इंटरनेट मानक

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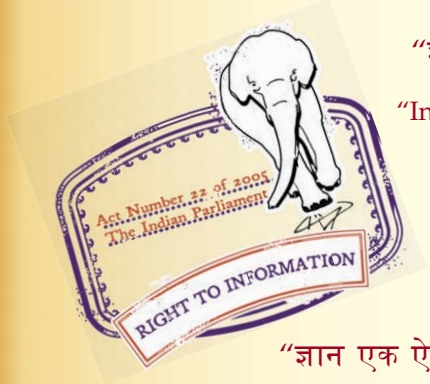
"पुराने को छोड नये के तरफ"
Jawaharlal Nehru
"Step Out From the Old to the New"

IS 398-2 (1996): Aluminium conductors for overhead transmission purposes, Part 2: Aluminium conductors, galvanized steel reinforced [ETD 37: Conductors and Accessories for Overhead Lines]



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Bhartṛhari—Nītiśatakam
"Knowledge is such a treasure which cannot be stolen"

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IS 398 (Part 2) : 1996
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2002

भारतीय मानक

शिरोपरि प्रेषण प्रयोजन के लिए एल्यूमिनियम चालक – विशिष्टि

भाग 2 एल्यूमिनियम चालक, जस्तीकृत इस्पात प्रबलन

(तीसरा पुनरीक्षण)

Indian Standard

ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES — SPECIFICATION

PART 2 ALUMINIUM CONDUCTORS, GALVANIZED STEEL-REINFORCED

(Third Revision)

Second Reprint OCTOBER 2001

ICS 29.240.20

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December 1996

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AMENDMENT NO. 1 MARCH 1999
TO
IS 398 (PART 2) : 1996 ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES — SPECIFICATION

PART 2 ALUMINIUM CONDUCTORS, GALVANIZED STEEL-REINFORCED

(Third Revision)

(*Page* 5, *clause* 13.6, *first para, formula*) — Substitute the following for the existing:

$$'R_{20} = R_T \frac{1}{1 + \alpha (T - 20)}$$

where

R_{20} = resistance corrected at 20°C;
R_T = resistance measured at T°C;
α = constant mass temperature co-efficient of resistance, 0·004 03; and
T = ambient temperature during measurement.

(*Page* 6, *clause* 14.1(b) *and* (c)] — Insert superscript '(1)' at both the places.

(*Page* 8, *Table* 3, *col* 2, *row* 12) — Substitute '54/3.53' *for* '54/4.13'.

(*Page* 8, *Table* 5, *Heading*) — Substitute 'Stranding Constants' *for* 'Standing Constants'.

(*Page* 8, *Table* 5, *col* 2, *row* 1) — Substitute '1' *for* '0'.

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 2 MARCH 2000
TO
IS 398 (PART 2) : 1996 ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES — SPECIFICATION

PART 2 ALUMINIUM CONDUCTORS, GALVANIZED STEEL-REINFORCED

(Third Revision)

(*Page* 2, *clause* **6.1.1**) — Substitute '5484 : 1997' *for* '5484 : 1978'.

(*Page* 2, *clause* **9.2.2**) — Delete and renumber the subsequent clauses.

(*Page* 2, *clause* **9.2.3**) — Delete subheading '*Conductors Containing More Than Seven Wires*'.

(*Page* 2, *clause* **9.2.3**, *first sentence*) — Delete 'For stranded conductor containing more than seven wires'.

(*Page* 3, *clause* **12.1**) — Substitute 'IS 1778 : 1980' *for* 'IS 1778 : 1981'.

[*Page* 3, *clause* **12.1**(c) *and* (d)] — Substitute 'Net mass' and 'Gross mass' *for* 'Net weight' and 'Gross weight' respectively.

(*Page* 3, *clause* **13.1.5**, *para* 1) — Delete last line.

(*Page* 5, *clause* **13.6**) — Substitute '0.004 03' *for* '0.004' for description of '*X*'.

(*Page* 5, *clause* **13.9**, *para* 1) — Substitute the following for the existing:

'This test is applicable to conductors of nominal aluminium area greater than 100 mm^2.

(*Page* 5, *clause* **13.10**, *para* 1) — Substitute the following for the existing:

'This test is applicable to conductors of nominal aluminium area greater than 100 mm^2.'

