# Kursus “Lightning & Surge Protection”

# Lightning Protection System

**Cawangan Kejuruteraan Elektrik**

2020

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## 3. Physical Damage to Structures/ Buildings & Life Hazard

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3.9 Misconceptions About Lightning

3.10 Non-conventional LPS

# 1.1 Scope

## What is Lightning Protection System?

- IEC 62305-1 - Complete system used to <u>reduce</u> physical damage due to lightning flashes to a building
- It consists of both external and internal LPSs.

# 1.1 Scope

## Lightning Protection System

**LPS**

### External Lightning Protection

- Air termination systems
- Down conductor systems
- Earth termination system
- Components
- Materials & Dimensions

### Internal Lightning Protection

- Lightning equipotential bonding
- Electrical insulation / separation of the external LPS
- SPDs

# 1.2 References

- IEC 62305-1 Part 1: General Principles
- IEC 62305-2 Part 2: Risk Management
- IEC 62305-3 Part 3: Physical Damage to Structure and Life Hazard
- IEC 62305-4 Part 4: Electrical and Electronic Systems within Structures
- IEC 62561 series: Lightning Protection Components

# 1.2 References

**Akta Bekalan Elektrik 1990 (Akta 447):**

***Seksyen* 47. Langkah awasan terhadap elektrik atmosfera.**

Mana-mana jabatan Kerajaan Persekutuan atau mana-mana Kerajaan Negeri atau mana-mana pengguna lain yang mengambil atau menggunakan elektrik daripada mana-mana pepasangan hendaklah, jika Suruhanjaya menghendaki sedemikian, memperuntukkan apa-apa kaedah bagi menghindarkan apa-apa risiko kerosakan kepada pepasangan itu melalui elektrik atmosfera sebagaimana yang diarahkan oleh Suruhanjaya atau sebagaimana yang ditetapkan melalui peraturan-peraturan di bawah Akta ini.

PDF

# 1.3 Terms & Definitions

## IEC Terminology

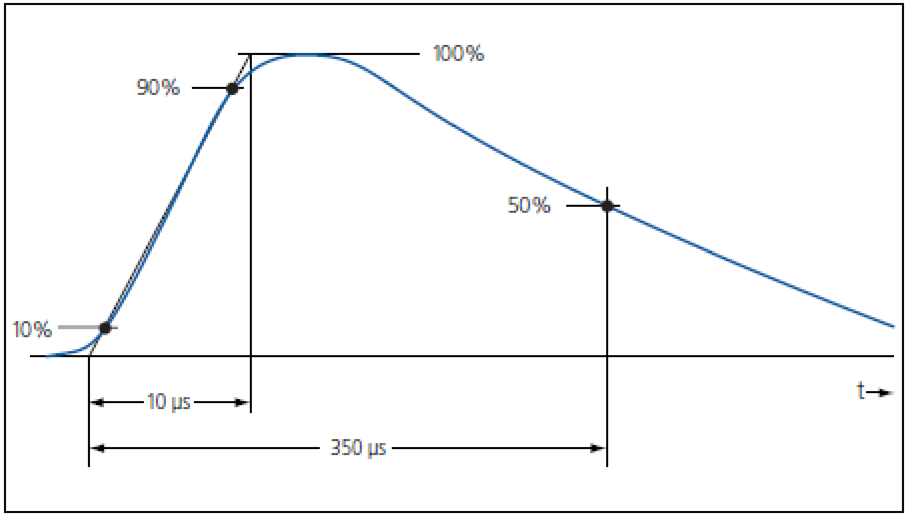
| Term | Definition |
|---|---|
| **Lightning stroke** | Single electrical discharge in a lightning flash to earth |
| **Lightning flash to earth** | Electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes |

## Common vs IEC Terminology

| Common Terminology | IEC Terminology |
|---|---|
| **Lightning strike** | **Lightning flash/stroke** |
| **Discharge current** | **Lightning current** |

# 1.4 Lightning Current Parameters

- As shown in figure, lightning current waveshape, the front time (also known as rise time) is 10 μs duration and the time to decay to 50% (also known as tail time) is 350 μs.




Waveshape

# 1.5 Lightning in Malaysia

- **Malaysia is a <u>tropical country</u> which has recorded a high number of lightning strikes and thunderstorm activity throughout the year**

# 1.5 Lightning in Malaysia

**Thunderstorm Day & Ground Flash Density in Malaysia**

- Lightning ground flash density ($N_g$) defined as the number of cloud-to-ground flashes per square kilometer and per year ($km^{-2}\ yr^{-1}$)
- Is an important meteorological data that is used in calculating the risk of lightning strikes to a building
- $N_g$ can be captured or calculated from the Annual Thunderstorm days $T_D$ (keraunic level)

# 1.5 Lightning in Malaysia

- Malaysian Meteorological Department (MMD) has recorded more than 200 thunderstorm days per year in Malaysia.

Among the top 3 in the world

| Thunderstorm Days Per Year Worldwide | |
|---|---|
| Bogor, Indonesia (1988) | 322 |
| Cerromatoso, Columbia | 275-320 |
| Malaysia | 180-260 |
| Singapore | 160-220 |
| Florida, U.S. | 90-110 |
| Colorado, U.S. | 65-100 |
| Brazil | 40-200 |
| Argentina | 30-200 |
| Japan | 35-50 |
| Most of Europe | 15-40 |
| Australia | 10-70 |
| England | 5-10 |

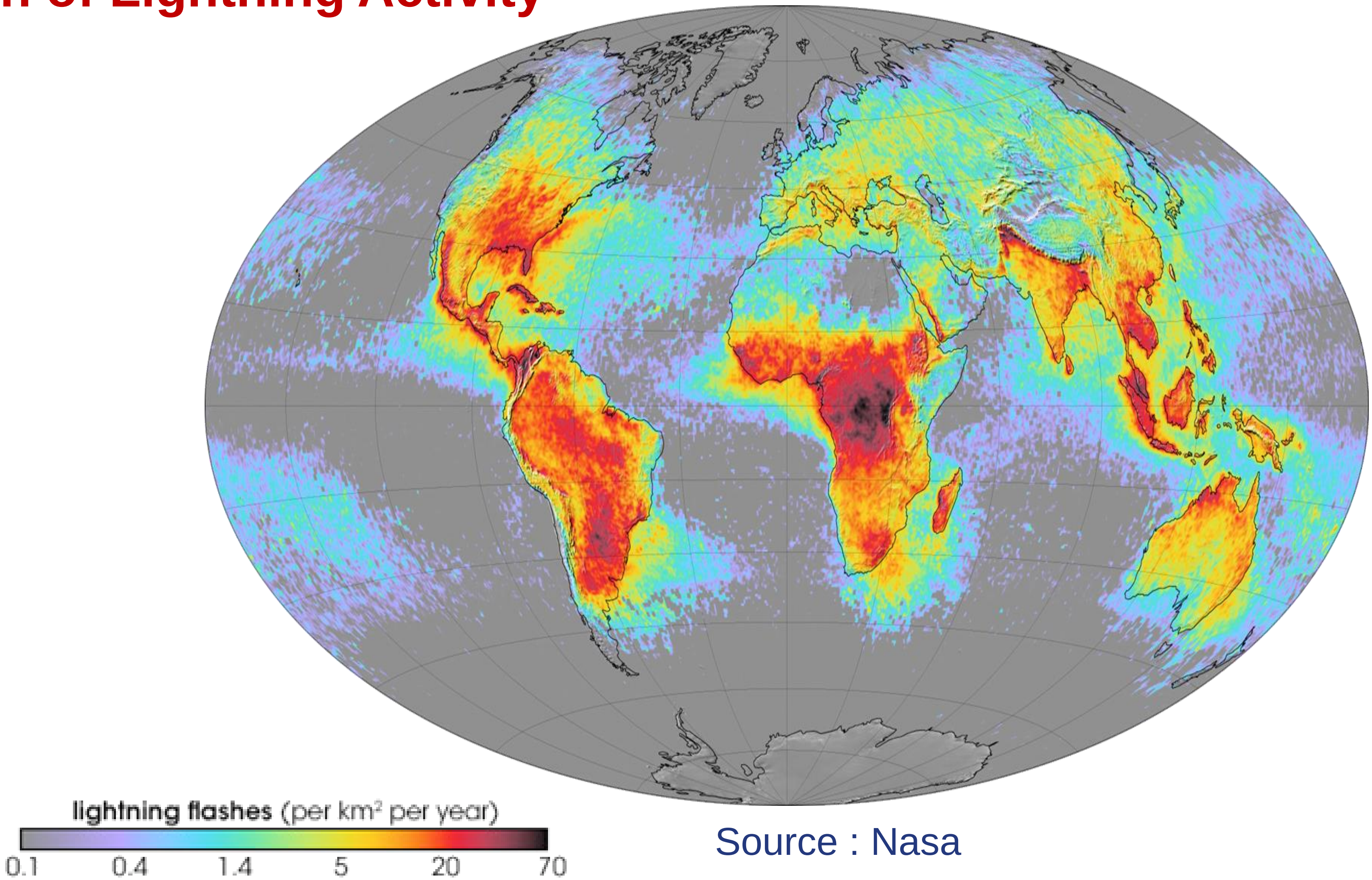
# 1.5 Lightning in Malaysia

- TNBR has recorded as high as 484.4 kA lightning impulse current in Malaysia using their Lightning Detection Network (LDN)

| Top Lightning Flash Density (ground strikes per km/sq) Sites Worldwide | |
|---|---|
| Kamembe, Rwanda | 82.7 |
| Boende, Dem. Rep. Congo | 66.3 |
| Lusambo, Dem. Rep. Congo | 52.1 |
| Kananga, Dem. Rep. Congo | 50.3 |
| Kuala Lumpur, Malaysia | 48.3 |
| Calabar, Nigeria | 47.3 |
| Franceville, Gabon | 47.1 |
| Posadas, Argentina | 42.7 |
| Ocana, Colombia | 39.9 |
| Concepcion, Paraguay | 37.0 |

# 1.5 Lightning in Malaysia

## Pattern of Lightning Activity




Source : Nasa

# 1.5 Lightning in Malaysia

## Pattern of Lightning Activity

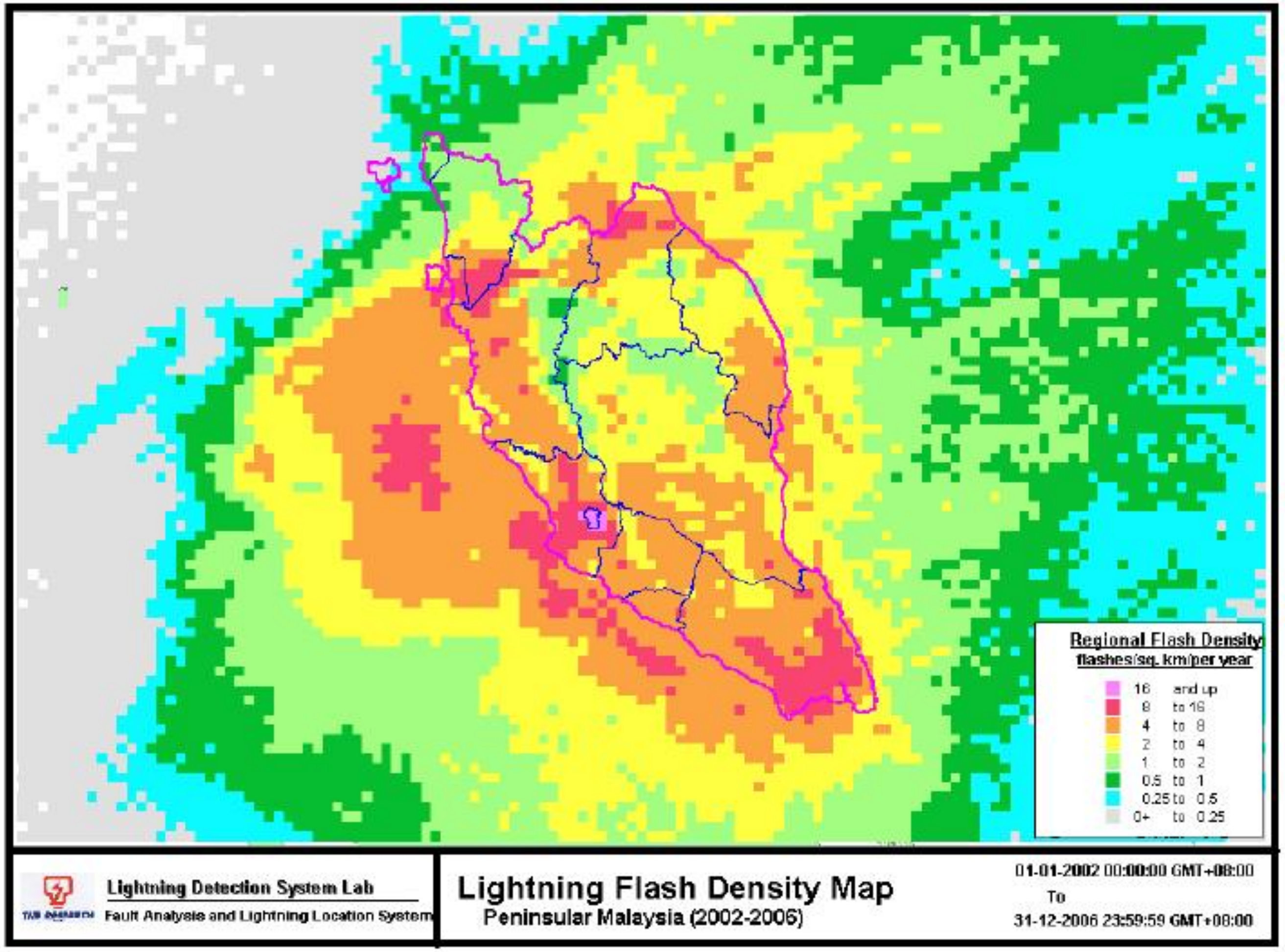
Annual Thunderstorm Day ($T_D$) Figures for the Year 1993 to 2002 (Hartono 2003)

| Major towns/cities | 10-year $T_D$ Ave. | Max $T_D$ | Min $T_D$ |
|---|---|---|---|
| Langkawi | 101 | 136 | 90 |
| Alor Star | 165 | 197 | 145 |
| Butterworth | 172 | 183 | 164 |
| Bayan Lepas | 202 | 239 | 185 |
| Ipoh | 165 | 200 | 135 |
| Sitiawan | 193 | 235 | 179 |
| Subang | 188 | 195 | 180 |
| Malacca | 137 | 165 | 103 |
| Kluang | 191 | 222 | 165 |
| Senai | 172 | 206 | 159 |
| Mersing | 171 | 188 | 151 |
| Kuantan | 154 | 173 | 128 |
| Temeloh | 112 | 156 | 92 |
| Kuala Trengganu | 163 | 184 | 141 |
| Kota Baru | 115 | 146 | 94 |
| Kuala Krai | 161 | 177 | 149 |
| Kuching | 184 | 231 | 151 |
| Sri Aman | 105 | 132 | 78 |
| Sibu | 103 | 115 | 85 |
| Bintulu | 133 | 180 | 102 |
| Miri | 88 | 101 | 68 |
| Labuan | 147 | 164 | 112 |
| Kota Kinabalu | 139 | 158 | 113 |
| Kudat | 79 | 96 | 60 |
| Sandakan | 155 | 193 | 118 |
| Tawau | 84 | 124 | 45 |

