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TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.89

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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Design of suspension wires, telecommunication poles and guy-lines for optical access networks

Recommendation ITU-T L.89

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Design of suspension wires, telecommunication poles and guy-lines for optical access networks

Summary

Recommendation ITU-T L.89 describes the general requirements and a design guide for suspension wires, telecommunication poles and guy-lines that support aerial cables for optical access networks. This Recommendation also describes loads applied to the infrastructures.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.89	2012-02-13	15

Keywords

Aerial infrastructure, guy-line, ice loading, suspension wire, suspension wire tension, telecommunication pole, vertical load, wind loading.

FOREWORD

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

Suspension wires, telecommunication poles and guy-lines that support aerial optical fibre cables are important facilities for providing broadband services. An appropriate design is needed to maintain the reliability of these facilities and services. Moreover, they are big facilities installed at a high position, and so they should be managed in a way that ensures sufficient safety. To realize these requirements, a design is needed that carefully considers facility strength.

Recommendation ITU-T L.89

Design of suspension wires, telecommunication poles and guy-lines for optical access networks

1 Scope

This Recommendation deals mainly with fundamental requirements for designing suspension wires, telecommunication poles and guy-lines supporting aerial optical cables. In this Recommendation aerial infrastructures mean suspension wires, telecommunication poles and guy-lines. The intent of such a plant is to support outdoor cables that will be attached by lashings, clips, or similar mechanisms.

Note that self-supporting cables such as the one shown in Figure 8, ADSS, or others, while not specifically addressed by this Recommendation, have the same issues applicable to their installation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.26] Recommendation ITU-T L.26 (2002), *Optical fibre cables for aerial application*.

[ITU-T L.58] Recommendation ITU-T L.58 (2004), *Optical fibre cables: Special needs for access network*.

[ITU-T L.87] Recommendation ITU-T L.87 (2010), *Optical fibre cables for drop applications*.

[ITU-T L.88] Recommendation ITU-T L.88 (2010), *Management of poles carrying overhead telecommunication lines*.

3 Definitions

3.1 Term defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 guy-line: A wire installed to prevent poles collapsing as a result of tension imbalances that occur during or after cable installation. One end of the guy-line is fixed to the pole and the other end is fixed to the ground by a guy anchor.

3.2.2 messenger: An alternative term for suspension wire.

3.2.3 suspension wire: Wire that is installed in advance between telecommunication poles from which aerial optical cables are suspended. It supports a tension applying to non-self-supporting aerial optical cables.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADSS All-Dielectric Self-Supporting

CAPEX Capital Expenditure

5 Conventions

None.

6 Configuration of aerial infrastructure

The aerial infrastructure consists of a suspension wire (messenger), a telecommunication pole and a guy-line as shown in Figure 1, and supports the optical fibre cables for aerial applications described in [ITU-T L.26], [ITU-T L.58] and [ITU-T L.87].

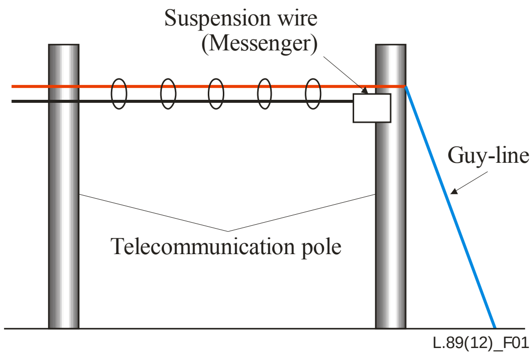

Figure 1 – Aerial infrastructure

6.1 Aerial communication infrastructure on shared poles

The aerial optical cable infrastructure may also be co-located on poles carrying power cables. While such installations follow the intent of this Recommendation, the effects of the loading, spacing, and guy-line construction for the power cables must also be considered. Local regulations will also affect the spacing and sag of communication plants.

7 General requirements for aerial infrastructure design

7.1 Clarification of optical fibre cables

The main function of the aerial infrastructure is to support optical fibre cables. The type and number of optical fibre cables that are supported are decided based on demand forecasts and future plans for networks, and so the design of an aerial infrastructure strongly depends on the optical fibre cables supported. Therefore, telecommunication companies shall know what kind of optical fibre cables will be installed; taking account of their future plans.

7.2 Classification of site conditions

Ideally, aerial infrastructure is designed in accordance with the conditions of each individual site. However, designing on such an individual basis raises capital expenditure (CAPEX). Therefore, a certain level of design standardization is necessary to simplify the design and construction process, in order to reduce CAPEX. As one example of this standardization, site conditions may be classified based on wind loading, ice loading and/or soil property. Telecommunication companies should carefully investigate the site conditions so that the site can be correctly classified.