(*Page* 5, *clause* **13.10**, *last two lines*) — Substitute the following for the existing:

'The actual breaking load falls below the specified breaking strength requirement.'

(*Page* 5, *clause* 13.11, *para* 1) — Substitute the following for the existing:

'This test is to be conducted if agreed between the purchaser and supplier'.

(*Page* 6, *clause* 13.11.3.6, *last line*) — Substitute '13.11.3.2' *for* '5.3.5'.

(*Page* 6, *clause* 13.11.5, *line* 3) — Delete the word 'and' after '70 percent'.

(*Page* 6, *clause* 13.11.5) — Insert the following para in the end:

'For the purpose of calculating stress-strain data at 20°C, the following formula may be used:

$$\varepsilon_{20} = \varepsilon_t \times \frac{1}{1 + \alpha (t - 20)}$$

where

ε_{20} is the stress-stain value at 20°C, and

ε_t at room temperature.'

[*Page* 6, *clause* 14.1(a)] — Delete '1)' and the corresponding footnote.

(ETD 37)

Reprography Unit, BIS, New Delhi, India

AMENDMENT NO. 3 DECEMBER 2002 TO IS 398 (PART 2) : 1996 ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSE — SPECIFICATION

PART 2 ALUMINIUM CONDUCTORS, GALVANIZED STEEL — REINFORCED

(Third Revision)

[*Page* 5, *clause* **13.6** (*see also Amendments No.* 1 *and* 2)] — Delete the matter in the Amendment No. 2.

[*Page* 6, *clause* **14.1**(b) *and* (c) *and the footnote* (*see also Amendments No.* 1 *and* 2)] — Delete the superscript '1)' at both the places and the corresponding footnote.

Reprography Unit, BIS, New Delhi, India

Conductors and Accessories for Overhead Lines Sectional Committee, ET 37

FOREWORD

This Indian Standard (Third 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 was originally published in 1953, the first revision was brought out in 1961.

In this revision, the standard had been modified in the light of the modern development in the techniques of the conductor manufacture. The other salient point incorporated in this revision was the inclusion of wrapping test for the aluminium wires in place of the elongation test originally specified for aluminium as well as steel wires.

The second revision was brought out in 1976 and the third revision has been undertaken with a view to effecting the following considerations:

a) To line up with the International Standards.

b) All amendments approved and circulated after 1976 have been considered while preparing this standard for third revision.

c) The most important consideration has been taken regarding improvement in conductivity of EC grade aluminium, the maximum resistivity of 0.028 264 ohm. mm^2/mm at 20°C as per IEC Standard.

d) Measurement of wire diameter, lay ratio, test procedure and testing of routine tests and acceptance tests have been included.

e) Type tests have been included.

While revising this standard, it was decided to issue it in different parts covering different types of conductors. This part dealing with galvanized steel-reinforced aluminium conductors form Part 2 of the series. Other parts in this series are given below:

Part 1 Aluminium stranded conductors
Part 3 Aluminium conductors, aluminized steel-reinforced
Part 4 Aluminium alloy stranded conductors
Part 5 Aluminium conductors, galvanized steel-reinforced for extra high voltage (400 kV and above).

In the preparation of this standard, assistance has been derived from the following:

IEC 888 : 1987 Zinc coated steel wires for stranded conductors.
IEC 889 : 1987 Hard drawn aluminium wire for overhead line conductors.
IEC 1089 : 1991 Round wire concentric lay overhead electrical stranded conductors.
BS 215 : Part 2 : 1970 Specification for aluminium conductors and aluminium conductors, steel-reinforced for overhead power transmission: Part 2 Aluminium conductors, steel-reinforced. British Standards Institution.

The value of modulus of elasticity and coefficient of linear expansion are given in Annex B for information.