# 1.5 Lightning in Malaysia

## Pattern of Lightning Activity

Lightning Flash Density ($N_g$) for Peninsular Malaysia (2002 – 2006) (TNBR)




$$N_g = 0.04\, T_D^{1.25}$$

# 1.5 Lightning in Malaysia

- Malaysia encounters more than 70% of power outages due to lightning

# 1.6 Damage Due to Lightning

## Damage to a structure

- **Construction (e.g. wood, brick, concrete etc.)**
- **Occupants (persons and animals)**
- **Connected lines (power lines, telecommunication lines, pipelines)**

# 1.6 Damage Due to Lightning

## Kes-Kes Panahan Petir di Malaysia

| Tahun | Jumlah Kes |
|---|---|
| 2010 | 30 |
| 2011 | 30 |
| 2012 | 42 |
| 2013 | 12 |
| 2014 | 20 |
| 2015 | 13 |
| 2016 | 13 |
| 2017 | 13 |
| 2018 | 2 |
| 2019 | 1 |

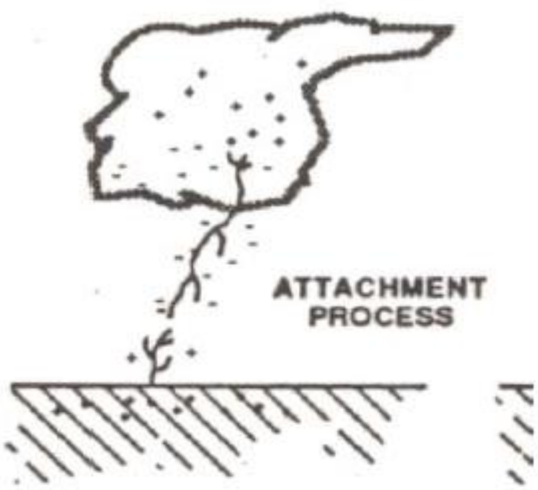
# 1.6 Damage Due to Lightning

## Kes-Kes Panahan Petir di Malaysia

Putrajaya

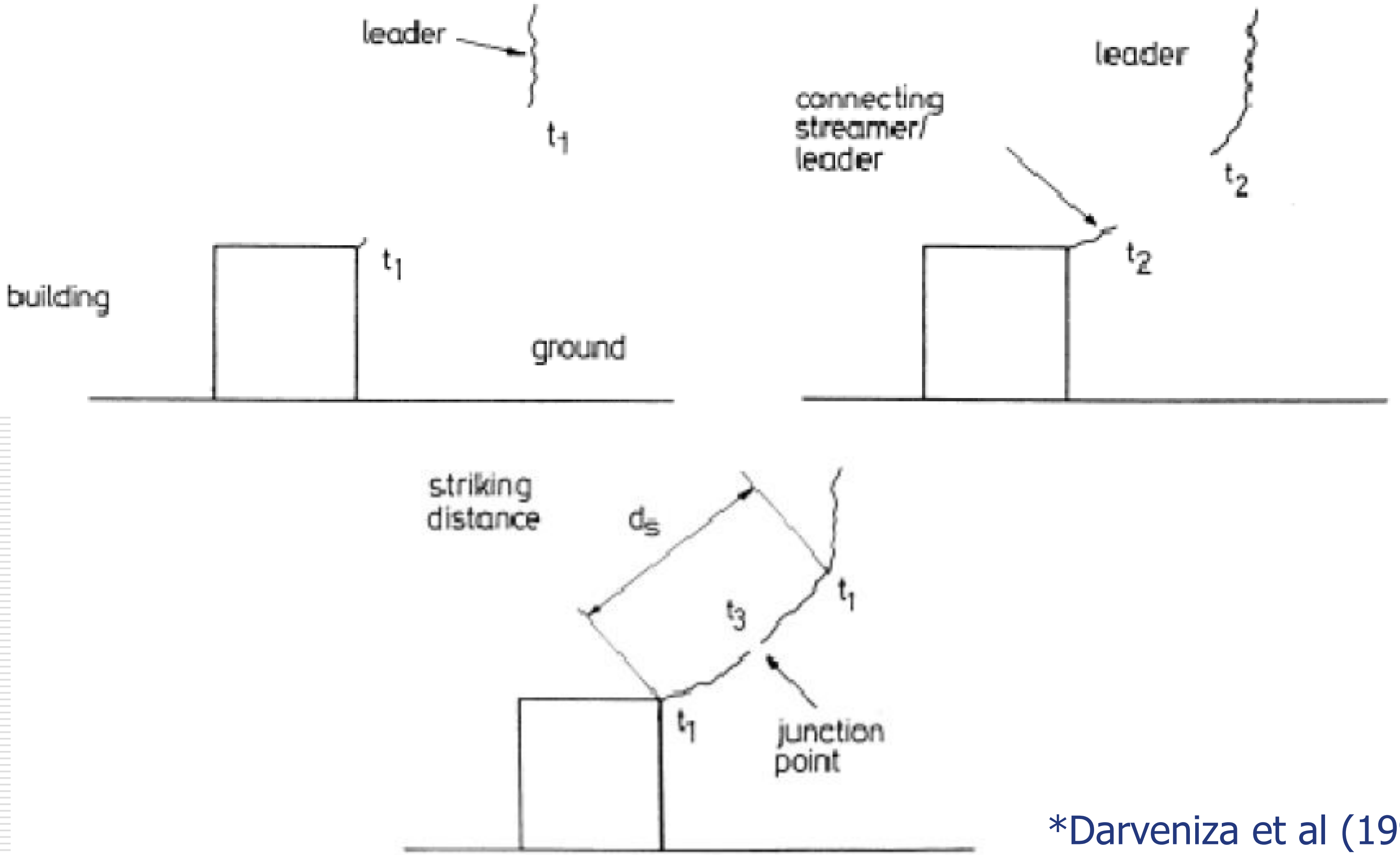
# 1.7 Theory of Lightning

- **Lightning attachment occurs when a discharge from a thundercloud attaches itself to an object on the ground**



# 1.7 Theory of Lightning

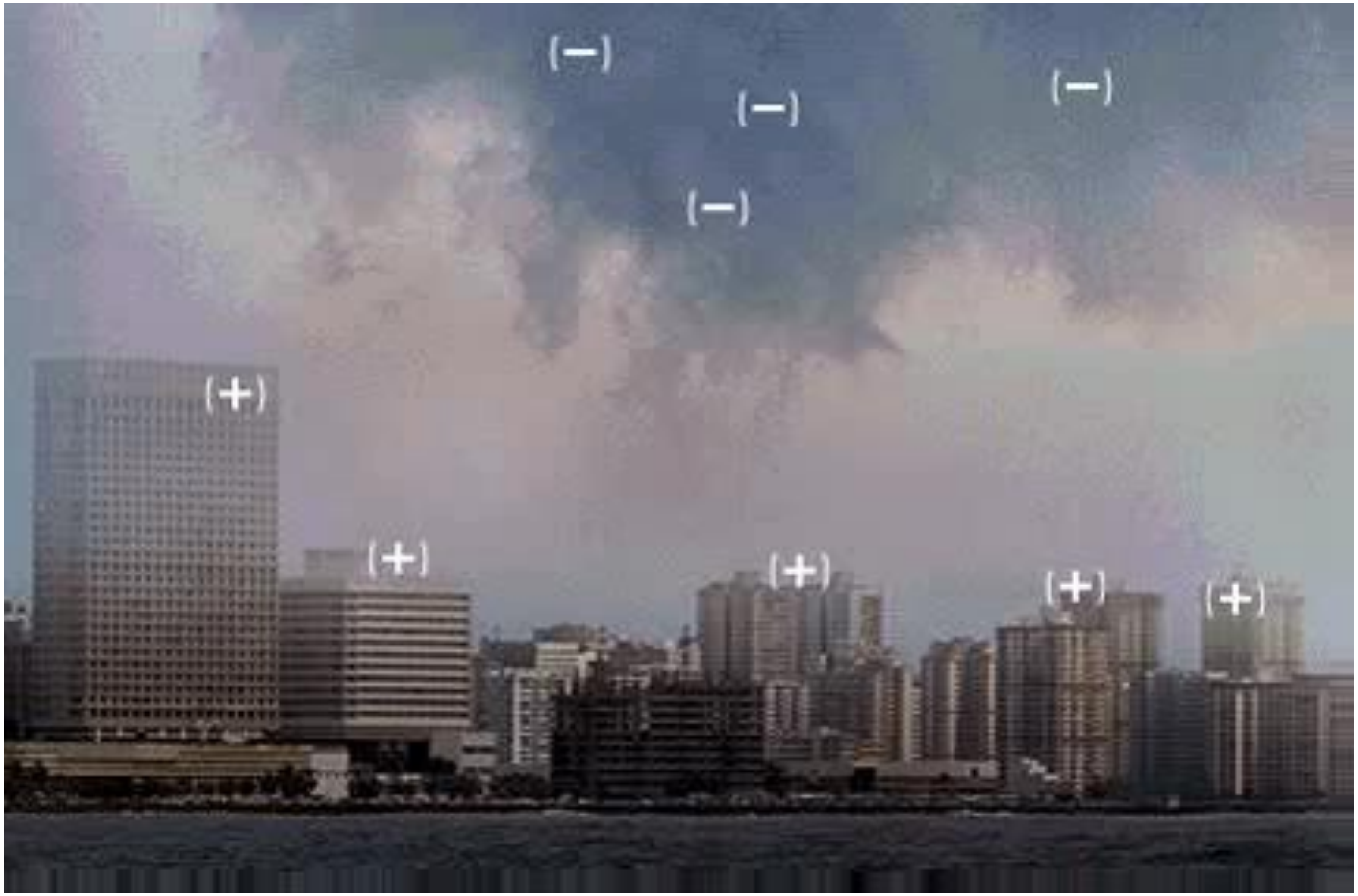
## Lightning attachment process




*Darveniza et al (1997)