7.3 Safety and economic considerations

Aerial infrastructure consists of large facilities that are installed high above the ground. So, it is recommended that telecommunication companies carefully consider safety and avoid any accidental destruction to aerial infrastructure by employing a design with sufficient strength and protection against lightning. Note that telecommunication companies should also consider reducing CAPEX while maintaining safety.

7.4 Management of ground height and offset distance

It is recommended that aerial infrastructure (including cables shown in [ITU-T L.26], [ITU-T L.58] and [ITU-T L.87]) has sufficient ground height to prevent any component from being a traffic barrier and to eliminate risks to people and other constructions. The ground height shall be evaluated in wind-free conditions. An offset distance that is as great as possible should be established between optical fibre cables and electrical cables to achieve safety and workability. In general, ground height and offset distances are defined by regulations, and so telecommunication companies shall follow these regulations when designing aerial infrastructure.

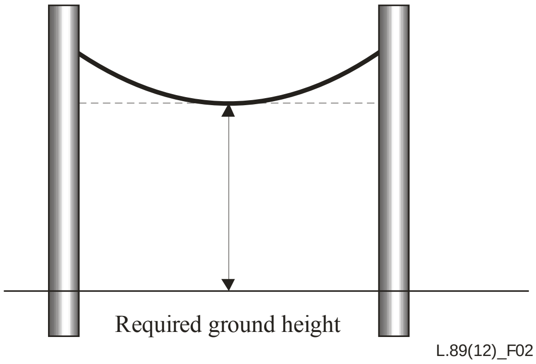

Figure 2 – Ground height

7.5 Loads applied to aerial infrastructure

Aerial infrastructure should be designed in accordance with the loads applied to them to maintain their reliability and safety. In particular, telecommunication companies should carefully consider wind loading, suspension wire tension and vertical load, as shown in Figure 3. These loads must include the weight of the cable(s) which are expected to be supported by the suspension wire (see clause 7.1).

7.5.1 Wind loading

The wind load T_w [N] can be obtained by the following equation.

$$T_w = \frac{1}{2}\rho C_D V_w^2 S \tag{7-1}$$

where ρ, C_D, V_w and S are the air density, the drag coefficient of the infrastructure determined by wind tunnel testing, the wind velocity and the profile area of the cable and the suspension wire, respectively. Note that ice accretion to the cable and suspension wire may increase in their profile area.

7.5.2 Suspension wire tension

The suspension wire tension is the load supported by suspension wire. The suspension wire tension T [N] can be obtained with the following equation.

$$T = \frac{WL^2}{8d} \tag{7-2}$$

where L is a span length. d is a sag and has an inverse ratio to T. In terms of the ground height, a smaller sag is desirable, but this increases suspension wire tension as shown in Figure 4, and so an aerial infrastructure with greater mechanical strength is required. Therefore, telecommunication companies should design the sag and the suspension wire tension so that they are in balance. As shown in Figure 5, W is the load imposed by the sum of the wind load and the cable weight. Note that the resultant load W [N/m] should be defined as the value per unit length. So, it is given by:

$$W = \sqrt{w^2 + \left(\frac{T_w}{D}\right)^2} \tag{7-3}$$

where w and D are an aggregate of cable and suspension wire weights per unit length and aggregate of cable and wire diameters, respectively. Note that the suspension wire tension reaches its maximum value at its minimum temperature because metal contracts as the temperature falls. Ice loading should be included in cable weight. Ice loading guidelines are generally established by local, regional, or national authorities. Different ice density values for radial and rime ice may be used depending upon local conditions.

7.5.3 Vertical load

This is load applied to a telecommunication pole vertically. Typical vertical loads are as follows:

- weight of telecommunication pole;
- weight of snow and ice adhering to telecommunication pole;
- vertical component of guy-line tension;
- weight of workers and tools.

It is recommended for telecommunication companies to consider maximum vertical load when designing telecommunication poles.