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 IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

ALUMINIUM CONDUCTORS FOR OVERHEAD TRANSMISSION PURPOSES — SPECIFICATION

PART 2 ALUMINIUM CONDUCTORS, GALVANIZED STEEL-REINFORCED

(Third Revision)

SECTION 1 GENERAL

1 SCOPE

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

2 REFERENCES

2.1 The following Indian Standards are necessary adjuncts to this standard.

IS No.	*Title*
209 : 1992	Zinc ingot (*fourth revision*)
1778 : 1980	Reels and drums for bare wire (*first revision*)
1885 : (Part 32) 1993	Electrotechnical vocabulary: Part 32 Electric cables (*first revision*)
4826 : 1979	Hot dipped galvanized coating on round steel wires (*first revision*)
5484 : 1978	EC grade aluminium rod produced by continuous casting and rolling
7623 : 1993	Lithium base grease for industrial purposes (*second revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions, in addition to those given in IS 1885 (Part 32) : 1993 shall apply.

3.1 Aluminium Conductor, Galvanized Steel-Reinforced

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

3.2 Diameter

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

3.3 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.

3.4 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

4 PHYSICAL CONSTANTS FOR HARD-DRAWN ALUMINIUM

4.1 Resistivity

The resistivity of aluminium depends upon its purity and physical condition. For the purpose of this standard, the maximum value permitted is 0.028 264 ohm mm^2/m at 20°C and this value has been used for calculation of the maximum permissible values of resistance.

NOTE — It is not intended to check the resistivity from the measured values of resistance.

4.2 Density

At a temperature of 20 °C, the density of hard-drawn aluminum has been taken as 2.703 g/cm^3.

4.3 Constant-Mass Temperature Coefficient of Resistance

At a temperature of 20 °C the constant-mass temperature coefficient 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 0.004 03 °C.

4.4 Coefficient of Linear Expansion

The coefficient of linear expansion of hard-drawn aluminium at 0 °C has been taken as 23.0×10^{-6}/°C. This value holds good for all practical purposes over the range of temperature from 0 °C to the highest safe operating temperature.

5 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/cm^3

5.2 Coefficient at 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 aluminium conductors.

SECTION 2 MATERIALS

6 MATERIAL

6.1 The conductor shall be constructed of hard-drawn aluminium and galvanized steel wires which have the mechanical and electrical properties specified in Tables 1 and 2.

6.1.1 The EC grade aluminium rods for use in the manufacture of aluminium wires shall conform to IS 5484 : 1978.

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

6.2 The zinc used for galvanizing shall be electrolyte high grade zinc not less than 99.95 percent purity. It shall conform to and satisfy all the requirements of IS 209 : 1992.

The coating on the galvanized steel wires may be applied by the hot process or the electrolytic process. When specified by the purchaser, neutral grease may be applied between the layers of wires.

6.3 When specified by the purchaser, neutral grease has to be applied as per one of the following cases:

a) Steel core only,
b) All conductor except outer layer,
c) All conductor including outer layer, and
d) All conductor except outer surface of the wires in the outer layer.

NOTE— Lithium soap grease corresponding to Grade II of IS 7623 1993 having minimum drop point not less than 180 °C is suitable for such application.

7 FREEDOM FROM DEFECTS

7.1 The wires used for standard conductor shall be smooth and free from imperfections, such as spills and splits.

SECTION 3 DIMENSIONS AND CONSTRUCTION

8 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.

8.2 Aluminium Conductors, Galvanized Steel-Reinforced

8.2.1 The sizes of stranded aluminium conductors, galvanized steel-reinforced shall be as given in Table 3.

8.2.2 The resistance shall be in accordance with Table 3. The mass (excluding the mass of grease, if applied) are given in Table 3 for information.

9 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 Joints in Aluminium Stranded 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 *Conductor Containing Seven Wires*

Joints in wires other than those permitted under **9.1** shall not be permitted in any wire of stranded conductor containing seven wires.

9.2.3 *Conductors Containing More Than Seven Wires*

For stranded conductor containing more than seven wires, 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.

9.2.4 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.

9.2.5 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 Joints in Galvanized Steel Wires

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

10 STRANDING

10.1 The wires used in the construction of a galvanized steel-reinforced aluminium conductor shall, before 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.

11 LENGTHS AND VARIATIONS IN LENGTHS

11.1 Unless otherwise agreed to between the purchaser and the manufacturer, galvanized steel reinforced aluminium conductor shall be supplied in the manufacturer's usual production lengths 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 manufacturer, it shall be permissible to supply not more than 10 percent of the lengths on any one order in random lengths; none of them shall be shorter than one-third of the nominal length.

