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A STUDY OF NON-CONVENTIONAL AIR TERMINALS AND STRICKEN POINTS IN A HIGH THUNDERSTORM REGION.

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Abstract: The widespread use of the non-conventional air terminals in Malaysia, in particular the Early Streamer Emission (ESE) type, has resulted in many buildings being struck by lightning. The study includes the various types of ESE air terminal that was widely used on new buildings in the 1990s. The study also reveals the pattern of lightning strikes on buildings of various shapes and sizes. This can lead to improved methods of protecting selected parts of buildings from the damaging effects of lightning and the prevention of lightning strikes on roof mounted equipment.

Keywords: Early Streamer Emission, Stricken Points.

1. INTRODUCTION

Kuala Lumpur, the capital city of Malaysia, is located in a very high thunderstorm region (TD>200). The city can be considered as a natural test bed for evaluating the performance of the various makes of air terminals and for evaluating the various methods of lightning protection designs. Field tests that would have required several decades to produce the desired results in a temperate climate could be done in about a fraction of the time.

It is possible to confirm the reliability of any air terminal or lightning protection system design under this intense natural lightning condition simply by studying a large population of the installed devices and systems on real buildings over several years.

One of the major results from this study is the performance of the air terminals using the Early Streamer Emission (ESE) technology. About a dozen different type of ESE air terminals were and are being used on buildings throughout the country over the last decade resulting in many of these building being struck by lightning.

The evidence obtained from this study confirmed that the ESE technology is unreliable since it has failed to prevent lightning from striking the buildings.

The prevalence of lightning strikes on buildings of various shapes and sizes also revealed valuable information on the behavior of the lightning discharge and the ways to intercept them. The data gathered can be developed into guidelines for the protection of these buildings and equipment installed on them.

2. LONG TERM PERFORMANCE OF THE ESE AIR TERMINALS UNDER NATURAL LIGHTNING CONDITIONS.

Several types of ESE air terminals have been subjected to a number of laboratory and field tests to compare them against the conventional air terminal [1][2]. Tests using rocket triggered lightning resulted in a different type of lightning discharge which does not represent the natural lightning discharges.

There has not been any concerted effort to test these air terminals using natural lightning discharges since the sparse and random nature of lightning makes it virtually impossible to be used in a controlled experiment. The only viable alternative is to study a large number of these air terminals under their designed configurations (i.e. being installed on actual buildings by their vendors) in a naturally high thunderstorm region.

Such a study has been conducted in Kuala Lumpur and surrounding areas for the last decade where dozens of new buildings were equipped with the ESE air terminals. The time period to detect the first stricken point can take just a few months to a few years.

In the study, many of these buildings had progressively accumulated a number of stricken points over the years of observation indicating that the ESE air terminals had failed to protect the building against direct lightning discharges.

In a few cases, the buildings were struck several times by lightning within a period of several months although they were expected to be struck by lightning at the rate of once or twice per year. It is estimated that about 80% of the buildings over 60m in height had been struck by lightning at least once within three years after they were installed with the ESE air terminal.

2.1 ESE air terminal failures with pre-strike and post strike photographs.

This study was conducted since the early 1990s and involved all makes and models of the ESE technology. There are more than a dozen different models of the ESE air terminals being used throughout Malaysia. The following two case studies are representative of the failure of all models of the ESE air terminals.

2.1.1 Case Study No.1.

This case study was conducted on a training academy of Malaysia Airline, the national carrier company. The building measures approximately 20m high, 20m wide and 45m long and was expected to be struck by lightning at the rate of once in every two years. A single ESE air terminal was installed on the roof of the building located near the center of the building (Figure 1).

A photograph of the new building was taken in 1995 that show the air terminal and the yet-to-be damaged building part that was identified as having a high probability of being struck by lightning. Another photograph was taken in 1999 when the stricken point was observed, indicating a lightning strike had occurred (Figure 2). Another stricken point was observed to have occurred earlier at another part of the building.

2.1.2 Case study No. 2.

This case study was conducted on a residential apartment building, the Villa Putra Apartments. The building measures approximately 110m high, 20m wide and 40m long and was expected to be struck by lightning at the rate of one to two times a year.

The building was completed in 1995 and installed with two ESE air terminals. The first stricken point was observed in 1996 followed by another in 1997. This was followed by a year long drought in 1998.

Five new stricken points were discovered during the second half of 1999 after a spate of intense thunderstorms that broke out from June to August (Figures 3 and 4).

The case studies mentioned above are a part of more than two dozen cases of ESE air terminal failures recorded in this way i.e. complete with pre-strike and post-strike photographs. A sample of these case studies had been submitted to the National Fire Protection Association in response to their call for information on the ESE technology [3].