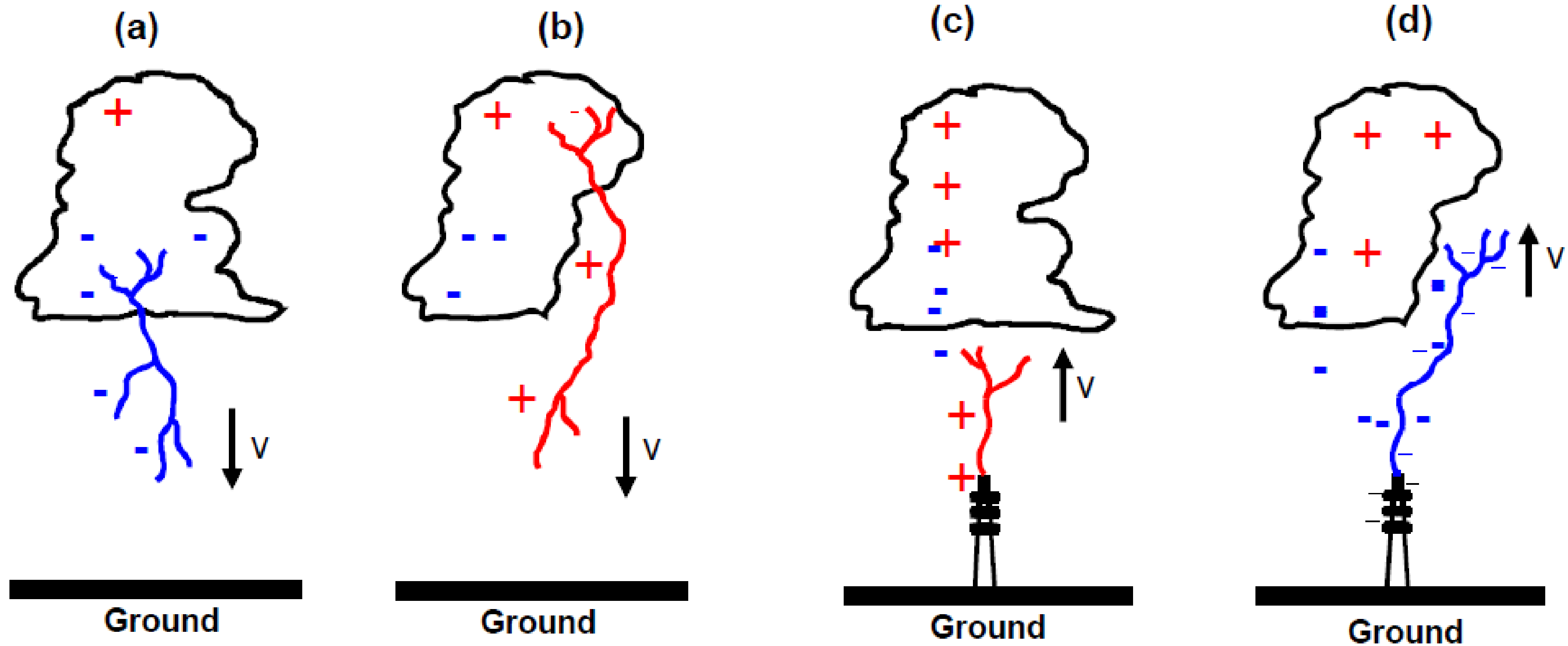
# 1.7 Theory of Lightning

## Lightning attachment process



# 1.7 Theory of Lightning

## Types of Lightning to Ground




(a) negative downward lightning,

(b) positive downward lightning,

(c) positive upward lightning

(d) negative upward lightning

# 1.7 Theory of Lightning

- Lightning strikes thousands of structures on the ground annually
- In most cases, they attach themselves to the corners and edges
- Sometimes it strikes the highest point of a structure

Lightning attachment to structure
[Photo: The Star Publications]

# 1.7 Theory of Lightning

- On rare occasions, lightning can also strike the sides of tall structures

[Photo: K. Ambrose]

Lightning attachment to structure

# 1.7 Theory of Lightning

## Lightning attachment to structures

- Studies on high-rise buildings with lightning attachment points in Kuala Lumpur and Singapore revealed a regular pattern of occurrence
- Lightning attachment points seemed to accumulate at corners, exposed points and edges

* CIGRE C4 Colloquium 2010, Kuala Lumpur

# 1.7 Theory of Lightning

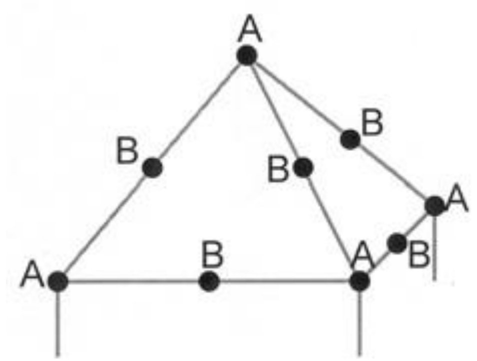
## Lightning attachment to structures

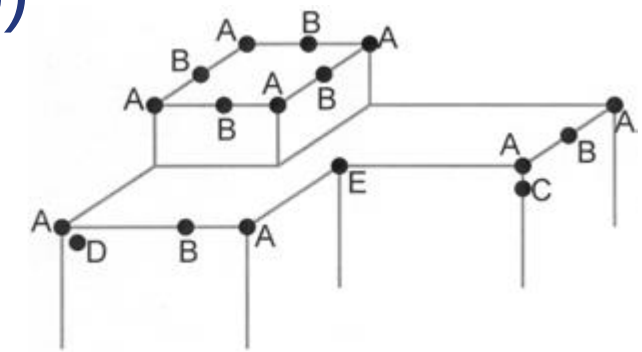
- The higher the structure height, the higher the chances of getting struck by the lightning, although that is not always going to be the case

# 1.7 Theory of Lightning

## Lightning attachment to structures

- A: Exposed corners and points (>90%)
- B: Straight or curved horizontal edges (<5%)
- C: Vertical edges near A (<2%)
- D: Flat surfaces near A (<1%)
- E: Included corners, etc. (0%)




*(Hartono & Robiah 1995, 2000)

# 1.7 Theory of Lightning

## Exposed corners and points

(Photo: Hartono)

# 1.7 Theory of Lightning

## Exposed edges

(Photo: Hartono)

# 2. Risk Management

- To determine if lightning protection is required
- If so, to select the appropriate lightning class (I,II,III,IV)
- To determine values of rolling sphere radius
- To determine the protective angle
- To determine values of mesh size
- To determine no. of down conductors
- To determine the separation distance

# 2. Risk Management

- Lightning protection can be installed even when the risk assessment process may indicate that it is not required.
- A greater level of protection than that required may also be selected.
- IEC 62305-2 standard is over 100 pages in length and is extremely comprehensive and complex.
- Manual calculation of risk assessment can take 10 hours to complete.
- Therefore, a reduced analysis is conducted, with an electronic tool.
- Third-party software is also available.

# 2. Risk Management

Four classes of LPS are defined in IEC 62305-2 corresponding to lightning protection level

| LPL | Class of LPS |
|---|---|
| I | I |
| II | II |
| III | III |
| IV | IV |

# 2. Risk Management

Identify the structure to be protected

Identify the types of loss relevant to the structure to be protected

R1 risk of loss of human life

R2 risk of loss of services to the public
(i.e water, power, gas, data/telecommunications)

R3 risk of loss of cultural heritage (*warisan budaya*)

R4 risk of economic loss

Identify the tolerable level of risk
Rt

R1,2,3,4 ≤ Rt

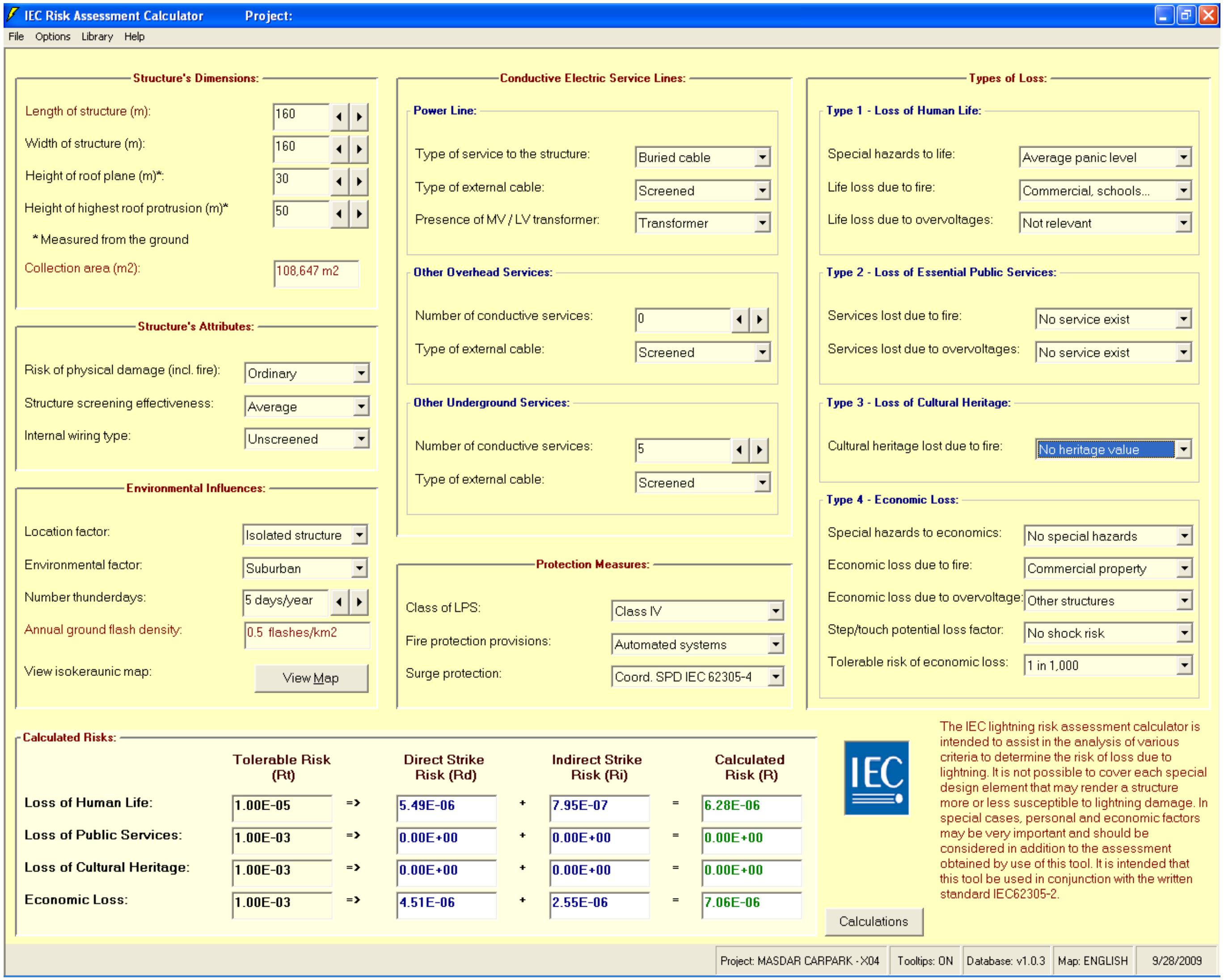
YES

Structure is sufficiently protected

NO

Install LPS in order to reduce
R1,2,3,4

# 2. Risk Management



# 2. Risk Management

## Primary risks

Following primary risks ($R_n$) relate to corresponding types of loss (L)

- $R_1$ – Risk of loss of human life
- $R_2$ – Risk of loss of services to the public
- $R_3$ – Risk of loss of cultural heritage
- $R_4$ – Risk of loss of economic value

# 2. Risk Management

$R_2$ – Risk of loss of <u>services</u> to the public

"services" – water, power, gas, fuel or data/telecommunications

– any type of company who, due to lightning damage, cannot provide their "service" to the public.

(e.g. Supermarket closed due to damage to cash register or a Bank unable to transact business due to phone or website failure)

# 2. Risk Management

## Risk Criteria

Protection against lightning is required if the primary risk $R_n$ (whether that is $R_1$ *or* $R_2$ *or* $R_3$ *or* $R_4$ ) is greater than the tolerable level of risk $R_T$

If $R_n \leq R_T$ No LPS required
If $R_n > R_T$ LPS is required

$R_T$ = max value of the risk which can be tolerated for the building to be protected

# 2. Risk Management

Identification of Tolerable Risk $R_T$

| Types of Loss | $R_T$ / annum |
|---|---|
| Loss of human life or permanent injury | $1 \times 10^{-5}$ |
| Loss of service to the public | $1 \times 10^{-3}$ |
| Loss of cultural heritage | $1 \times 10^{-3}$ |

If risk $R_n$ is less than or equal to value of $R_T$ – structure doesn't require protection

If risk $R_n$ is greater than $R_T$ – structure require protection and further calculation will determine exactly what type of protection is require.

# 3.1 External LPS

- intercept a lightning flash to the structure/building (with an air-termination system)
- conduct the lightning current safely towards earth (using a down-conductor system)
- disperse the lightning current into the earth (using an earth-termination system).

# 3.2 Internal LPS

- prevents dangerous sparking within the structure/building using either equipotential bonding or a separation distance (electrical insulation) between the external LPS components and other electrically conducting elements internal to the structure.

# 3.3 LPS Design

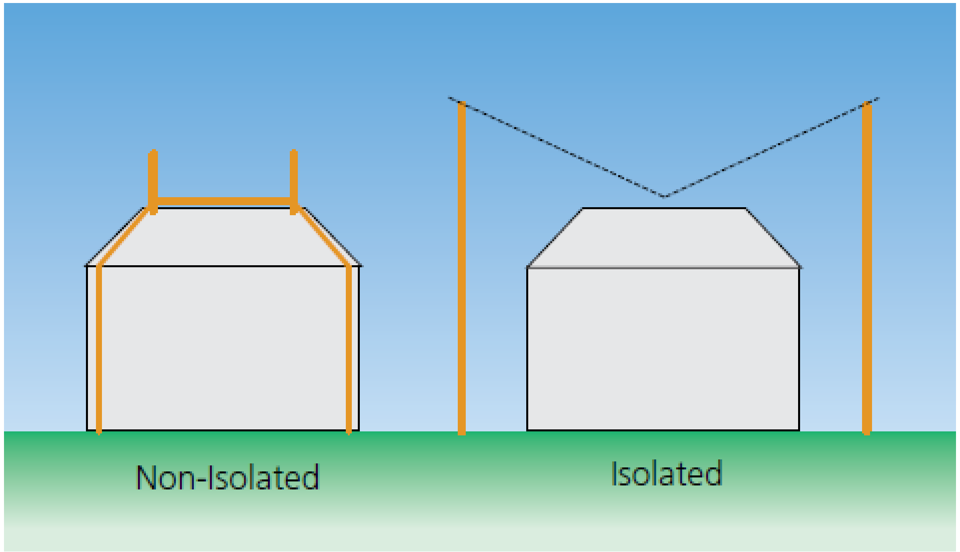
The design of a lightning protection system needs to:

