BSB Circular No. 31 of 2003

Lightning Protection System

The design of lightning protection system for government buildings usually follows the British Standard BS 6651 "Code of Practice for Protection of Structures against Lightning". The standard, even though applicable to most forms and shapes of building structures, may not be adequate to cover antique buildings like temples, curved metallic structures etc. In such cases, alternative methods of lightning protection based on other national standards could be considered.

2. In this connection, a study report has been prepared to give an outline of the four common design approaches for lightning protection namely, "Franklin Rod", "Faraday Cage", "Rolling Sphere" and "Collection Volume" versus the four common national standards, namely British Standard, French Standard, Australian Standard and American National Standard. Project Officers are advised to make reference to the data contained in the report when making the choice of the lightning protection system for a specific project.

3. It should be borne in mind that lightning protection systems complying with either Standard or a combination of them are not mutually exclusive. They can be concurrently installed to protect the same building or structure against lightning strikes according to the perceived risk of the project.

4. Hard copy of the report is available in the BSB Library and soft copy can be obtained through BSB Intranet.

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STUDY REPORT ON
LIGHTNING PROTECTION SYSTEM

1. THE LIGHTNING MECHANISM

Lightning is an electrical discharge either between the opposite charged regions within a cloud or between the lower region of a cloud and the ground. The former event is a cloud-to-cloud discharge, while the latter, known as cloud-to-ground lightning or simply ground strike, is much more destructive.

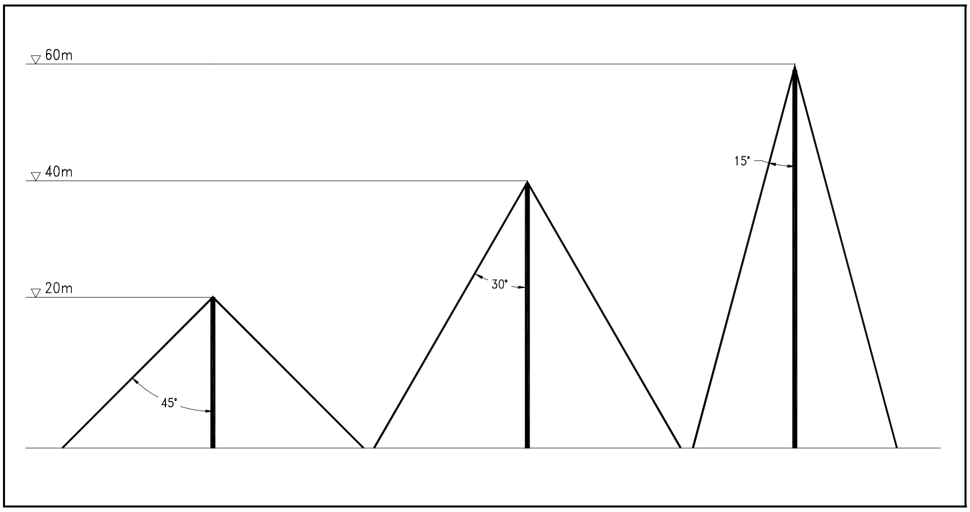
In the case of ground strike, a downward leader progresses from a thundercloud. The charge distributed along the leader causes a rapid increase in the electric field between it and the ground. When a critical field value is reached approximately 100 m from the earth, a ground point will launch an intercepting upward leader. The distance at which this occurs is known as the “Striking Distance”. Once interception occurs, the lightning path is completed and the main discharge takes place.

To prevent the buildings from a ground strike, a lightning protection system is required and there are 4 common design approaches to follow, namely,