SECTION 4 PACKING AND MARKING

12 PACKING AND MARKING

12.1 The conductor shall be wound on reels or drums (it is recommended that reels and drums conforming to IS 1778 : 1981 be used) and marked with the following:

a) Manufacturer's name,
b) Size and type of conductor,
c) Net weight of conductor in kg,
d) Gross weight of conductor in kg, and
e) Length of conductor in m.

12.1.1 The conductor may also be marked with the BIS Standard Mark.

12.1.2 The use of the Standard Mark is governed by the provisions of the *Bureau of Indian Standards Act*, 1986 and the Rules and Regulations made thereunder. The details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers may be obtained from the Bureau of Indian Standards.

SECTION 5 TESTS

13 TESTS

13.1 Selection of Test Samples for Acceptance and Routine Test

13.1.1 Samples of individual wires for tests specified in **13.2**, **13.3.1**, **13.4**, **13.5**, **13.6**, **13.7** and **13.8** shall normally be taken by the manufacturer before stranding, from the outer ends of not less than 10 percent of wire coils.

13.1.2 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 1.2 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.

13.1.3 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.

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

13.1.5 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 against each order in the presence of the purchaser.

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.

13.2 Measurement of Diameter of Individual Aluminium Wires and Galvanized Steel Wires

One sample cut from each of samples taken under **13.1.1** and **13.1.2** 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.

13.3 Breaking Load Test

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

13.3.1 The breaking load of one specimen cut from each of the sample taken under **13.1.1** or **13.1.2** 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 ultimate breaking load of the specimens shall be not less than the appropriate value specified in Tables 1 and 2.

13.4 Ductility Test

This test shall be made on galvanized steel wires only, by any of the procedures given in **13.4.1** and **13.4.2**.

13.4.1 *Torsion Test*

One specimen cut from each of the samples taken under **13.1.1** or **13.1.2** 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.

The test may be carried out on gauge length of 150 mm for all wire sizes when the number of twists, which the wire shall withstand, shall be direct ratio to the numbers specified for 100 times the diameter of the wires.

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.

NOTE — For two or more fractures occurred during twisting, the first fracture would be called as primary fracture and the subsequent fractures would be called as secondary fractures.

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.

13.4.2 *Elongation Test*

The elongation of one specimen cut from each of the samples taken under **13.1.1** or **13.1.2** shall be determined. The specimen shall be straightened by hand and an original gauge length of 200 mm shall be marked on the wire. A tensile load shall be applied as described in **13.3.1** and the elongation shall be measured after the fractured ends have been fitted together. If the fracture occurs outside the gauge mark, 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.

NOTE — The sample has to pass either the torsion test or elongation test, that is, if the conductor is passing any of the two tests, the sample should be considered as passing.

13.5 Wrapping Testing

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

13.5.1 *Aluminium Wires*

One specimen cut from each of the samples of aluminium wire taken under **13.1.1** and **13.1.2** shall be wrapped round a wire of its own diameter to form a close helix of eight turns. Six turns shall then be unwrapped and again closely wrapped in the same direction as before. The wire shall not break.

13.5.2 *Galvanized Steel Wires*

One specimen cut from each of the samples of galvanized steel wire taken under **13.1.1** or **13.1.2** 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.

13.6 Resistance Test

This test shall be made on aluminium wires taken before stranding or after stranding.

NOTE — The resistance of individual wires shall be such that the completed stranded conductor meets the requirements of the maximum resistance specified in Table 3 calculated by applying the relevant stranding constants given in Table 5.

The electrical resistance of one specimen of aluminium wire cut from each of the samples taken under **13.1.1** or **13.1.2** shall be measured at ambient temperature. The measured resistance shall be corrected to the value at 20 °C by means of the formula:

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

where

R_{20} = resistance corrected at 20 °C;

R_T = resistance measured at T °C;

X = constant-mass temperature coefficient of resistance, 0.004; and

T = ambient temperature during measurement.

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

13.7 Galvanizing Test

This test shall be made on galvanized steel wires only.

13.7.1 This test shall be made on one specimen cut from each of the samples of the galvanized steel wires taken under **13.1.1** or **13.1.2**.

13.7.2 The uniformity of galvanizing and the weight of coating shall be in accordance with IS 4826 : 1979.

13.8 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, **10.5** and lay direction shall be as per requirement of **10.4**.