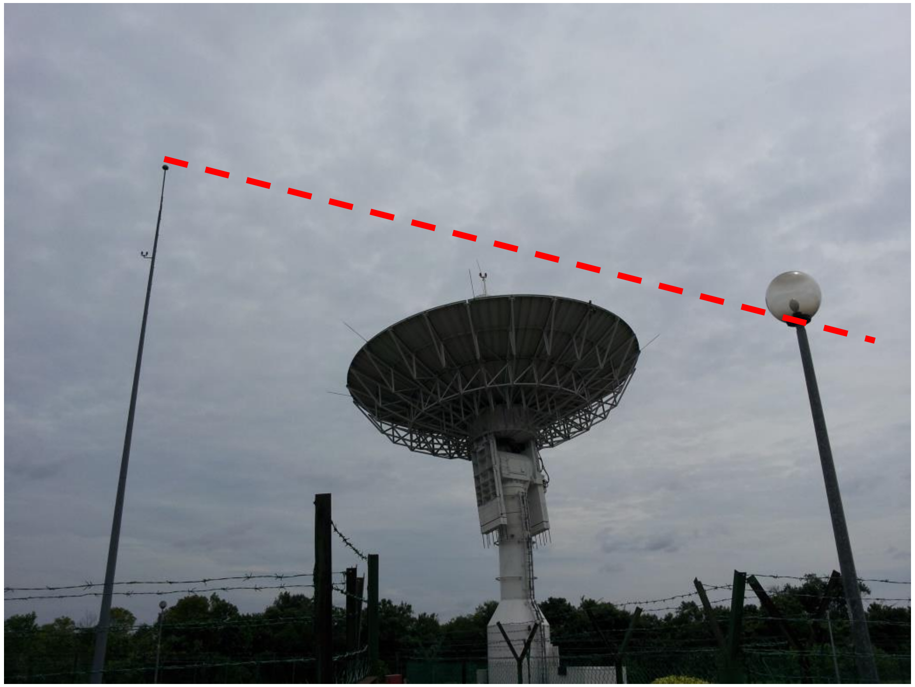
- Intercept lightning flash (i.e. create a preferred point of strike)
- Conduct the lightning current to earth
- Dissipate current into the earth
- Create an equipotential bond to prevent hazardous potential differences between LPS, structure and internal equipment/circuits

# 3.3 LPS Design

## Protection Methods & Risks

➢ Lightning protection systems typically follow two approaches:



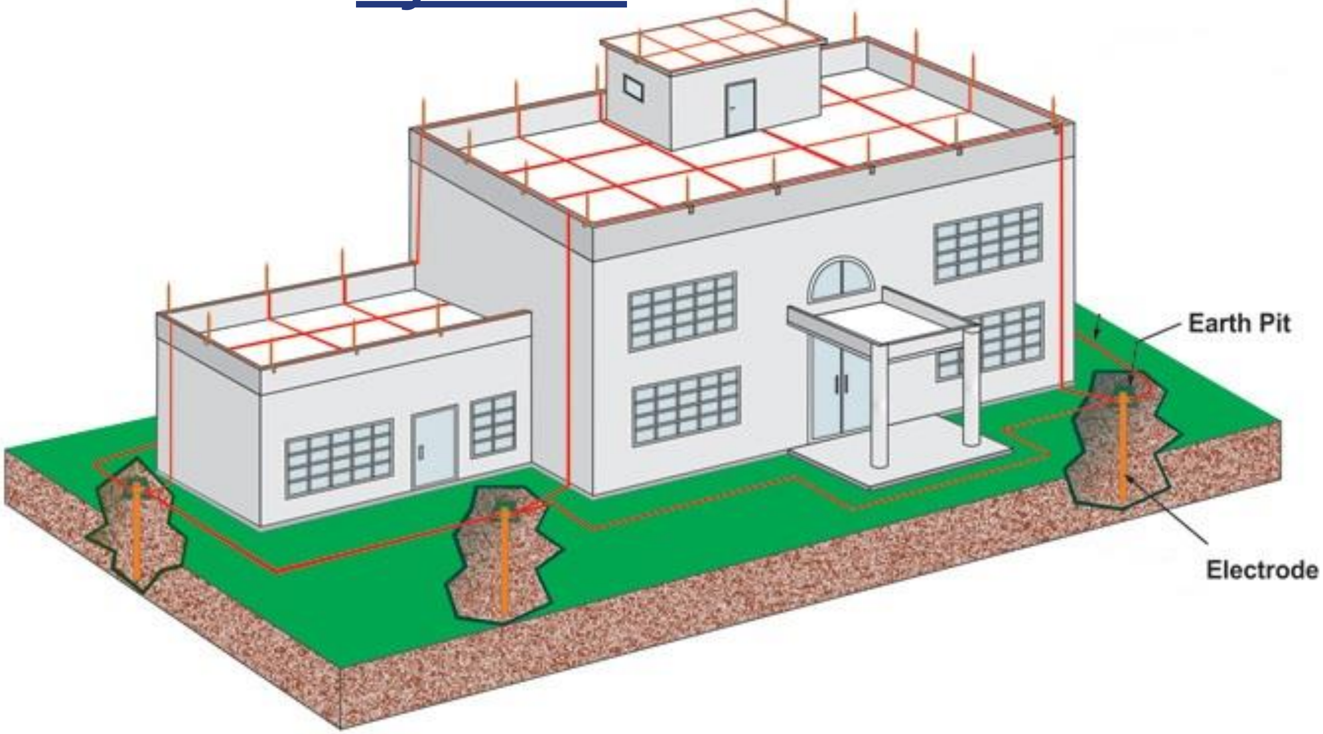



# 3.3 LPS Design

A. Air termination system

B. Down conductor system

C. Earth termination system

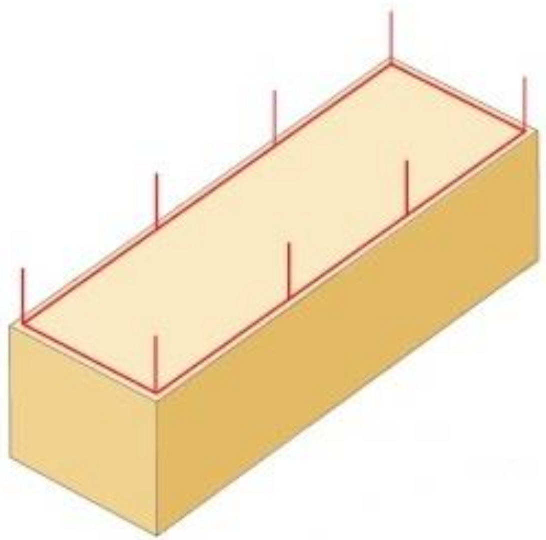


## A. Air termination system

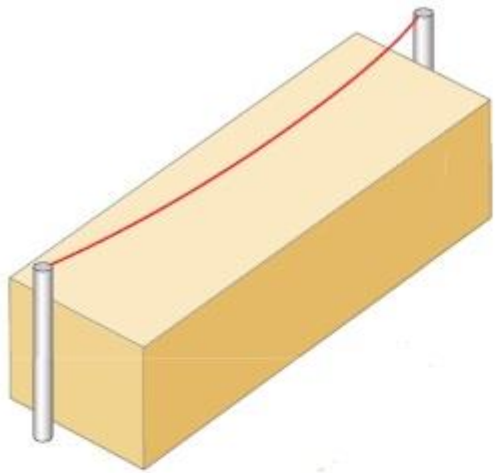
### Components

1. Rods
   - the individual rods should be connected together at roof level to ensure current division
2. Catenary wires
3. Mesh conductors
4. Natural air termination components (metal sheets, railings, coverings of parapets, metal pipes, tanks)

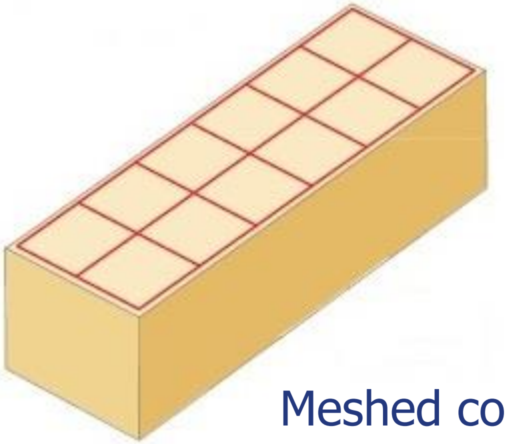
# 3.3 LPS Design



Air rods (finials)



Catenary (or suspended) wires



Meshed conductors

# 3.3 LPS Design

## Natural air termination components

| Material | Minimum thickness (mm) | |
|---|---|---|
| | Puncturing, hot spot or ignition *not* permitted | Puncturing, hot spot or ignition permitted |
| Lead | Not suitable | 2 |
| Steel | 4 | 0.5 |
| Titanium | 4 | 0.5 |
| Copper | 5 | 0.5 |
| Aluminum | 7 | 0.65 |
| Zinc | Not suitable | 0.7 |

# 3.3 LPS Design

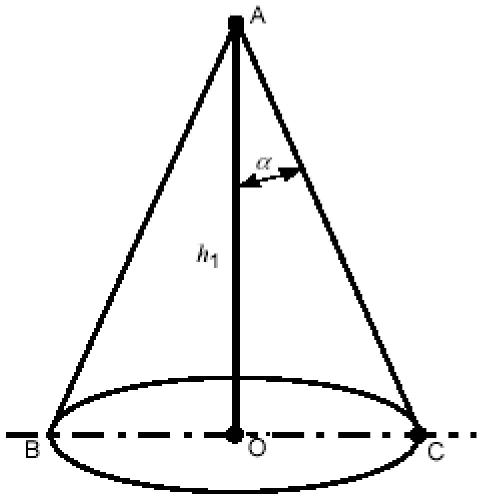
- **A. Air termination system**

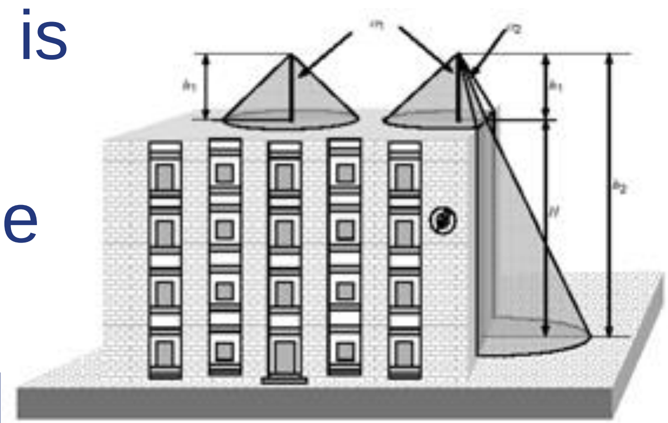
**Methods for determining the POSITION of the Air Termination System**

1. Protection angle method
   - subject to limits in Figure below
2. Rolling sphere method
   - suitable in all cases
3. Mesh method
   - suitable for flat surfaces

# 1. Protection angle method (PAM)

- Developed by Gay Lussac in 1823
- Air terminal/rod provide a protection zone in the shape of an imaginary cone
- Lightning will attach on the tip of the cone
- Objects within the imaginary cone is protected from lightning strokes
- Method was found to be unsuitable for highrise structures

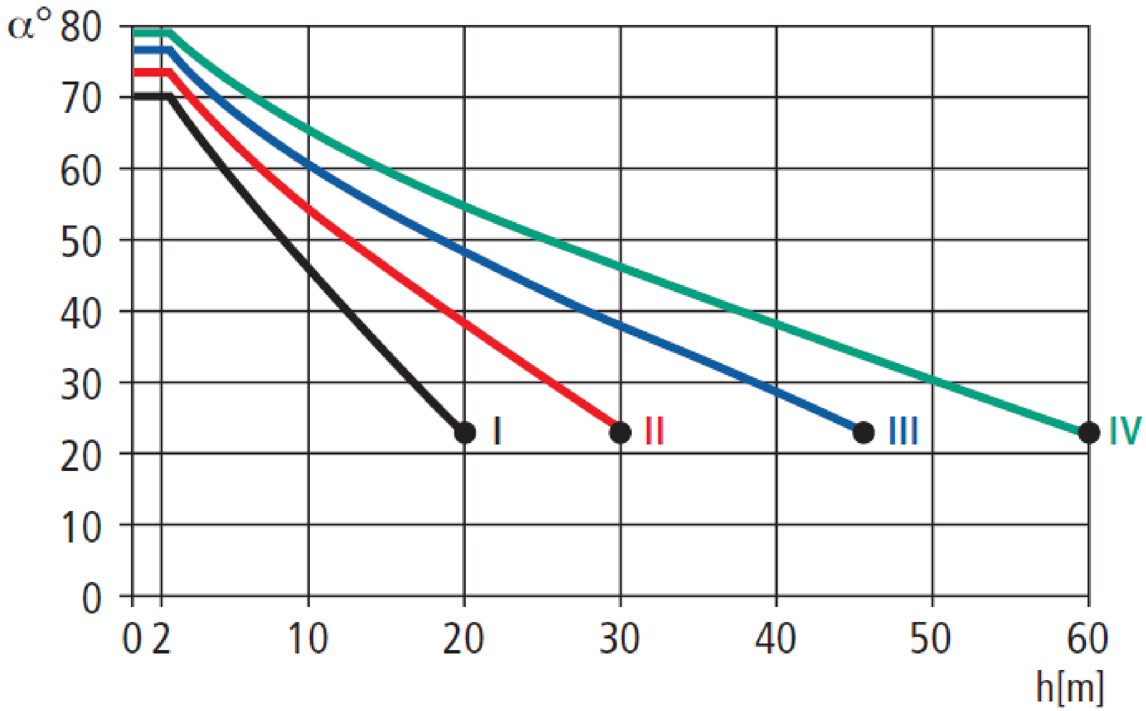


[ Note: Diagrams from IEC 62305]