a. Franklin Rod
b. Faraday Cage
c. Rolling Sphere
d. Collection Volume

1.1 FRANKLIN ROD

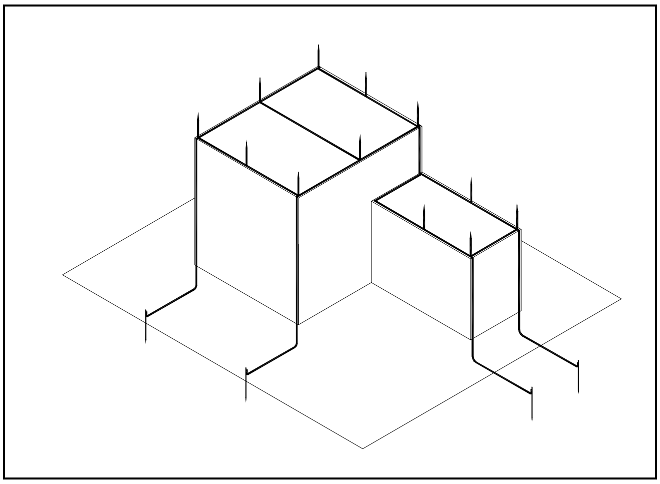
This is the oldest concept in lightning protection. The technology was developed in Year 1752 when Benjamin Franklin first started experimenting with the lightning mechanism. As shown in Figures 1 and 2, the Franklin Rod offers a cone of protection based upon its installed height above the structure. It assumes a positive angle from projections and the structural components within the cone are deemed to be protected against direct strikes.



<Figure 1> : Franklin Rod Cone of Protection

The current recommendation for applying the Cone is for structure of low to medium height (up to 60 m).

The lightning protection systems for this design method should be manufactured from materials having highly corrosion-resistive characteristic.



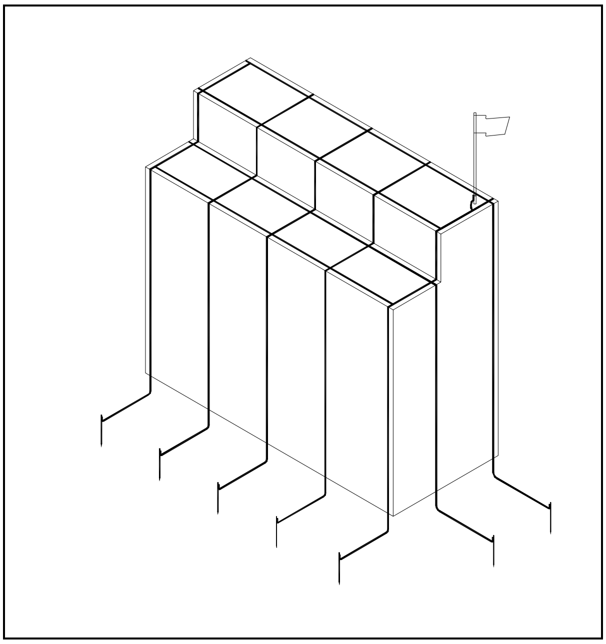
<Figure 2> :   Franklin Rod Method

BS Standard 6651:1999 specifies a few designs of lightning protection systems according to this principle.

1.2 FARADAY CAGE

The design concept of Faraday Cage is very similar to Franklin Rod.

As shown in Figure 3, the Faraday Cage comprises of horizontal air termination where external down conductors descend vertically from the air terminations. These should be horizontally bonded at set intervals. The structural steel of reinforcing bars, if bonded, may be used to conduct the lightning current. This technique, however, allows a pseudo random current flow of lightning current within the building. The vertical down conductors should be spaced at least every 30 m around the perimeter of the structure.



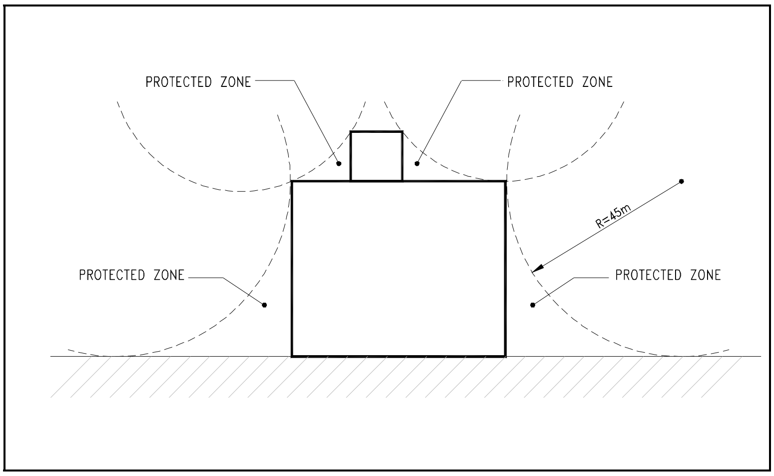
<Figure 3> : Faraday Cage Method

BS Standard 6651:1999 specifies a few designs of lightning protection systems according to this principle.