13.9 Surface Condition Test

This test is applicable to conductors of nominal aluminium area 100 mm² and above.

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.

13.10 Test for Ultimate Breaking Load on Stranded Conductor

This test is applicable to conductors of nominal aluminium area 100 mm² and above.

A sample of conductor of minimum 5 m length suitably clamped at either end. The load shall be increased at a steady rate up to rated ultimate breaking load 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 centimetre of the end fittings and the tensile strength falls below the specified breaking strength requirement.

13.11 Stress-Strain Test

This test is applicable to conductors of nominal aluminum area 100 mm² and above.

13.11.1 This test is contemplated only to collect the creep data of the conductor from the supplier. A sample of conductor of minimum 10 m length shall be suitably compressed with dead end clamps.

13.11.2 *Test Set-up*

13.11.2.1 The test sample shall be supported in a trough over its full length and the trough adjusted so that the conductor will not be lifted by more than 10 mm under tension. This shall be ascertained by actual measurement.

13.11.2.2 The distance between the clamp and the sleeve mouth shall be monitored with callipers during the test to ensure that, after the test, it does not change by more than 1 mm ± 0.1 from the value before the test.

13.11.2.3 The conductor strain shall be evaluated from the measured displacements at the two ends of the gauge length of the sample. The gauge reference targets shall be attached to the clamps which lock the steel and aluminium wires together. Target plates may be used with dial gauges or displacement transducers and care shall be taken to position the plates perpendicular to the conductor. Twisting the conductor, lifting it and moving it from side-to-side by the maximum amounts expected during the test should introduce not more than 0.3 mm error in the reading.

13.11.3 *Test Loads for Complete Conductor*

The loading conditions for repeated stress-strain tests for complete conductor shall be as follows.

13.11.3.1 1 kN load shall be applied initially to straighten the conductor. The load shall be removed after straightening and then the strain gauges are to be set at zero tension.

13.11.3.2 For non-continuous stress-strain data, the strain readings at 1 kN intervals at lower tensions and 5 kN intervals above 30 percent of ultimate breaking load shall be recorded.

13.11.3.3 The sample shall be reloaded to 50 percent of ultimate breaking load and held for 1 h. Reading

are to be noted after 5, 10, 15, 30, 45 and 60 min during the hold period. The load shall be released after the hold period.

13.11.3.4 Reloading up to 70 percent of ultimate breaking load shall be done and held for 1 h. Readings are to be noted after 5, 10, 15, 30, 45 and 60 minutes. The load shall then be released.

13.11.3.5 Reloading up to 85 percent of ultimate breaking load shall be done and held for 1 h. Reading are to be noted after 5, 10, 15, 30, 45 and 60 minutes and then load shall be released.

13.11.3.6 Tension shall be applied again and shall be increased uniformly until the actual breaking strength is reached. Simultaneous readings of tension and elongation shall be recorded up to 90 percent of ultimate breaking load at intervals described under 5.3.5.

13.11.4 *Test Loads for Steel Core Only*

The loading condition of repeated stress-strain tests for the steel core of ACSR shall be as follows.

13.11.4.1 The test shall consist of successive application of load applied in a manner similar to that for the complete conductor at 30 percent, 50 percent, 70 percent and 85 percent of ultimate breaking load.

13.11.4.2 The steel core shall be loaded until the elongation at the beginning of each hold period corresponds to that obtained on the complete conductor at 30 percent, 50 percent, 70 percent and 85 percent of ultimate breaking load respectively.

13.11.5 *Stress-Strain Curves*

The design stress-strain curve shall be obtained by drawing a smooth curve through the 0.5 and 1 h points at 30 percent, 50 percent and 70 percent and of ultimate breaking load loadings. The stress-strain curves shall be submitted to the purchaser alongwith test results. The stress-strain data obtained during the test shall be corrected to the standard temperature that is 20 °C.

14 CLASSIFICATION OF TESTS

14.1 Type Tests

[1]a) Surface condition test (*see* 13.9),

b) Test for ultimate breaking load on stranded conductor (*see* 13.10),

c) Stress-strain test (13.11),

d) Measurement of diameter of individual aluminium and steel wires (13.2),

e) Measurement of lay ratio (13.8),

f) Breaking load of individual wires (13.3.1),

g) Ductility test (13.4),

h) Wrapping test (13.5),

j) Resistance test (13.6), and

k) Galvanizing test (13.7).