# 3.3 LPS Design

## 1. Protection angle method



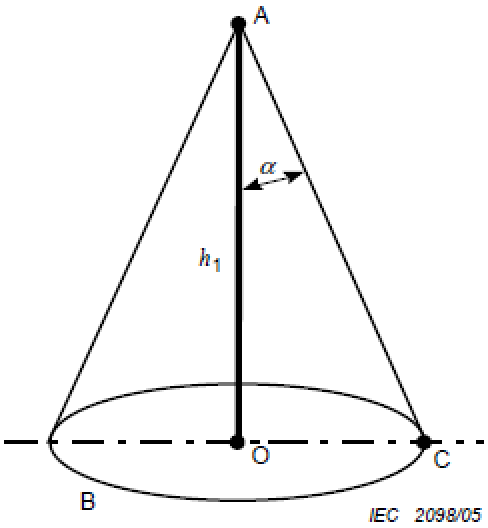

*Note 1 : Not applicable beyond the values marked with • Only rolling sphere and mesh methods apply in these cases*

*Note 2 : h is height or air-termination above the reference plane of the area to be protected.*

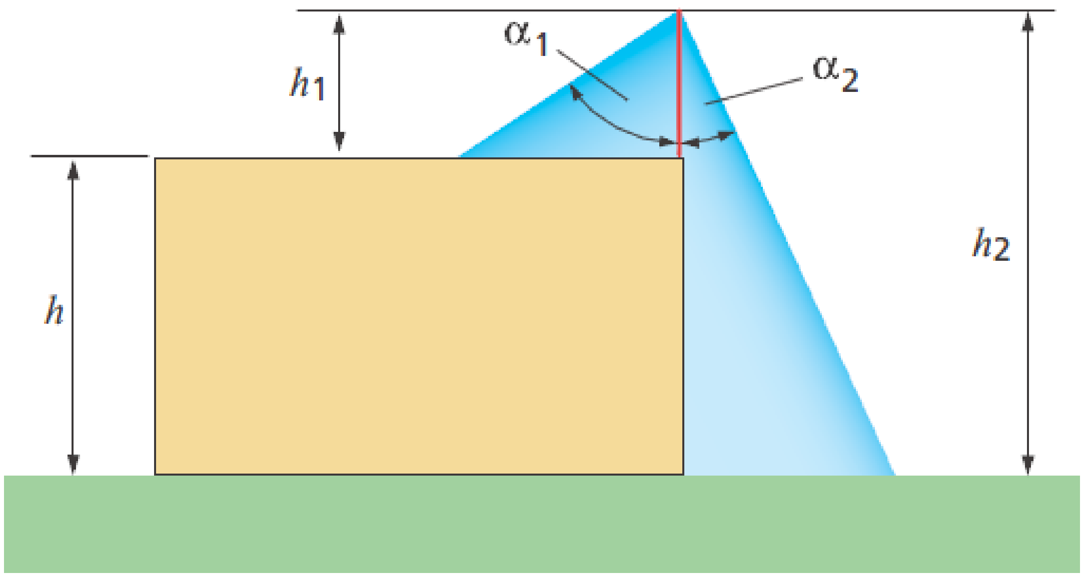
*Note 3 : The angle will not change for values of h below 2m*

# 3.3 LPS Design

## 1. Protection angle method



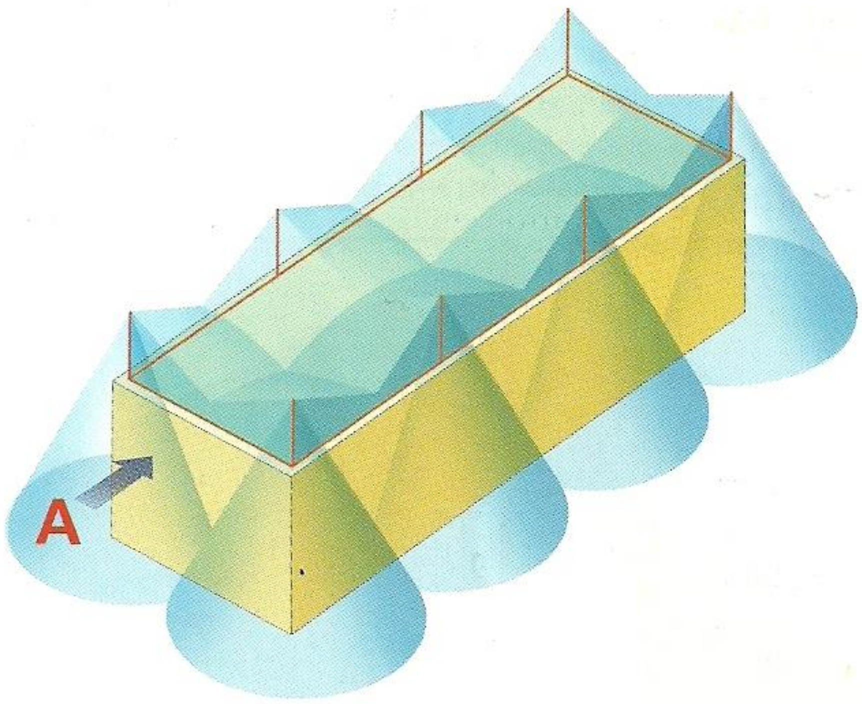

A – tip of air terminal
B – reference plane
OC – radius of protected area
$h_1$ – height of an air terminal above the reference plane of the area to be protected
$\alpha$ – protective angle according to **Table 1**

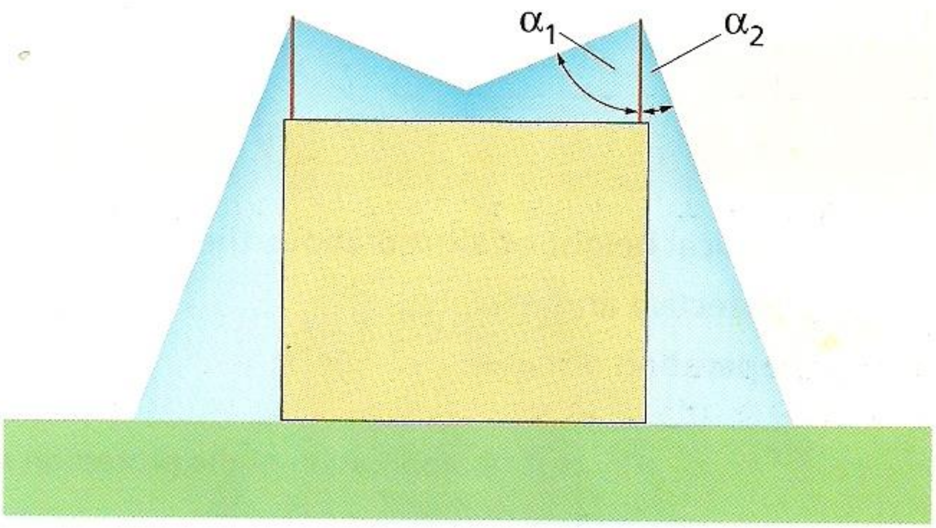



Protective angle according to Table 1 is a change to the simple $45^0$ zone of protection in BS 6651

# 3.3 LPS Design

## 1. Protection angle method



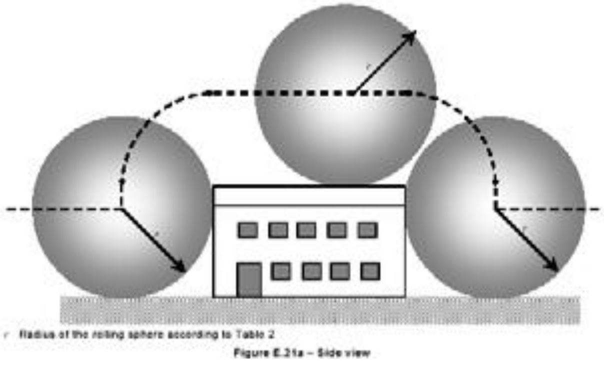



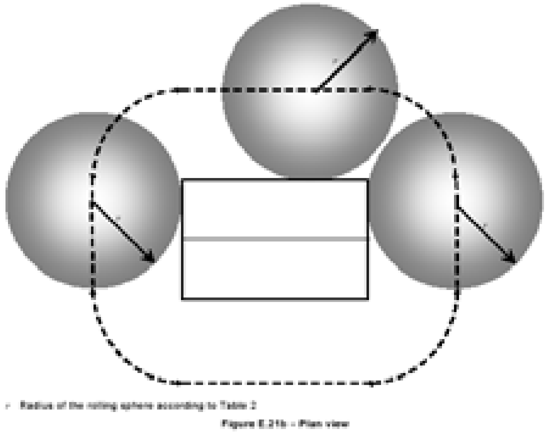

View from **A**

# 3.3 LPS Design

## 2. Rolling sphere method (RSM)

- Developed by Dr. Tibor Horvath in 1950s
- An imaginary sphere is rolled over and around the structure to be protected
- Radius of sphere equal to striking distance
- Parts of structure touched by imaginary sphere are at risk of being struck by lightning
- Applied in international standards since 1970s

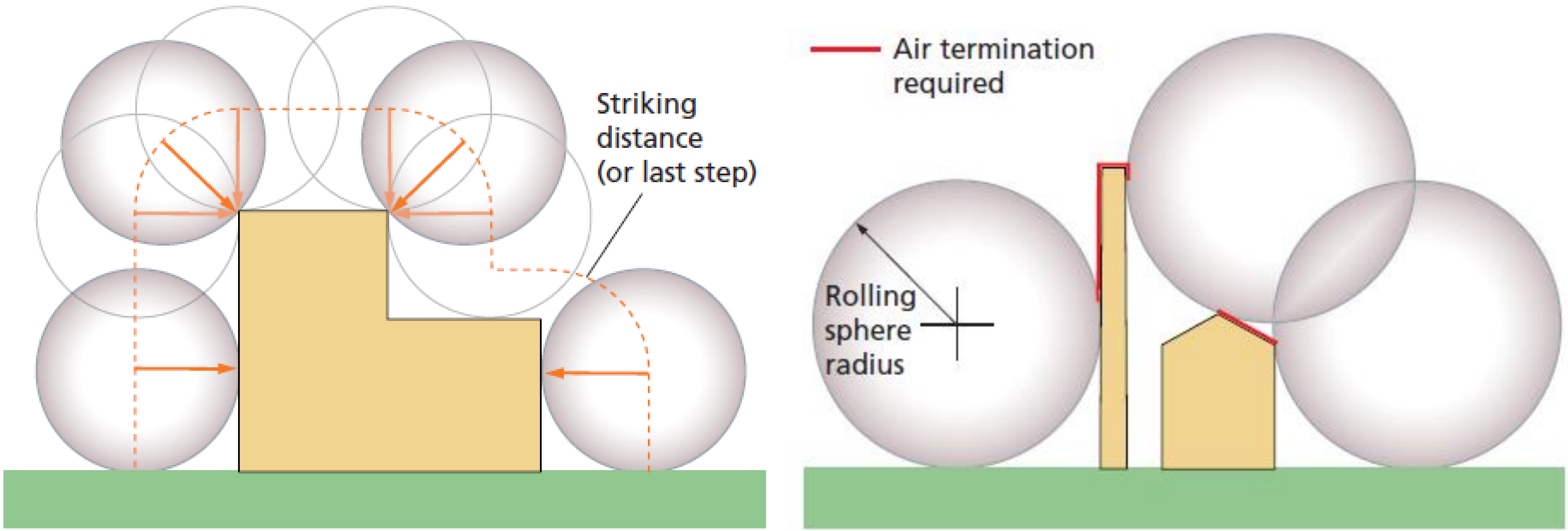




[Note: Diagrams from IEC 62305]