1.3 ROLLING SPHERE

The essence of Rolling Sphere method is based on an imaginary sphere, typically 45 m in radius for standard level of protection to roll over the structure. All surface contact points by this sphere are deemed to require protection against lightning strikes.

The principle of protection is shown in Figure 4:



<Figure 4> : Rolling Sphere Method

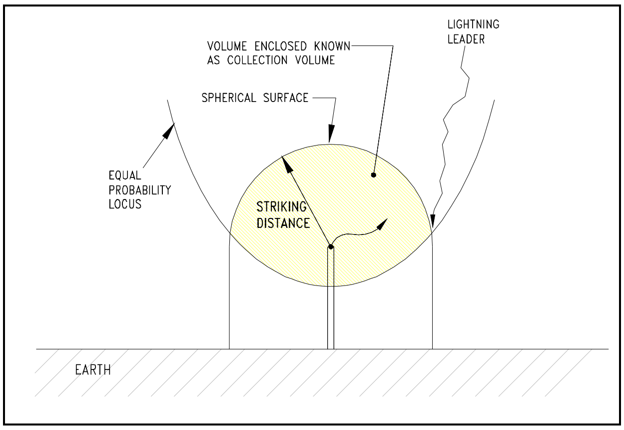
It assumes equal leader initiation ability to all touch points of the structure, irrespective of the electric field intensification created by geometric shape.

This method is commonly used in most National and International Standards such as Australian Standard AS 1768 –1991.

1.4 COLLECTION VOLUME

The design parameters of Collection Volume method include structure height, field intensification of structural projections, leader charge, site altitude and relative propagation velocities of the intercepting leaders. It is also known as Early Streamer Emission (ESE) method.

The Collection Volume method takes into account the relative velocities of the upward and downward leaders. Not all leaders which enter a striking distance hemisphere will proceed to interception. Leaders entering the outer periphery of the hemispheres are likely to continue their downward movement and to intercept a different upward leader (issuing from an alternative structure or feature on the ground). This leads to the development of a limiting parabola. The enclosed volume is known as the Collection Volume. Figure 5 shows how the velocity parabola determines the size of the collection volume.



<Figure 5> : Collection Volume Method

The Collection Volume method assumes all points on the structure are potential striking points and as such exhibit natural collection volumes. The air terminals should be so positioned that their collection volumes overlap the natural small collection volumes of the structural projections.

Collection Volume is adopted by some National Standards like French NF C 17 -102 July 1995.

2. COMMON STANDARDS

The common national standards on lightning protection systems, based on one type or a combination of the four methods described above, are listed below and their detailed comparisons are summarized in the Tables that follow.

a. British Standard - BS 6651:1999
b. French Standard - NF C 17-102 (July 1995)
c. Australian Standard - AS 1768-1991
d. American National Standard - NFPA 780 (1995 Edition)

	British Standard BS 6651:1999	**French Standard** NF C 17-102 (July 1995)	**Australian Standard** AS 1768-1991	**American National Standard** NFPA 780 (1995 Edition)
Name of the standard	Code of practice for protection of structures against lightning.	Lightning protection - Protection of structures and open areas against lightning using early streamer emission air terminals.	Lightning protection.	Standard for the installation of lightning protection systems.
Basic theory	Franklin Rod design method & Faraday Cage method (Section 15). Rolling Sphere design method (Section 15.3.4 and Appendix A5).	火 Rolling Sphere design method (Section 4.2.1). Collection Volume design method (Appendix A).	Major part of the standard is based on Rolling Sphere design method (Section 4.2.1). A short description of Collection Volume design method is included (Section A8).	Franklin Rod design method & Faraday Cage method (Section 3-11 7 K-3.4). Rolling Sphere design method (Section 3-10.3.1).
Triggering process	No special devices.	A lightning rod equipped with a system which creates the triggering advance (ΔT) of the upward leader when compared with simple rod method. (Section 1.3.10).	No special devices. Triggering devices for Collection Volume Design not mentioned.	No special devices.