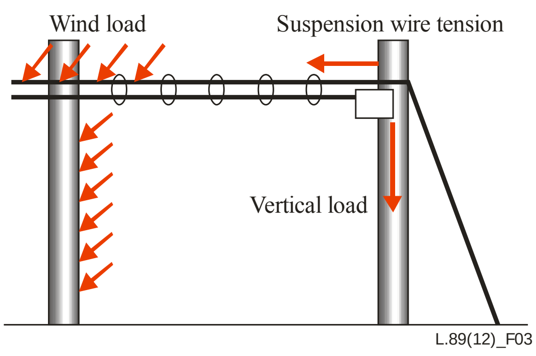

Figure 3 – Wind load, suspension wire tension and vertical load

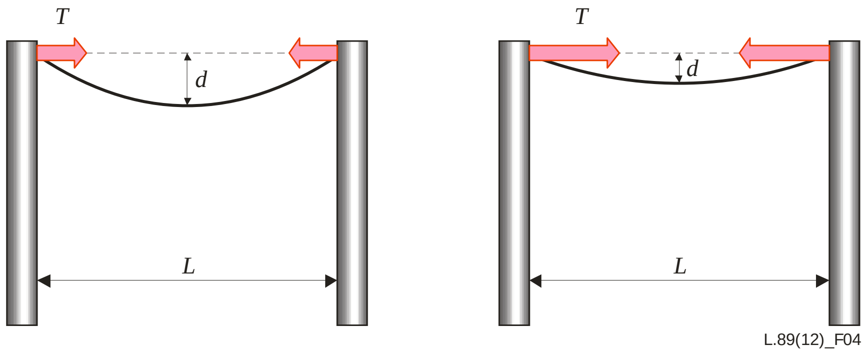

Figure 4 – Relationship between suspension wire tension and sag

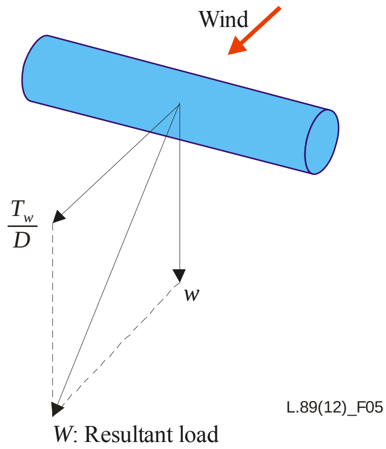

Figure 5 – Resultant load applied to a suspension wire

8 Design of suspension wires

8.1 Materials

It is recommended that stranded steel wire be used as suspension wire. Anticorrosive material, e.g., aluminium-coated steel or zinc-coated steel, should be used for the suspension wire in areas with a corrosion risk. Typical corrosion risk areas are as follows:

− Near the coast; corrosion by salt breeze.

− Industrial and mining areas; corrosion by sulphur dioxide gas.

− Hot springs (warm water found in a volcanic location) and volcanic areas; corrosion by hydrogen sulphide.

8.2 Selection of suspension wire type

It is recommended for telecommunication companies to select the suspension wire in accordance with the specifications of the aerial cables that it supports. When a future expansion plan for optical cables becomes clear, telecommunication companies may employ the suspension wire that conforms to their plan in advance. The applicable type of suspension wire should be decided carefully based on its tensile strength, calculated suspension wire tension and safety margin.

8.3 Sag

The sag of a suspension wire reaches its maximum value at the maximum temperature or under the maximum weather loading. So, it is recommended for telecommunication companies to carefully consider the temperature conditions at the installation site.

9 Design of telecommunication poles

9.1 Materials

Telecommunication poles should be made of steel, reinforced concrete or wood.

9.2 Embedded depth

The embedded depth of the pole shall be decided in accordance with the subsurface condition of the ground and the material of the pole to prevent poles from collapsing. A greater embedded depth shall be employed for soft ground such as a paddy field area, an embanked zone and peat soil. The use of a pole anchor is also effective for coping with such ground conditions. The method for evaluating a telecommunication pole's foundation is described in [ITU-T L.88].

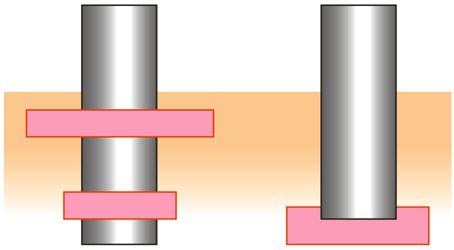

Figure 6 – Example of pole anchor

9.3 Pole length

The pole length is limited by the ground height defined by regulations. So, the pole length should be designed to satisfy the required ground height whenever the sag (temperature) reaches its maximum value. At that time, the embedded depth and the surplus length should also be considered.

9.4 Classification

Telecommunication poles are typically classified based on their purpose as follows (Figure 7):

- intermediate pole;
- corner pole;
- terminal pole.