# 3.3 LPS Design

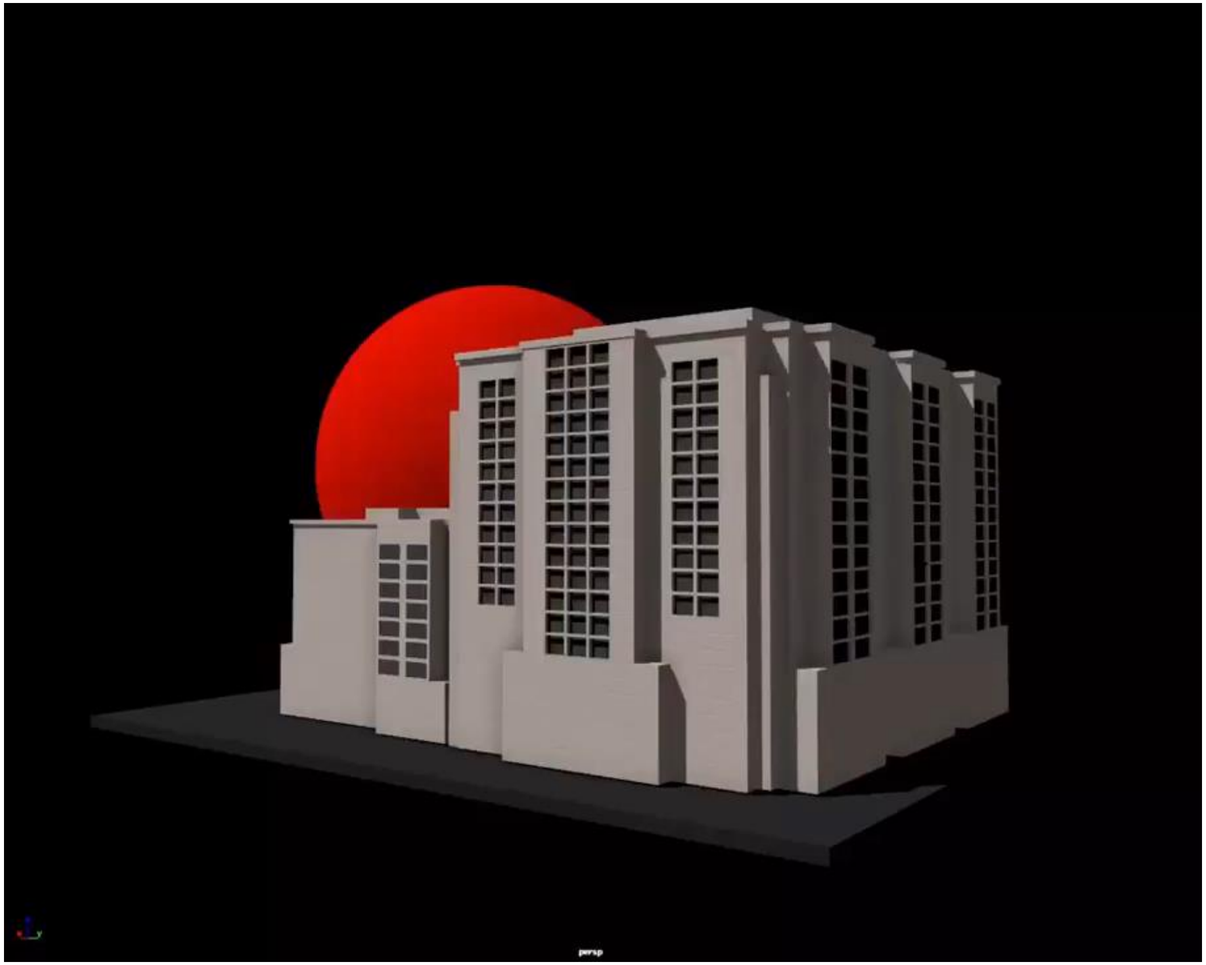
## 2. Rolling sphere method




| Class of LPS | Rolling sphere radius *r* (m) |
|---|---|
| I | 20 |
| II | 30 |
| III | 45 |
| IV | 60 |

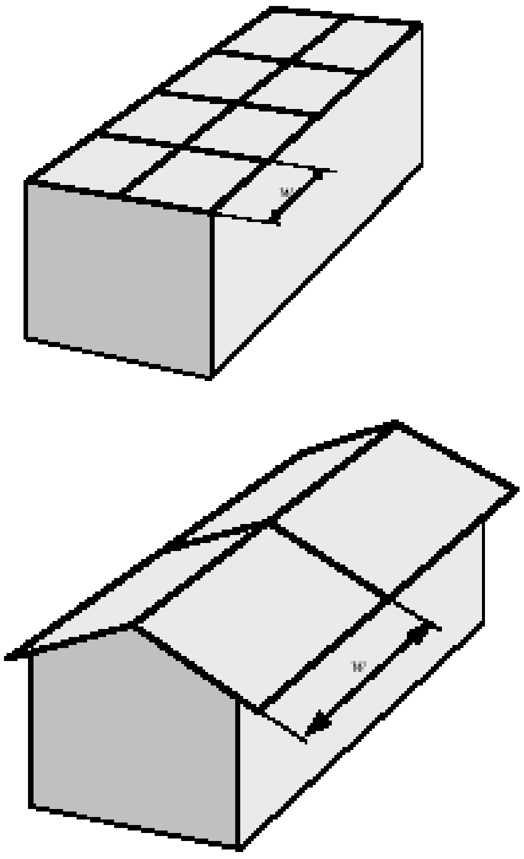
# 3.3 LPS Design

## 2. Rolling sphere method (RSM)



## 3. Mesh method (MM)

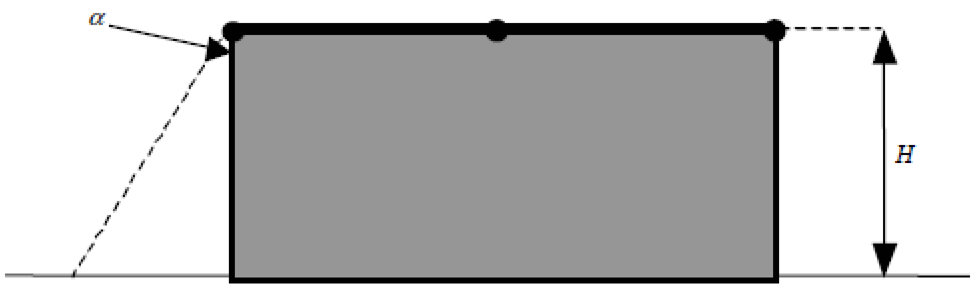
- Developed by J.C. Maxwell in 1876
- Lightning will attach to the grid instead of the structure
- Method was found to be very costly and degrade the aesthetics of the structure

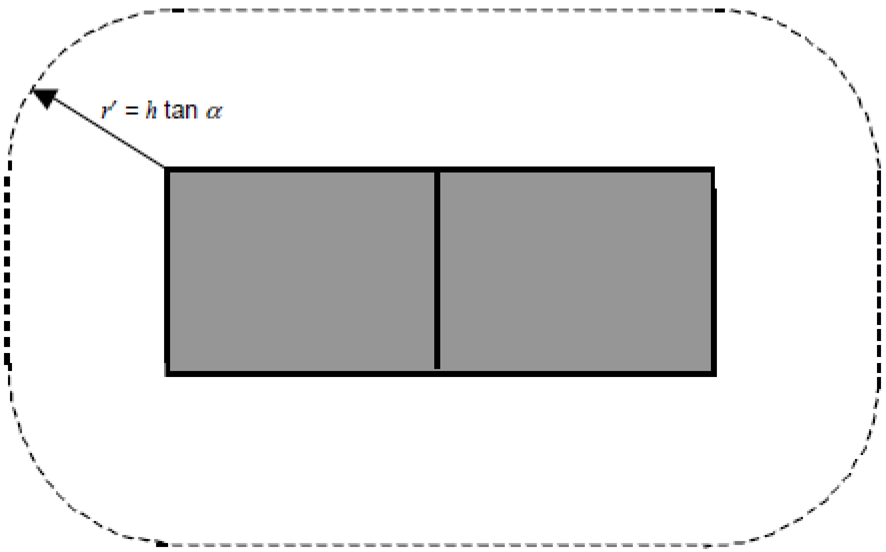


[Note: Diagrams from IEC 62305]

# 3.3 LPS Design

## 3. Mesh method




| Class of LPS | Mesh size $W$ (m) |
|---|---|
| I | 5 x 5 |
| II | 10 x 10 |
| III | 15 x 15 |
| IV | 20 x 20 |

# 3.3 LPS Design

## B. Down conductor system

- There should always be a min. of 2 down conductors distributed around the perimeter of the structure
- Down conductors should wherever possible be installed at exposed corner of the structure
- An equal spacing of the down conductors is preferred around the perimeter
- It is also good practice for the upper section of the conductor entering into the earth to be insulated. 3 mm thick PVC protecting the first 2-3 m of conductor

# 3.3 LPS Design

- Typical values of the distance between down-conductors

| Class of LPS | Typical Distances (m) |
|---|---|
| I | 10 |
| II | 10 |
| III | 15 |
| IV | 20 |

# 3.3 LPS Design

## Components

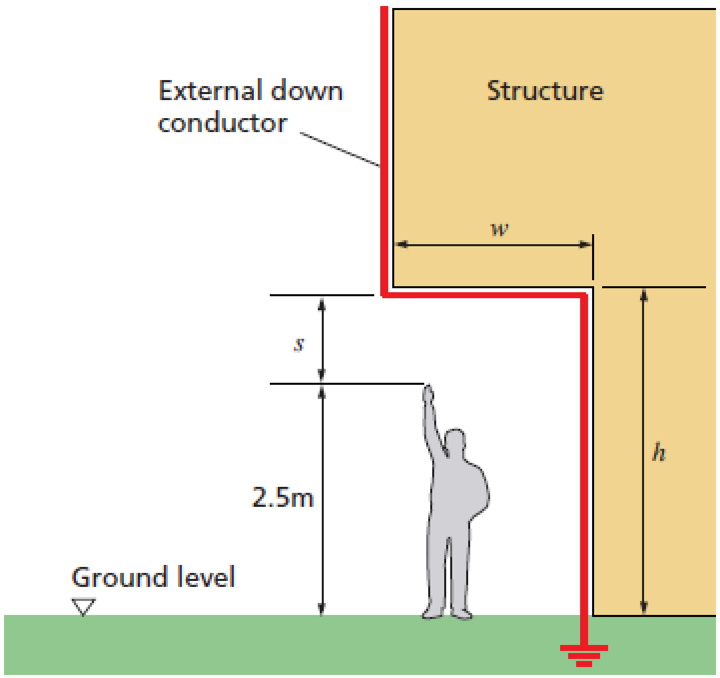
1. Copper tapes, aluminium tapes, galvanized steel wires
2. Natural down conductors (metal of the reinforced concrete, steel framework)
   - » The electrical continuity of the reinforcing bars shall be determined by electrical testing between the uppermost part and ground level
   - » The overall electrical resistance should not be greater than 0.2 Ω
   - » If this value is not achieved, or it is not practical to conduct such testing, the reinforcing steel shall not be used as a natural down-conductor

# 3.3 LPS Design

- **Structure with a cantilevered part**

# 3.3 LPS Design

## ➢ Structure with a cantilevered part




To reduce the risk of the person becoming an alternative path for the lightning current to that of the external down conductors, then the following condition should be satisfied:

$$h > 2.5 + s$$

Where:

$h$ = Height of the overhang (in metres)

$s$ = Required separation distance calculated in accordance with Section 6.3 of BS EN 62305-3

$$s = k_i \times \frac{k_c}{k_m} \times l$$

Where:

$k_i$ = 0.08 for LPS Class I (see Table 4.13 )

$k_c$ = 0.66 for 2 down conductors (see Table 4.14 and Table 4.16 )

$k_m$ = 1 for air (see Table 4.15 )

$l$ = $w + h$

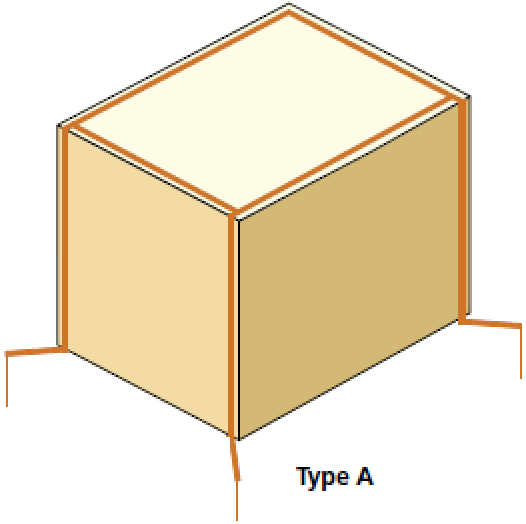
# 3.3 LPS Design

## C. Earth termination system

- A low earthing resistance is required (with an overall earth termination system of ≤ 10 Ω)
- 3 basic earth electrode arrangements:
  - Type A arrangement
  - Type B arrangement
  - Foundation earth electrodes

# 3.3 LPS Design

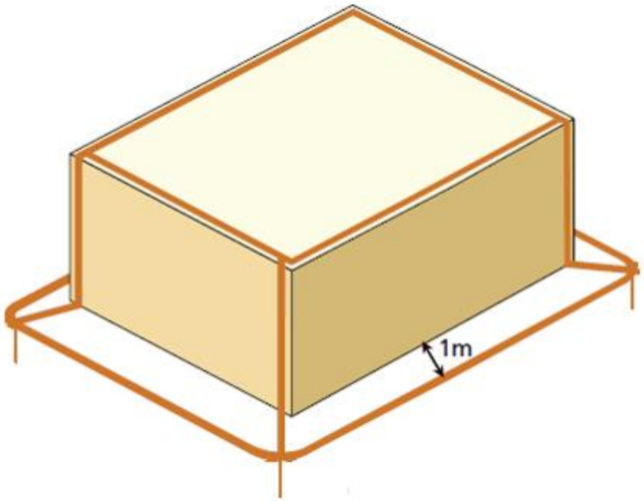
- Type A arrangement
  - Consist of vertical earth electrodes, connected to each down conductor fixed on the outside of the structure
  - The horizontal copper tapes shall be buried at a depth ≥ 0.5 m
  - If the 10 Ω value cannot be be necessary to use a Type electrode



Type A

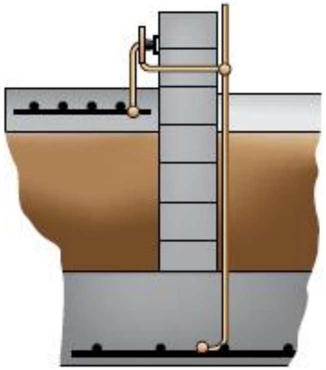
# 3.3 LPS Design

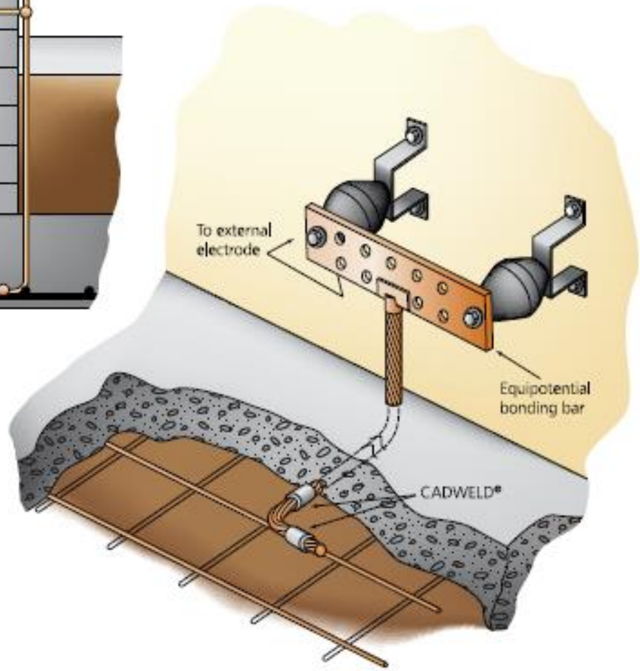
- Type B arrangement
  - Comprise a ring conductor external to the structure
  - The ring copper tapes shall be buried at a depth ≥ 0.5 m
  - Type B arrangement should preferably be buried at a distance of about 1 m around the external walls