	British Standard BS 6651:1999	French Standard NF C 17-102 (July 1995)	Australian Standard AS 1768-1991	American National Standard NFPA 780 (1995 Edition)
Risk factor calculation	Based on: a. Use of structure b. Type of construction c. Consequential effects d. Degree of isolation e. Type of terrain (flat/ hilly/mountain country) (Section 10.7)	Risk Assessment method based on: a. Building environment b. Type of construction c. Structure contents d. Structure occupancy e. Lightning stroke consequence (Appendix B)	Risk index based on: a. Type of structure a. Construction b. Height c. Situation d. Lightning prevalence (frequency and severity of thunderstorm) (Section 2.2.2)	Risk Assessment based on: a. Structure b. Construction c. Relative location d. Topography (type of terrain) e. Occupancy and content f. Lightning frequency isoceraunic level (frequency and severity of thunderstorm of USA) (Appendix H)
Lightning current amplitude I_{max}	200 kA (Section 4.2.1)	250 kA (Table D2)	130 kA (Table A1)	-
Rate of rise of lightning current $(di/dt)_{max}$	200 kA/ μ s (Section 4.2.1)	65 kA/ μ s (Table D10)	70 kA/ μ s (Table A1)	-
Capacitance of charge	10^{-7} F (Section 4.2.2)	-	-	-

	British Standard BS 6651:1999	French Standard NF C 17-102 (July 1995)	Australian Standard AS 1768-1991	American National Standard NFPA 780 (1995 Edition)
cell				
Total charge assumed	100 C (Section 4.2.2)	350 C (Table D3)	200 C (Table A1)	-
Lightning potential	10^9 V (or 100 MV) (Section 4.2.2)	-	-	-
Material of down conductor	Aluminum, copper and galvanized steel strip; aluminum, aluminum alloy, copper and galvanized steel rods. Stranded conductors are normally not used for down conductor or earth (Table 4).	1) Bare or tin-plated electrolytic copper. 2) 18/10-304 stainless steel. 3) A 5/L aluminum The min CSA shall be 50 mm^2. The use of insulated coaxial cable as down conductor is not permitted (Section 2.3.4).	Copper, aluminum, galvanized steel and stainless steel strip; copper, phosphor bronze, brass, aluminum brass, aluminum, aluminum bronze, galvanized steel and stainless steel rod; copper, aluminum, galvanized steel and stainless steel stranded conductors ; and galvanized material (Table 4.2 & 4.4). Insulated conductors can be considered in case of contamination by corrosion (Section 4.5.2.2 & 4.10.3).	Copper or aluminum conductor cable from AWG 13-17 (Section3-2).

	British Standard BS 6651:1999	**French Standard** NF C 17-102 (July 1995)	**Australian Standard** AS 1768-1991	**American National Standard** NFPA 780 (1995 Edition)
Down conductor arrangement	One bare down conductor for every 10/20 m of perimeter (Section 16.3). There should be at least 2 down conductors (Section 16.4) for tall structure.	One or more bare down copper conductors depending on height and projection of the building (Section 2.3.2).	One for every 30 m of perimeter. A non-metallic structure exceeding 30 m should have at least 2 down conductors (Section 4.10.1).	At least 2 down conductors. For structure exceeding 250 ft (76 m), a down conductor for each 100 ft (30 m) of the perimeter (Section 3-12.10).
Routing of the down conductor	Outside walls starting from corners; the light well and enclosed courtyards may be used but lift shaft should not be used (Section 16.5). Use of reinforced concrete structure cast in situ as down conductor is recommended (Section 16.6).	Two different main walls (Section 2.3.3).	Outside wall (Section 4.10.2). Use of reinforced concrete column is permitted (Section 4.14.1).	External wall. Use of reinforced concrete column is permitted (Section 3-12.13).

	British Standard BS 6651:1999	French Standard NF C 17-102 (July 1995)	Australian Standard AS 1768-1991	American National Standard NFPA 780 (1995 Edition)
Internal route	Down conductor may be housed in an air space provided by a non-metallic, non-combustible internal duct and taken straight down to ground level (Section 16.7).	Insulating internal ducts with area > 2000 mm^2 can be used (Section 2.3.3.1).	Inside an air space provided by a non-metallic, non-combustible internal duct (Section 4.10.2).	-
Earth termination	Max 10Ω (Section 17.1)	Max 10Ω (Section 4.3)	Max 10Ω (Section 4.12.2.2)	-
Air termination network	20m x 10m copper tape mesh.	An lightning rod equipped with a system which creates the initiation advance of the upward leader (Section 1.3.10).	Vertical rod for a spire, a single horizontal conductor as on the ridge of a small swelling, or system of horizontal conductors (Section 4.9.1). For horizontal air termination conductors, they should not be spaced more than 6 m.	Copper or aluminum conductor rod (Section 3-2) placed on ridges of pitched roofs and around the perimeter of flat or gently sloping roofs at interval not exceeding 20 ft (6m) (Section 3-11).

