be selected at random from each lot.

13.2.3 For the purpose of various tests, one specimen means one sample of the conductor

13.2.4 Selection of samples for Type tests:

Type test shall be conducted at the works of the firm and if such facilities are not available, the same shall be got conducted at some test house agreed to between the purchaser and the supplier. The supplier shall offer at least three drums of each size of conductor for selection of samples required for type test. Type test certificate of test house for same size of conductor carried out earlier shall be acceptable if agreed to between the purchaser and the supplier

13.3 Visual Examination

The conductor shall be examined visually for good workmanship and general surface finish of the conductor.

13.4 Measurement of Diameter of Individual Aluminum Wires and Galvanized Steel Wires

One sample cut from each of samples taken under 13.2.1 or 13.2.2 or 13.2.4 shall be measured using a micrometer having flat surface on both the anvil and the end of the spindle to be read with micrometer. The

diameter in millimetre shall be average of three diameter measurements, each of which is the average of the maximum reading at a point taken near each end and in the centre of the sample. The diameter of the wire shall be within the limit as specified in Tables 1 and 2.

13.5 Measurement of Lay Ratio /Direction of Lay

The lay ratio of each layer of the conductor shall be measured and checked as per the requirements specified in Table 4 and lay direction shall be as per requirements of 10.4

13.6 Breaking Load Test

The breaking load of one specimen cut from each of the sample taken under 13.2.1, 13.2.2 and 13.2.4 shall be determined by means of a suitable tensile testing machine. The load shall be applied gradually and the rate of separation of the jaws of the testing machine shall be not less than 25 mm/min and not greater than 100 mm/min.

The breaking load of the specimens shall be not less than the appropriate value specified in Tables 1 and 2.

13.7 Ductility Test

For the purpose of ductility test both torsion test and elongation test shall be carried out on galvanized steel wires only by the procedures given in 13.7.1 and 13.7.2 below.

13.7.1 Torsion Test

One specimen cut from each of the samples taken under 13.2.1, 13.2.2 and 13.2.4 shall be gripped at its ends in two vices, one of which shall be free to move longitudinally during the test. A small tensile load not exceeding 2 percent of the breaking load of the wire, shall be applied to the sample during testing. The specimen shall be twisted by causing one of the vices to revolve until fracture occurs and the number of twists shall be indicated by a counter or other suitable device. The rate of twisting shall not exceed 60 rev/min.

When tested before stranding, the number of complete twists before fracture occurs shall be not less than 18 on a length equal to 100 times the diameter of the wire. The primary fracture shall show a smooth surface at right angles to the axis of the wire. Any secondary fracture shall be ignored.

When tested after stranding, the number of complete twists before fracture occurs shall be not less than 16 on a length equal to 100 times the diameter of the wire. The fracture shall show a smooth surface at right angles to the axis of the wire.

13.7.2 Elongation Test

The elongation of one specimen cut from each of the samples taken under 13.2.1 or 13.2.2 or 13.2.4 shall be determined. The specimen shall be straightened by hand and an original gauge length of 250 mm shall be marked on the wire.

A tensile load shall be applied as described in 13.6 and the elongation shall be measured after the fractured ends have been fitted together. If the fracture occurs outside the gauge marks, or within 25 mm of either mark and the required elongation is not obtained, the test shall be disregarded and another test made.

When tested before stranding, the elongation shall be not less than 4 percent. When tested after stranding, the elongation shall be not less than 3.5 percent.

13.8 Wrapping Test

This test shall be made on both aluminium and galvanized steel wires.

13.8.1 Aluminium Wires

One specimen cut from each of the samples of aluminium wire taken under 13.2.1 or 13.2.2 or 13.2.4 shall be wrapped round a wire of its own diameter to form a close helix of 8 turns. Six turns shall then be unwrapped and again closely wrapped in the same direction as before. The wire shall not break or show any crack.

NOTE — Slight surface cracks shall not constitute cause for rejection.

13.8.2 Galvanized Steel Wires

One specimen cut from each of the samples of galvanized steel wire taken under 13.2.1 or 13.2.2 or 13.2.4 shall

be wrapped round a mandrel of diameter equal to 4 times the wire diameter to form a close helix of 8 turns. Six turns shall then be unwrapped and again closely wrapped in the same direction as before. The wire shall not break.