# 3.3 LPS Design

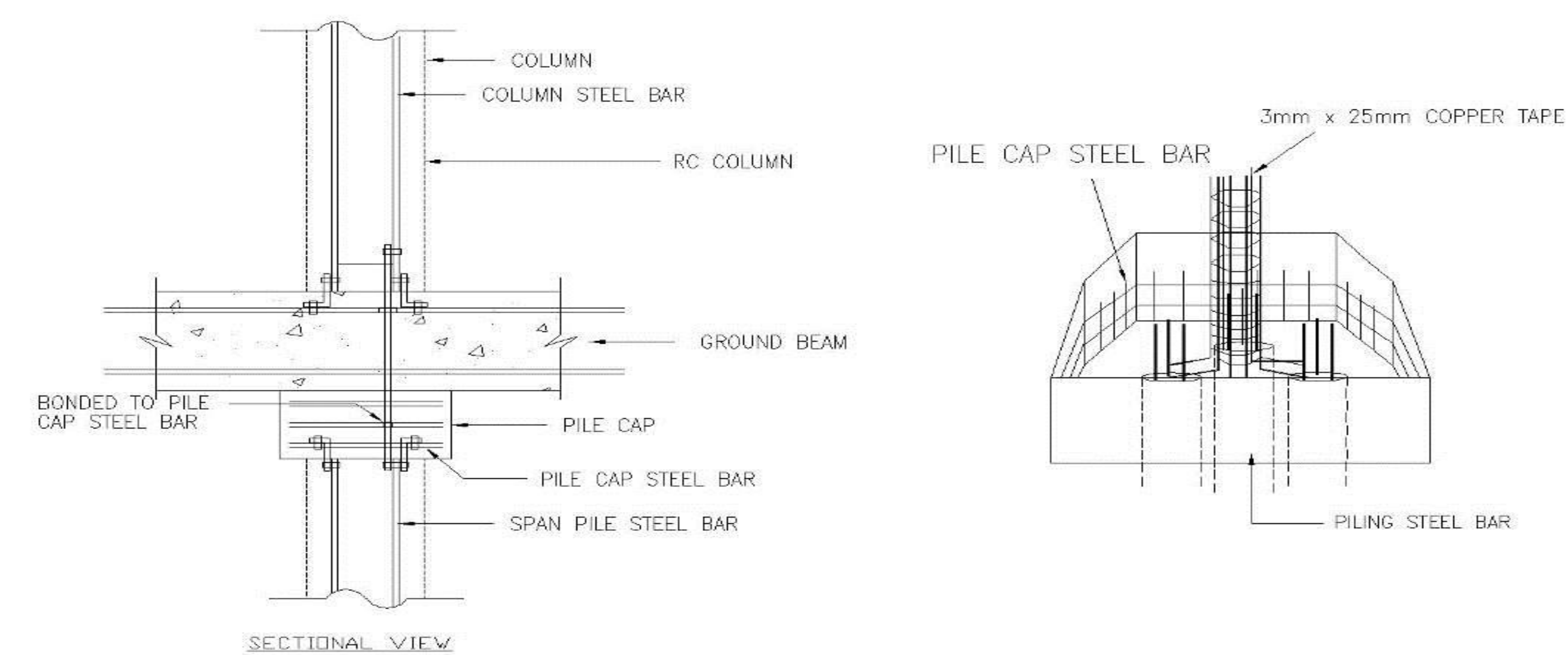
- Foundation earth electrodes
  - This is essentially a type B earthing arrangement
  - Interconnected reinforcing steel in concrete foundations





# 3.3 LPS Design

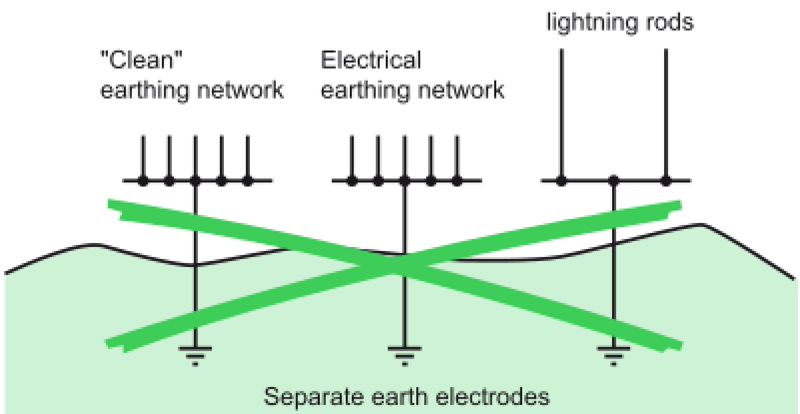
LIGHTNING PROTECTION SYSTEM DESIGN

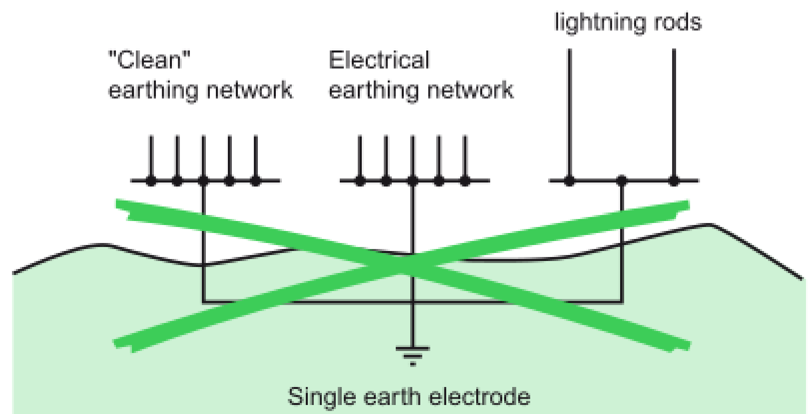


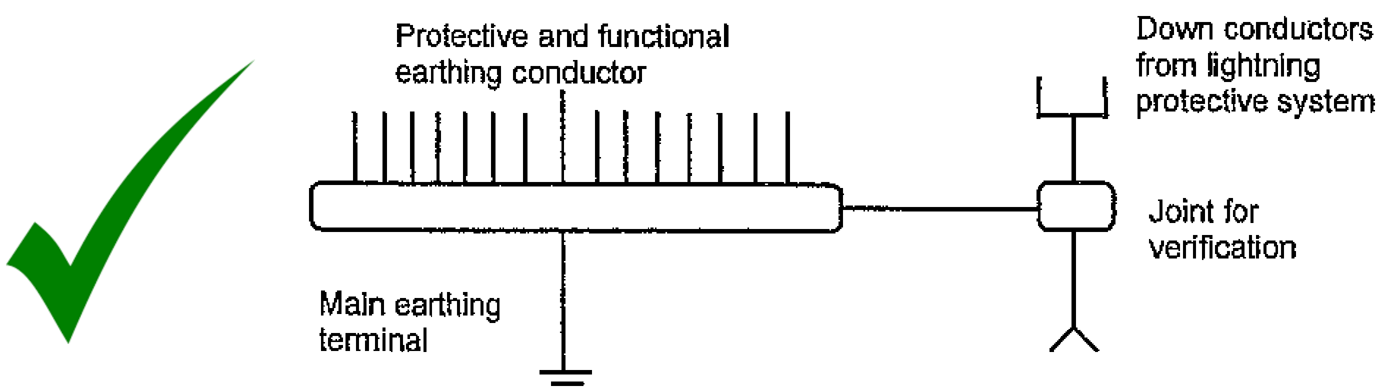

Detail connection at pile electrode

Earth Termination System : Using Steel Piles as an Earth Electrodes

# IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances



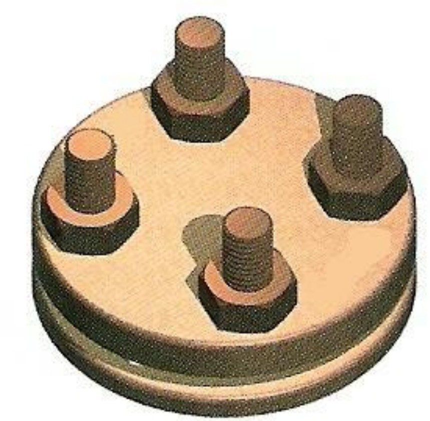



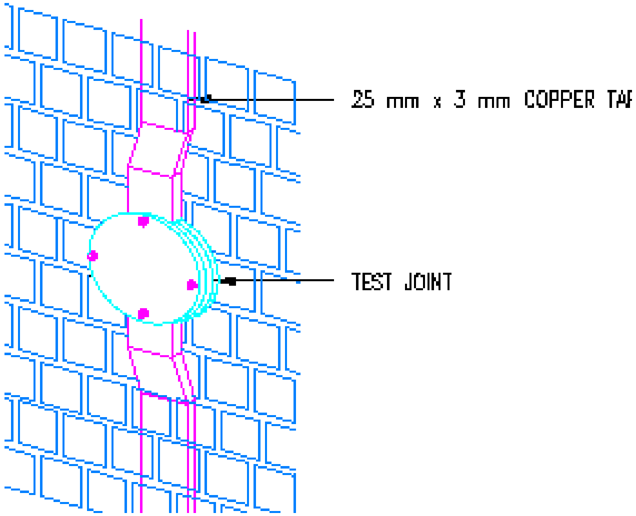

Interconnected earth electrodes

# 3.4 LPS Components

Selection of components such as rods and clamps shall conform to IEC 62561

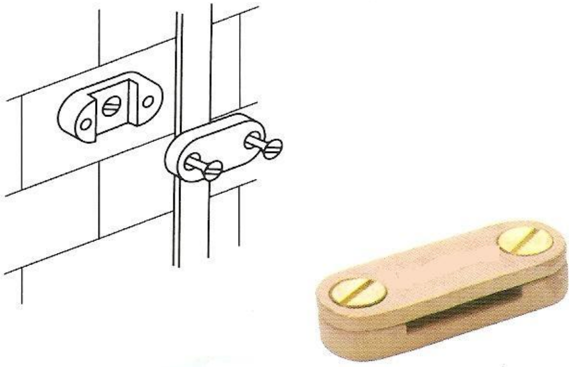
- Testing joints
  a) At each down conductor
  b) Installed at 2500 mm above ground level



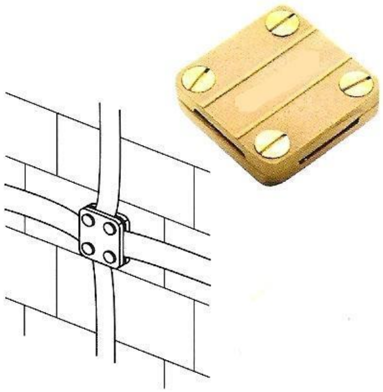


# 3.4 LPS Components

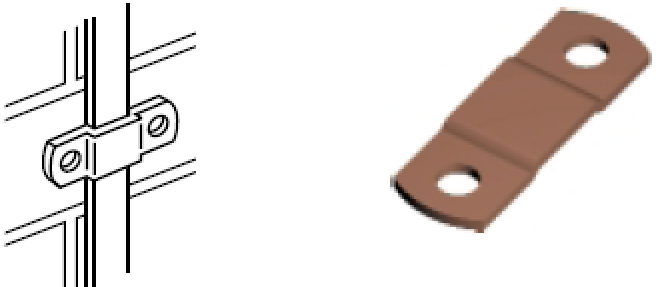
- Made of copper, naval brass or gunmetal



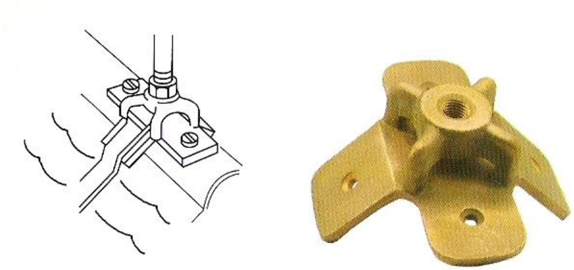
DC Tape Clip



Square Clamp



Tape Clip



Air Rod Base

# 3.4 LPS Components

**Adhesive DC tape clip**
Use on metal deck roof

# 3.5 Materials & Dimensions

## Copper versus aluminum

- Aluminium has the advantage of lower cost. Its lighter weight
- However, aluminium is less compatible with many building materials and can not be buried in the ground. Therefore, most lightning protection systems are entirely copper
- As aluminium and copper are not compatible, a bimetallic joint should be used to interconnect these two materials.