14.2 Acceptance Tests

a) Measurement of diameter of individual aluminium and steel wires (*see* 13.2),

b) Measurement of lay ratio (*see* 13.8),

c) Breaking load of individual wires (*see* 13.3.1),

d) Ductility test (*see* 13.4),

e) Wrapping test (*see* 13.5),

f) Resistance test (*see* 13.6), and

g) Galvanizing test (*see* 13.7).

14.3 Routine Test

The routine tests shall be done same as acceptance tests and shall be carried out before and after stranding.

15 REJECTION AND RETESTS

15.1 Should any one of the test pieces first selected fail to pass the tests, three further samples from the same batch shall be selected, one of which shall be from the length from which the original test sample was taken, unless that length has been withdrawn by the supplier.

15.2 Should all of the three test pieces from these additional samples satisfy the requirements of the tests, the batch represented by these samples shall be deemed to comply with the standard. Should the test pieces from any of the three additional samples fail, the batch represented shall be deemed not to comply with the standard.

[1] Applicable for conductors of nominal Aluminium Area 100 mm^2 and above

SECTION 6 TABLES

Table 1 Aluminium Wires Used in the Construction of Aluminium Conductors, Galvanized Steel-Reinforced
(*Clauses* 6.1, 8.1.1, 8.1.2.1, 13.2, 13.3.1, 13.5.1 *and* 13.6)

Diameter			Cross Sectional Area of Nominal Diameter Wire	Mass	Resistance 20 °C	Breaking Load, *Min*	
Nominal	*Min*	*Max*				Before Stranding	After Stranding
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mm	mm	mm	mm²	kg/km	Ohms/km	kN	kN
1.50	1.48	1.52	1.767	4.78	16.432	0.32	0.30
1.96	1.94	1.98	3.017	8.16	9.561	0.54	0.51
2.11	2.09	2.13	3.497	9.45	8.237	0.63	0.60
2.59	2.56	2.62	5.269	14.24	5.490	0.89	0.85
3.00	2.97	3.03	7.069	19.11	4.079	1.17	1.11
3.18	3.15	3.21	7.942	21.47	3.626	1.29	1.23
3.35	3.32	3.38	8.814	23.82	3.265	1.43	1.36
3.50	3.46	3.54	9.621	26.01	3.006	1.55	1.47
3.53	3.49	3.57	9.787	26.45	2.954	1.57	1.49
3.80	3.76	3.84	11.34	30.65	2.545	1.80	1.71
4.09	4.05	4.13	13.14	35.51	2.194	2.08	1.98
4.13	4.09	4.17	13.40	36.21	2.151	2.13	2.02
4.72	4.67	4.77	17.50	47.30	1.650	2.78	2.64

NOTE — The resistance has been calculated from the maximum value of resistivity and the cross sectional area based on the minimum diameter.

Table 2 Steel Wires Used in the Construction of Aluminium Conductors, Galvanized Steel-Reinforced
(*Clauses* 6.1, 8.1.1, 13.2 *and* A-3.2)

Diameter			Cross Sectional Area of Nominal Diameter Wire	Mass	Breaking Load, *Min*	
Nominal	*Min*	*Max*			Before Stranding	After Stranding
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mm	mm	mm	mm²	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
1.96	1.92	2.00	3.017	23.53	4.20	3.99
2.11	2.07	2.15	3.497	27.27	4.60	4.37
2.30	2.25	2.35	4.155	32.41	5.46	5.19
2.59	2.54	2.64	5.269	41.09	6.92	6.57
3.00	2.94	3.06	7.069	55.13	9.29	8.83
3.18	3.12	3.24	7.942	61.95	10.43	9.91
3.35	3.28	3.42	8.814	68.75	11.58	11.00
3.53	3.46	3.60	9.787	76.34	12.86	12.22
4.09	4.01	4.17	13.14	102.48	17.27	16.4

Table 3 Aluminium Conductors, Galvanized Steel-Reinforced
(*Clauses* 8.2.1, 8.2.2 *and* A-3.2)