The intermediate pole is located midway in the rectilinear cable region. The intermediate pole is affected by wind loads acting on it, wires and cables. So, guy-lines should be installed on both sides of the intermediate pole. The installation interval of the guy-line should be decided in accordance with the wind load at the site. It is recommended that two side guy-lines be installed every two poles as long as the site condition permits it when the wind load is classified at the highest level.

A corner pole is installed at a bent section of an aerial optical cable line. This corner pole is affected by the resultant load of angular bidirectional suspension wire tensions. So, it is recommended that a guy-line be installed on one side. Note that there is no need to use a guy-line when the suspension wire tension is sufficiently small.

The terminal pole is located at the start and end points of cable lines, and is affected by unbalanced suspension wire tension. So, it is recommended that a terminal guy-line be installed. Note that there is no need to use a guy-line when the suspension wire tension is sufficiently small.

10 Design of guy-lines

10.1 Configuration

A guy-line consists of an upper and a lower part. The upper part of the guy-line (i.e., upper guy-line) is attached to telecommunication poles. The lower part of the guy-line (i.e., guy anchor) is buried to exploit the bearing capacity of the soil.

10.2 Installation angle of upper guy-lines

The installation angle, which is formed by the pole and the upper guy-lines, may be more than 25 degrees.

10.3 Classification of upper guy-lines

Upper guy-lines are typically classified based on their purpose as follows (Figure 7):

- terminal guy-line;
- one side guy-line;
- two side guy-line.

Terminal guy-lines are attached to terminal poles, and should be installed parallel to optical cables. If the allowable strength of the single guy-line is insufficient, two guy-lines can be used. One side guy-lines are attached to the corner poles. One side guy-lines should be installed in the direction bisecting the corner angle. Two side guy-lines are mainly attached to the intermediate poles. Two side guy-lines should be installed every two poles when the wind load is classified at the highest level.

10.4 Classification of guy anchors

Guy anchors are typically classified according to their purpose as follows (Figure 8):

- piton anchor;
- block anchor;
- spiky bolt anchor.

The piton anchor, which is a spiky steel piton driven into the ground, is used in most cases except when the installation is on rock or when the driving action might damage existing underground installations or facilities. When it cannot be used, the next choice is the block anchor. The guy-line is held in place by an anchor block formed on site by pouring concrete into a hole, which is then refilled and compacted. However, this also cannot be installed on rock. For an installation on rock, a shallow hole is drilled and a spiky bolt is inserted and mortared in place.

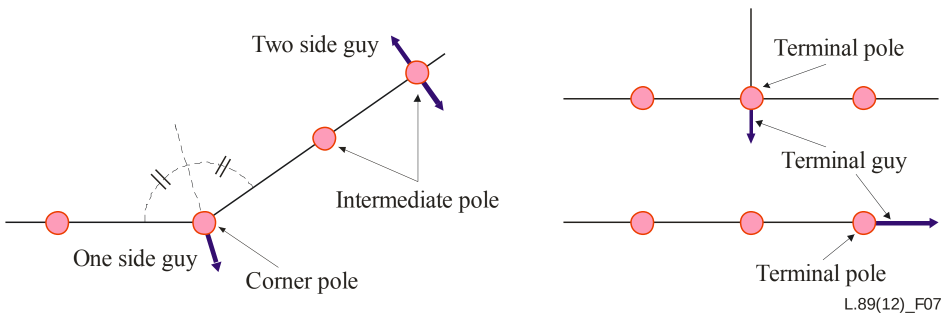

Figure 7 – Classification of telecommunication pole and upper guy-line

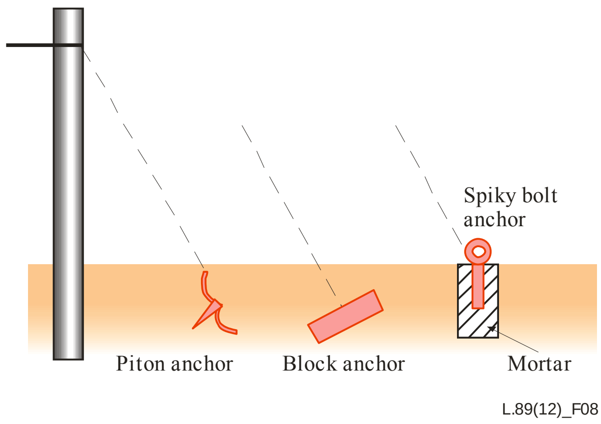

Figure 8 – Classification of guy anchors

Appendix I

Relationship between sag and the length of suspension wire

(This appendix does not form an integral part of this Recommendation.)