13.9 DC Resistance Test

This test shall be made on aluminium wires only. The electrical resistance of one specimen of aluminium wire cut from each of the samples taken under 13.2.1 or 13.2.2 or 13.2.4 shall be measured at ambient temperature. The measured resistance shall be corrected to the value at 20° C by means of the formula:

$$R_{20} = R_T \frac{1}{1 + \alpha(T - 20)}$$

Where

R_{20} = DC Resistance corrected at 20°C;

R_T = DC Resistance measured at T°C;

α = constant mass temperature coefficient of Resistance, 0.00403 and

T = ambient temperature during measurement.

The Resistance corrected at 20°C shall be not more than the maximum value specified in Table 1.

13.10 Galvanizing Test

This test shall be made on galvanized steel wires only.

13.10.1 This test shall be made on one specimen cut from each of the samples of galvanized steel wires taken under 13.2.1 or 13.2.2 or 13.2.4

13.10.2 The uniformity of galvanizing and the weight of coating shall be in accordance with IS 4826

13.10.3 The adherence of zinc shall be checked by wrapping around a mandrel four times the diameter of steel wire.

13.11 Procedure Qualification test on welded Aluminium wires

Two Aluminium wire shall be welded by cold pressure butt welding method and shall be subjected to tensile load. The breaking strength of the welded joint of the wire shall not be less than the breaking strength of joint.

13.12 DC Resistance Test on Stranded Conductor:

This test is applicable to conductors of nominal aluminum area 100 mm² and above. On a conductor sample of minimum 5m length two contact-clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by a Kelvin double bridge or digital ohm-metre of sufficient accuracy by placing the clamps initially zero metre and subsequently one metre apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20°C as per the formula mentioned at 13.9. The test results shall conform to the requirements specified in this standard.

13.13 Surface Condition Test

This test is applicable to conductors of nominal aluminium area greater than 100 mm². A sample of the finished conductor having a minimum recommended length of 5 m with compression type dead end clamps compressed on both ends in such a manner as to permit the conductor to take its normal straight line shape, shall be subjected to a tension of 50 percent of the ultimate breaking load of the conductor.

The surface shall not depart from its cylindrical shape nor shall the strands move relative to each other so as to get out of place or disturb the longitudinal smoothness of the conductor. The measured diameter at any place shall be not less than the sum of the minimum specified diameter of the individual aluminium and steel strands as indicated in Tables 1 and 2 of this standard.

13.14 Ultimate Tensile Strength Test on Stranded Conductor:

This test is applicable to conductors of nominal aluminum area 100 mm² and above. A sample of the finished conductor having a minimum length of 5 m with appropriate fittings at both ends in such a manner as to permit the conductor to take its normal straight line shape. Circles perpendicular to the axis of the conductor shall be marked at two places on the conductor sample. The load shall be increased at a steady rate up to 50 percent of the ultimate tensile strength of the Conductor and held for one minute. The circles drawn shall not be distorted due to relative movement of strands and the surface shall not depart from its cylindrical shape nor shall the strands move relative to each other so as to get out of place or disturb the longitudinal

smoothness of the conductor. The measured diameter at any place shall be not less than the sum of the minimum specified diameter of the individual aluminum and steel strands as indicated in Table 1 and 2 of this standard. Thereafter the load shall be increased at a steady rate up to rated ultimate tensile strength and held for one minute. When so tested, the conductor shall not show any fracture. The applied load shall then be increased until the failing load is reached and the value recorded. A re-test up to a total of three tests, may be made if wire fracture occurs within one centimeter of the end fittings and the tensile strength falls below the specified breaking strength requirement.

13.15 Corona Test

For 400 kV

Two samples of conductor of 5 m length shall be strung with a spacing of 450 mm between them, shall be subject to 50 Hz phase to earth voltage. The stringing height of the bundle for the purpose of this test shall be such that the minimum clearance to ground is not more than 8.84 m. The corona control rings shall be so selected that they shield the insulators strings and hardware fittings only and do not provide shielding for the conductor bundle.

For \pm 500 kV DC

Quadbundle conductors of maximum 5 m length shall be strung with a spacing of 457 mm between them, sample shall be subjected to dc voltage. The stringing height of the conductors for the purpose of this test shall be such that minimum clearance from ground is not more than 12.5 m (Height shall be suitably adjusted so as to achieve a surface gradient of 22 kV/cm on the conductors) under dry condition. The corona control rings shall be so selected that they shield insulator strings and hardware fittings only and do not provide shielding for the conductor bundles.