Nominal Aluminium	Stranding and Wire Diameter		Sectional Area of Aluminium	Total Sectional Area[1)]	Approximate Diameter	Approximate Mass	Calculated Resistance at 20°C, *Max*	Approximate Calculated Breaking Load
	Aluminium	Steel						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
mm²	mm	mm	mm²	mm²	mm	kg/km	Ohm/km	kN
10	6/1.50	1/1.50	10.60	12.37	4.50	43	2.780	3.97
18	6/1.96	1/1.96	18.10	21.12	5.88	73	1.618	6.74
20	6/2.11	1/2.11	20.98	24.48	6.33	85	1.394	7.61
30	6/2.59	1/2.59	31.61	36.88	7.77	128	0.928 9	11.12
50	6/3.35	1/3.35	52.88	61.70	10.05	214	0.552 4	18.25
80	6/4.09	1/4.09	78.83	91.97	12.27	319	0.371 2	26.91
100	6/4.72	7/1.57	105.0	118.5	14.15	394	0.279 2	32.41
150	30/2.59	7/2.59	158.1	194.9	18.13	726	0.187 1	67.34
200	30/3.00	7/3.00	212.1	261.5	21.00	974	0.139 0	89.67
400	42/3.50	7/1.96	404.1	425.2	26.88	1281	0.073 11	88.79
420	54/3.18	7/3.18	428.9	484.5	28.62	1621	0.068 68	130.32
520	54/4.13	7/3.53	528.5	597.0	31.77	1998	0.055 95	159.60
560	42/4.13	7/2.30	562.7	591.7	31.68	1781	0.052 31	120.16

NOTE — For the basis of calculation of this table (*see* Annex A).

[1)] The sectional area is the sum of the cross-sectional areas of the relevant individual wires.

Table 4 Lay Ratios of Aluminium Conductors, Galvanized Steel-Reinforced
(*Clauses* 10.2, 10.3 *and* 13.8)

Number of Wires		Ratio of Aluminium Wire Diameter to Steel Wire Diameter	Lay Ratios for Steel Core (6 Wire Layer)		Lay Ratios for Aluminium Wire					
					Outermost Layer		Layer Immediately Beneath Outermost Layer		Innermost Layer of Conductors with 3 Aluminium Wire Layers	
Aluminium	Steel		*Min*	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6	1	1.0	—	—	10	14	—	—	—	—
6	7	3.0	13	28	10	14	—	—	—	—
30	7	1.0	13	28	10	14	10	16	—	—
42	7	1.8	13	28	10	14	10	16	10	17
54	7	1.0	13	28	10	14	10	16	10	17

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 Standing Constants
(*Table 1 and Clauses* 13.6, A-2.1, A-2.2 *and* A-2.3.1)

Number of Wires in Conductor		Mass		Stranding Constant Electrical Resistance
Aluminium	Steel	Aluminium	Steel	
(1)	(2)	(3)	(4)	(5)
6	0	6.091	1.000	0.169 2
6	7	6.091	7.032	0.169 2
30	7	30.67	7.032	0.034 08
42	7	42.90	7.032	0.024 32
54	7	55.23	7.032	0.018 94

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
(*Foreword*)

MODULUS OF ELASTICITY AND COEFFICIENT OF LINEAR EXPANSION

No. of Wires		*Final Modulus of Elasticity (Practical)*	*Coefficient of Linear Expansion* / °C
Aluminium	Steel	GN/m^2	
(1)	(2)	(3)	(4)
6	1	79	19.1×10^{-6}
6	7	75	19.8×10^{-6}
30	7	80	17.8×10^{-6}
42	7	62	21.5×10^{-6}
54	7	69	19.3×10^{-6}

NOTES
1 These values are given for information only.
2 Moduli values quoted may be regarded as being accurate to within ± 3 GN/m^2.
3 Moduli values quoted may be taken as applying to conductors stressed between 15 and 50 percent of the ultimate strength of the conductor.
4 Coefficients of linear expansion have been calculated from the final (practical) moduli for the aluminium and steel components of the conductors and coefficients of linear expansion of 23.0×10^{-6} and 11.5×10^{-6} / °C for aluminium and steel respectively.

ANNEX C
(*Clause* 6.1.2)

CHEMICAL COMPOSITION OF HIGH CARBON STEEL

C-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* to 0.035
Sulphur	*Max* 0.045
Silicon	0.10 to 0.35

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