# 3.5 Materials & Dimensions

## LPS materials and conditions of use

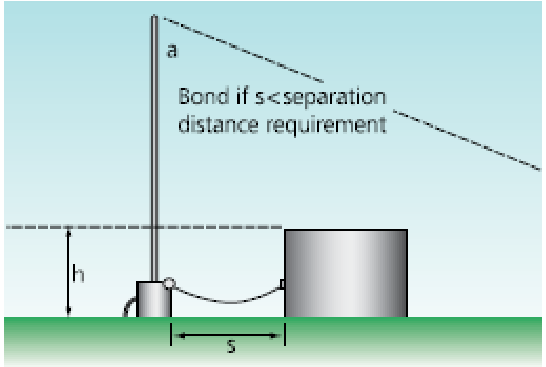
| Material | Use | | | Corrosion | | |
|---|---|---|---|---|---|---|
| | In open air | In earth | In concrete | Resistance | Increased by | May be destroyed by galvanic coupling with |
| Copper | Solid<br>Stranded | Solid<br>Stranded<br>As coating | Solid<br>Stranded<br>As coating | Good in many environments | Sulphur compounds<br>Organic materials | – |
| Hot galvanized steel | Solid<br>Stranded | Solid | Solid<br>Stranded | Acceptable in air, in concrete and in benign soil | High chlorides content | Copper |
| Stainless steel | Solid<br>Stranded | Solid<br>Stranded | Solid<br>Stranded | Good in many environments | High chlorides content | – |
| Aluminium | Solid<br>Stranded | Unsuitable | Unsuitable | Good in atmospheres containing low concentrations of sulphur and chloride | Alkaline solutions | Copper |
| Lead | Solid<br>As coating | Solid<br>As Coating | Unsuitable | Good in atmosphere with high concentration of sulphates | Acid soils | Copper<br>Stainless steel |

# 3.5 Materials & Dimensions

## Material, configuration and minimum csa of air-termination conductors, air-termination rods and down-conductors

| Material | Configuration | Minimum cross-sectional area mm² | Comments [10] |
|---|---|---|---|
| Copper | Solid tape | 50 [8] | 2 mm min. thickness |
| | Solid round [7] | 50 [8] | 8 mm diameter |
| | Stranded | 50 [8] | 1,7 mm min. diameter of each strand |
| | Solid round [3], [4] | 200 [8] | 16 mm diameter |
| Tin plated copper [1] | Solid tape | 50 [8] | 2 mm min. thickness |
| | Solid round [7] | 50 [8] | 8 mm diameter |
| | Stranded | 50 [8] | 1,7 mm min. diameter of each strand |
| Aluminium | Solid tape | 70 | 3 mm min. thickness |
| | Solid round | 50 [8] | 8 mm diameter |
| | Stranded | 50 [8] | 1,7 mm min. diameter of each strand |
| Aluminium alloy | Solid tape | 50 [8] | 2,5 mm min. thickness |
| | Solid round | 50 | 8 mm diameter |
| | Stranded | 50 [8] | 1,7 mm min. diameter of each strand |
| | Solid round [3] | 200 [8] | 16 mm diameter |
| Hot dipped galvanized steel [2] | Solid tape | 50 [8] | 2,5 mm min. thickness |
| | Solid round [9] | 50 | 8 mm diameter |
| | Stranded | 50 [8] | 1,7 mm min. diameter of each strand |
| | Solid round [3], [4], [9] | 200 [8] | 16 mm diameter |
| Stainless steel [5] | Solid tape [6] | 50 [8] | 2 mm min. thickness |
| | Solid round [6] | 50 | 8 mm diameter |
| | Stranded | 70 [8] | 1,7 mm min. diameter of each strand |
| | Solid round [3], [4] | 200 [8] | 16 mm diameter |

# 3.6 Separation Distance




$$S = k_i \frac{k_c}{k_m} l$$

Where

$k_i$ is a factor that depends upon the chosen lightning protection level.

$k_c$ is a factor that depends upon the number of down-conductors (note that a range is given for 2 or more down-conductors, and depends on the current-sharing between down-conductors).

$k_m$ is a factor that depends upon the electrical insulation material (1.0 for air, 0.5 for concrete and bricks).

$l$ is the length of down-conductor from the point being considered to the closest equipotential bonding point.

Bond if s < separation distance requirement

| Class of LPS | $k_i$ |
|---|---|
| I | 0.08 |
| II | 0.06 |
| III & IV | 0,04 |

***Table 28.*** *Separation Distance – Values of $k_i$.*

Copper – 6mm2
Aluminium – 8mm2
Steel – 16mm2

| Number of down-conductors - n | $k_c$ |
|---|---|
| 1 | 1 |
| 2 | 1 to 0.5 |
| 4 and more | 1 to 1/n |

*l* = the length of the air-termination system or down-conductor system from the point at which the separation distance shall be determined to the next point of equipotential bonding

# 3.6 Separation Distance

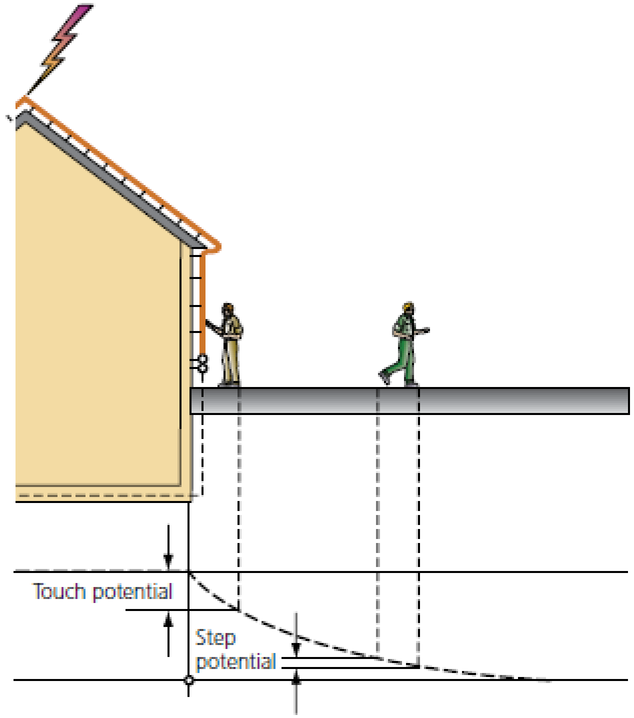

# 3.7 Protection Against Touch & Step Voltages

Main protection measures against injury to living beings due to touch and step voltages are intended to:

- reduce the dangerous current flowing through bodies by <u>insulating</u> exposed conductive parts, and/or by <u>increasing the surface soil resistivity</u>
- reduce the occurrence of dangerous touch and step voltages by <u>physical restrictions</u> and/or <u>warning notices.</u>

# 3.7 Protection Against Touch & Step Voltages

- The voltage difference exists between the hand and feet.
- The hazard is considered to be reduced if:
  - The probability of persons approaching, or duration of presence is very low – limiting access to the area can be a solution
  - Natural down-conductors (building façades) are used where extensive metal framework or steel work is interconnected
  - A surface layer with ≥ 5 k ohm.m insulating barrier such as 50 mm of asphalt (bitumen) or 150 mm of gravel (*batu kerikil*)  is used
  - The down-conductor is insulated with at least 100 kV 1.2/50 μs impulse insulation (3 mm PVC)



# 3.7 Protection Against Touch & Step Voltages

# 3.8 Site Coordination

Regular consultation between Electrical Engineers, Architects, C&S Engineers, Mechanical Engineers and Contractors is essential in order to achieve the best result

# 3.8 Site Coordination

Coordination between Test Joint and Rainwater Pipe

# 3.9 MISCONCEPTIONS ABOUT LIGHTNING

- Most common misconceptions are:
  - "Lightning always strike the highest part of a structure"
  - "Air terminals always attract lightning"
  - Metal rebars in structures attract lightning and cause more damages to structures
  - Air terminals must be positioned away from corners and edges
  - Non-conventional air terminal technologies are new and effective

*CIGRE C4 Colloquium 2010, Kuala Lumpur

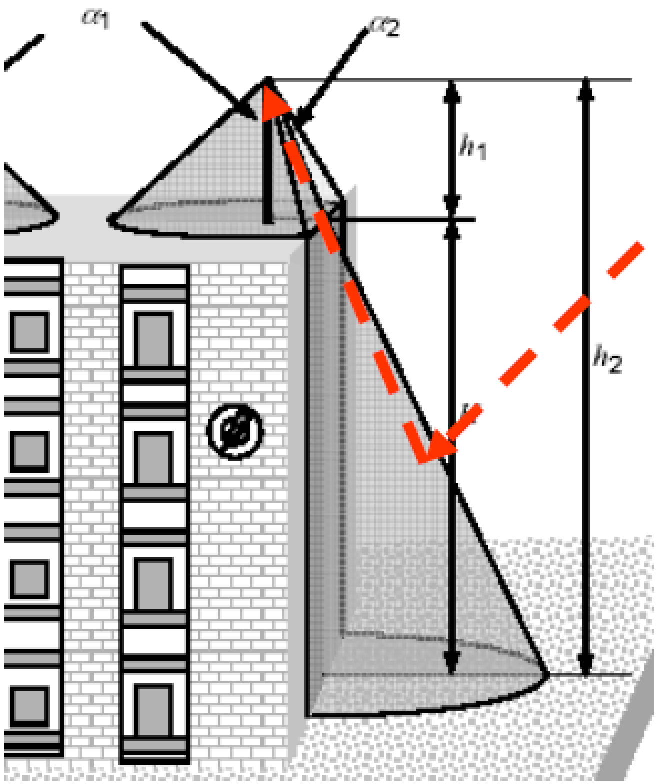
# 3.9 MISCONCEPTIONS ABOUT LIGHTNING

- Impact:
  - More engineers believed that air terminals can attract lightning
  - More engineers disregard the use of lightning protection standards
  - More engineers look for non-conventional air terminal technologies

*CIGRE C4 Colloquium 2010, Kuala Lumpur

# 3.9 MISCONCEPTIONS ABOUT LIGHTNING

- Impact:
  - "A stepped leader entering the cone will be attracted to the air terminal"

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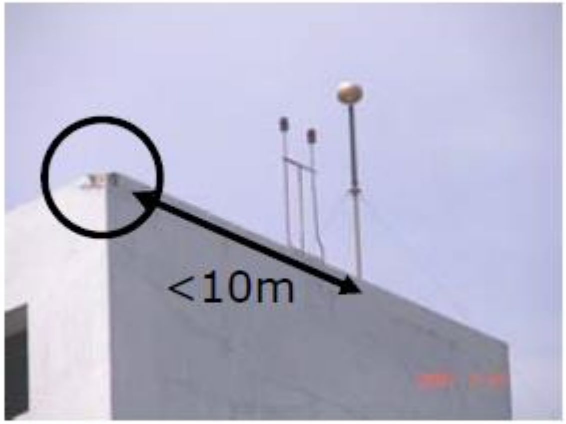
# 3.9 MISCONCEPTIONS ABOUT LIGHTNING

Misconception: “Air terminals must be positioned away from corners and edges”



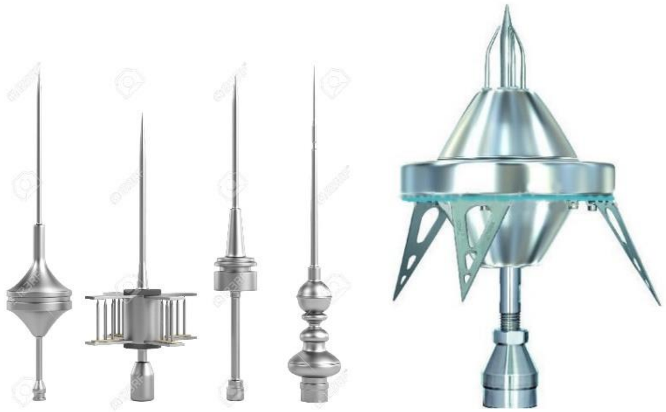

Significant number of bypasses occurred within ESE claimed zone of protection

*CIGRE C4 Colloquium 2010, Kuala Lumpur

# 3.10 Non-conventional LPS

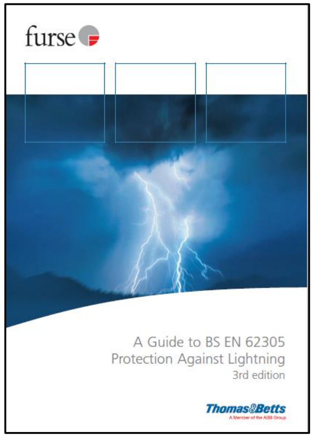
**What is not lightning protection?**

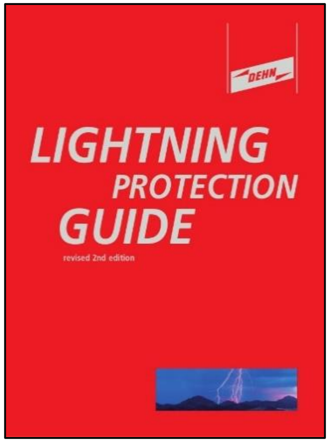
- Early Streamer Emission – ESE
  - Radioactive
  - Pulse Voltage
  - Sparking – Controlled Leader Trigger (CLT)
- Lightning Elimination
  - Dissipation Array System (DAS)
  - Charge Transfer System (CTS)
- Not allowed by
  - ST
  - NFPA
  - IEEE
  - IEC
  - US Military
  - Underwriter Laboratory (UL)



# Further Reading

- “A Guide to BS EN 62305:2006, Protection Against Lightning”, U.K: Thomas & Betts
- “Lightning Protection Guide”, 2nd Updated Edition, Germany: Dehn and Sohne, 2007
- “Panduan Sistem Perlindungan Kilat di Bangunan”: Suruhanjaya Tenaga




# Terima Kasih