For 765 kV

Quadbundle or Hexabundle conductors, as the case may be, of minimum 5 m shall be strung with a spacing of 457 mm between them, shall be subjected to 50 Hz voltage. The stringing height of conductor for the purpose of this test shall be such that the minimum clearance from ground is not more than 15 m. The corona control rings shall be so selected that they shield the insulator strings and hardware fittings only and do not provide shielding for the conductor bundles.

For \pm 800 kV DC

Hexa bundle conductors of maximum 5 m length shall be strung with a spacing of 457 mm between them, sample shall be subjected to dc voltage. The stringing height of the conductors for the purpose of this test shall be such that minimum clearance from ground is not more than 18 m (Height shall be suitably adjusted so as to achieve a surface gradient of 22 kV/cm on the conductors) under dry condition. The corona control rings shall be so selected that they shield insulator strings and hardware fittings only and do not provide shielding for the conductor bundles.

13.15.1 The specimen shall have a corona extinction voltage with or without corona rings of not less than the following values:

<i>Line Voltage</i>	<i>Corona Extinction Voltage (rms)</i>	<i>No. of Sub-Conductor in Bundle</i>	<i>Bundle Spacing</i>	<i>Height Above Ground</i>
400 kV AC	320 kV (rms)	2	45 cm	8.84 m
\pm 500 KV DC	550 KV (line to ground) (surface gradient 22kV/cm)	4	45.7 cm	12.5 m*
765 kV AC (Quad)	510 kV (rms)	4	45.7 cm	15m
765 kV AC (Hexa)	510 kV (rms)	6	45.7 cm	15 m

**ANNEX A
(Table 3)**

NOTES ON CALCULATION OF RESISTANCE, MASS AND BREAKING LOAD

A-1 INCREASE IN LENGTH DUE TO STRANDING

A-1.1 When straightened out, each wire in any particular layer of standard conductor, except the central wire, is longer than the stranded conductor by an amount depending on the lay ratio of that layer.

A-2 RESISTANCE AND MASS OF CONDUCTOR

A-2.1 In aluminium conductors, steel reinforced the conductivity of the steel core is neglected and the resistance of the conductor is calculated with reference to the resistance of the aluminium wires only. The resistance of any length of stranded conductor is the resistance of the same length of any one aluminium wire multiplied by a constant, as set out in Table 5.

A-2.2 The mass of each wire in a length of stranded conductor, except the central wire, will be greater than that of an equal length of straight wire by an amount depending on the lay ratio of the layer (see A-1.1). The total mass of any length of conductor is, therefore, obtained by multiplying the mass of an equal length of straight wire by the approximate constant set out in Table 5. The masses of the steel core and aluminium wires are calculated separately and added together.

A-2.3 In calculating the stranding constants in Table 5, the mean lay ratio, that is, the arithmetic mean of the relevant minimum and maximum values in Table 4, has been assumed for each layer.

A-3 CALCULATED BREAKING LOAD OF CONDUCTOR

A-3.1 The breaking load of an aluminium conductor-galvanized steel, reinforced in terms of the sum of the strength of the individual component wires, may be taken to be as follows:

- a) 98 percent of the sum of the breaking loads of the aluminium wires plus 89 percent of the sum of the breaking loads of the galvanized steel wires, when taken from the stranded conductor and tested; or
- b) 98 percent of the sum of the breaking loads of the aluminium wires plus 85 percent of the sum of the breaking loads of the galvanized steel wires, based on the breaking loads of the component wires before stranding, that is, in the coil.

A-3.2 The values of approximate breaking load of conductors, given in Table 3 have been calculated in accordance with (b) above and on the basis of the minimum breaking loads of the component wires given in Table 1 and 2

ANNEX B
(Clause 6.1.1)
CHEMICAL COMPOSITION OF HIGH CARBON STEEL

B-1 The chemical composition of high carbon steel used in the manufacture of steel wire of ACSR conductor is given below for guidance:

Element	Percentage Composition
Carbon	0.50 to 0.85
Manganese	0.50 to 1.10
Phosphorus	Max 0.035
Sulphur	Max 0.045
Silicon	0.10 to 0.3