	British Standard BS 6651:1999	French Standard NF C 17-102 (July 1995)	Australian Standard AS 1768-1991	American National Standard NFPA 780 (1995 Edition)
Building height	Not clearly stated.	Less than 60 m (Section 1.1.1).	1) For conventional installation using rolling sphere method, less than 45 m. For building in excess of this height, direct strikes to the side of the structure above 45 m is anticipated but is considered less probable (Section 4.2.2). 2) For Collection Volume method, the height may be higher than 60 m (Section A.8.3).	Not clearly stated.
Maintenance frequency	Simple maintenance for traditional method (Section 8).	Require specialists to carry out regular checking at 2-year, 3-year and 3-year interval for protection level 1, 2 and 3 respectively under normal interval (Section 7.2).	Simple maintenance for traditional method (Section 8). No specific description for Collection Volume method.	General testing and visual check (Appendix B).

	British Standard BS 6651:1999	French Standard NF C 17-102 (July 1995)	Australian Standard AS 1768-1991	American National Standard NFPA 780 (1995 Edition)
Maintenance charge	Insignificant amount.	A few thousand dollars per annum.	Insignificant amount for Rolling Sphere method design. A few thousand dollars per annum for Collection Volume method.	Insignificant amount.
Reliability of the system	The system is simple and has been in use for long time.	In general, the system includes electronic circuit which creates the triggering advance (ΔT). System reliability is to be proved.	Simple & reliable for Rolling Sphere design method. For Collective Volume method system, it may consist of electronic circuit which creates the triggering advance (ΔT). System reliability is to be proved.	The standard was seldom adopted in HK.
Aesthetic consideration	Not good for Faraday Cage design method.	Good.	Good for Collection Volume method.	Not good due to presence of down conductor.
Typical product brand (For reference only)	Copper tapes and rods are very commonly available.	Pulsar/Indelec Lightning protection systems etc.	LPI/EF Lightning protection systems etc.	-

3. COMMENTS AND DISCUSSIONS

The design of lightning protection system for most types of government premises usually follows the British Standard BS 6651:1999 "Code of Practice for Protection of Structures against Lightning". The standard is developed from Franklin Rod and Faraday Cage methods and is very comprehensive for implementation of lightning protection system for buildings.

The French Standard NF C 17-102 (July 1995) is a standard specifically developed from the Collection Volume and Rolling Sphere methods. The Early Streamer Emission systems which base on this standard can preserve a better outlook of a building but is more expensive for maintenance. Many useful data and design details have been included into the standard.

The Australian Standard AS 1768-1991 is alike of the French standard but with variations in the system design and assumptions in the amplitude of the lightning current. This may be attributable to the geographical differences between continents of Europe and Australia.

The American National Standard NFPA 780 (1995 Edition) is for traditional lightning system only. Its comprehensiveness is considered not sufficient for use as a design tool. For example, data of the design criteria such as maximum amplitude and rate of rise of lightning current etc. are not explicitly stated out. This standard is therefore not commonly quoted by the local designers.

4. RECOMMENDATION

In general, the design lightning protection systems based on the British Standard is prevailing for most types of buildings with regular shapes and roof structure. When the following scenarios are encountered, it is also advisable to consider using appropriate types of systems in compliance with French Standard or Australian Standard:

a. Some special buildings, e.g. antique buildings like temples, where the use of the conventional lightning protection system may have adverse effect on their appearance.

b. Open areas such as football pitches & swimming pools if requested where installation of conventional lightning protection system is not practicable.

c. Tall metallic structures like antenna towers where traditional lightning protection system is practically not feasible.

d. Buildings with special aesthetic outlook.

It should be borne in mind that lightning protection systems complying with either British Standard, French Standard, Australian Standard or a combination of them are not mutually exclusive. They can be concurrently installed to protect the same building or structure against lightning strikes according to the perceived risk of the project.

5. REFERENCE

Paper on "Active Lightning Protection Systems and A Means of Calculating the Protective Area" by A.J. Surtees, Technical Marketing Manager – Facility Electrical Protection Division of ERICO Inc., Cleveland, OHIO, USA.