I.1 Introduction

It is useful to calculate the suspension wire length to meet the requirement of the sag which is decided according to the required ground height. Here, a basic formula for the calculation of the required suspension wire length is introduced.

I.2 Calculation of required suspension wire length

A shape of a suspension wire supported by poles is the catenary curve. Therefore, the length of suspension wire can be calculated based on a well-known arc length of the catenary curve. The length of suspension wire supported by poles l [m] is express as follows.

$$l = L + \frac{L^3 W^2}{24T^2} \tag{I-1}$$

where L [m], T [N] and W [N/m] are a span length, the suspension wire tension and the load imposed by the sum of the wind load and the cable weight, respectively. The following formula is given by substituting equation (7-2) for T in equation (I-1).

$$l = L + \frac{8d^2}{3L} \tag{I-2}$$

Moreover, Young's module E [N/m^2] is defined as follows.

$$E = \frac{\frac{T}{A}}{\frac{l - l_0}{l_0}} \tag{I-3}$$

where l_0 [m] is the length of suspension wire before supporting a load, i.e., the wire length which should be prepared before its construction. A [m^2] is the cross-section area of the wire. Finally, l_0 is calculated by substituting equation (I-2) for l in equation (I-3) and solving for l_0.

$$l_0 = L\left\{1 + \frac{8}{3}\left(\frac{d}{L}\right)^2\right\}\left(\frac{EA}{EA + T}\right) \tag{I-4}$$

Equation (I-4) immediately provides the required suspension wire length for arbitrary sag and span length.

I.3 Calculation considering the change of temperature and load applied to the wire

The environment where wires and cables are installed is not stable. In particular, the temperature and the load are momentarily changed. So, with regard to their design, it is significant to consider any changes.

Here, the situation in which the temperature and the load are changed from θ to θ_1 [^{o}C] and from W to W_1, respectively, is considered. Note that the change of the load is mainly caused by changes in wind pressure. The parameters used for the calculation are as follows.

L [m]: span length

l_0 [m]: length of suspension wire before supporting a load at temperature of θ

l_0' [m]: length of suspension wire before supporting a load at temperature of θ_1

l [m]: length of suspension wire supported by poles at temperature of θ and load of W

d [m]: sag at temperature of θ and load of W

T [N]: suspension wire tension at temperature of θ and load of W

l_1 [m]: length of suspension wire supported by poles at temperature of θ_1 and load of W_1

d_1 [m]: sag at temperature of θ_1 and load of W_1

T_1 [N]: suspension wire tension at temperature of θ_1 and load of W_1

α[/°C]: linear expansion coefficient of the wire

E [N/m^2]: Young's module of the wire

A [m^2]: cross-section area of the wire

When changing the temperature from θ to θ_1, the length of the suspension wire before supporting l_0' is expressed as,

$$l_0' = l_0\{1+\alpha(\theta_1-\theta)\} \tag{I-5}$$

So, when the wire is supported by poles, the length of the wire supported by poles l_1 is given by:

$$l_1 = l_0\{1+\alpha(\theta_1-\theta)\}\left(1+\frac{T_1}{EA}\right) \tag{I-6}$$

Here, by substituting equation (I-2) for l in equation (I-6), l_0 is expressed as follows.

$$l_0 = \frac{L\left\{1+\frac{8}{3}\left(\frac{d_1}{L}\right)^2\right\}}{\{1+\alpha(\theta_1-\theta)\}\left(1+\frac{T_1}{EA}\right)} \tag{I-7}$$

Regarding equation (I-4) and equation (I-7),

$$L\left\{1+\frac{8}{3}\left(\frac{d}{L}\right)^2\right\}\{1+\alpha(\theta_1-\theta)\}\left(1+\frac{T_1}{EA}\right) = L\left\{1+\frac{8}{3}\left(\frac{d_1}{L}\right)^2\right\}\left(1+\frac{T_1}{EA}\right) \tag{I-8}$$

When substituting equation (7-2) into equation (I-8) and by neglecting some smaller terms, the following relation is given.

$$T_1^3 + EA\left\{\alpha(\theta_1-\theta)+\frac{1}{24}\left(\frac{WL}{T}\right)^2-\frac{T}{EA}\right\}T_1^2 = \frac{1}{24}(W_1L)^2 EA \tag{I-9}$$

This is the formula to calculate the suspension wire tension T_1 when the temperature and the load change from θ to θ_1 and from W to W_1. Of course, the sag at this condition can also be immediately calculated by using equation (7-2).

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