3. PATTERNS OF STRICKEN POINTS ON THE VARIOUS PARTS OF STRUCTURES.

The size of the stricken point is dependent on the characteristics of the lightning discharge and the properties of the material. However, the location of the stricken point is not random but followed a very regular pattern.

An analysis of the stricken points revealed a regular pattern in their location on the structure. By comparing the shape and location of the various damages of similar nature, it is possible to design simple air terminations to fit the high risk parts and thereby afford a better protection for the building.

Figure 1. A picture of the Malaysia Airline building taken in 1995 showing the ESE air terminal (left).

Figure 2. The same building photographed some years later showing the stricken point (top right).

Figure 3. A photograph of the Villa Putra apartment taken in February 1999 showing the undamaged upper level roof. Two stricken points had been observed on two other lower level roofs.

Figure 4. The same building photographed six months later showing two (out of five) new stricken points.

This information could also be used to formulate guidelines for the safe installation of plant and equipment on the roof. By being able to identify these high risk locations, the system engineer can determine a safe location for the installation of the equipment and prevent unnecessary damages.

3.1 Stricken points on slim structure.

Most slim structures (such as spires, minarets, roof mounted emblems etc.) that were observed to have been struck by lightning exhibited stricken points that were below the pinnacle (Figure 5). This indicates that the air terminal installation for these structures must anticipate a strike to the entire structure and not just at the highest point only.

The shielding effect of a corona discharge on the pinnacle could offer one explanation for lightning discharges to strike the fabric below slim structures [4].

3.2 Stricken points on facades.

Facades built on the roofs of buildings are highly prone to be struck by lightning since they are normally built on the edge of the roof where the risk is high. Most of the stricken points seemed to be located at the highest point on the facades, the location that has the highest risk of being struck by lightning (Figure 6). Hence every façade should have an air terminal installed at its highest point.

3.3 Stricken points on connected buildings.

In a row of connected buildings, such as terraced low level apartments, homes and shops, it has been observed that the units at the ends of the row are more prone to be struck by lightning (Figure 7).

Most of the stricken points seemed to be located on the highest point of the last unit in the row.

3.4 Stricken points on curved and straight edged features.

The occurrence of stricken points on curved and edged features is very low compared to those that occur at sharp pointed features. However, their occurrence in the vicinity of other sharp pointed features raises the question as to how far the effect of electric field intensification has on the final path of the downward leader.

This effect is supposed to make sharp features have an advantage over other features in attracting lightning. Hence more investigation is required in this matter to determine the influence of electric field enhancement on the lightning leader.

In the observed cases, the stricken point on the curved feature may be higher, on the same level as or lower than the sharp feature. Some of the stricken points have even been observed to be located close to and below an air terminal that operate on the basis of electric field enhancement.

Figure 5. A lightning damaged spire on top of a dome. Note the stricken point below the pinnacle.

Figure 6. A close-up photograph of a severely damaged façade of a commercial building. In this case, the stricken point appears to be on the slant side of the facade instead of on the pinnacle.

Figure 7. Two adjacent residential apartments with similar stricken points on the roofs.

Figure 8. A stricken point located on the curved portion of the roof (right) with an undamaged sharp corner nearby (left).

Figure 9. A stricken point on the straight edge of the roof (far right). Inset: A close up of the stricken point.

4. THE USE OF METAL CAPS AS AN AIR TERMINAL.

Since most stricken points are located at and/or very near to the pointed corners of the buildings, it is apparent that the buildings can be economically and effectively protected by installing the air terminals at these locations.

It has been observed that the use of the Franklin rods at the corners of the tall buildings had resulted in lightning striking on the building fabric adjacent to the rod or some distance below the rod. This problem can be easily and economically solved by installing sheet metal caps on the high risk locations in addition to or in place of the Franklin rod.

It has been observed that where sheet metal caps were extensively used as an air terminal on top of parapet walls, such as that practiced in Japan, no visible sign of lightning damages could be found on the building fabric. The use of the sheet metal caps has an advantage over the Franklin rods since they cover a wider area of the high risk locations and hence are able to intercept the lightning discharge before it attach itself to the building fabric.

For small and low buildings, the recommended dimensions of these caps should extend at least 0.3m from the apex of the corners. These caps can then be grounded using down conductors or connected to the building reinforcement bars where applicable.

For very tall buildings (i.e. >60m), the recommended dimension of the caps to be installed at the extreme corners of the roof should be at least 1.0m for the horizontal dimensions and 2.0m for the vertical dimension (see Figure 10). This is to cater to the observed stricken points below the corner edges of tall buildings. The caps can then be grounded to the building reinforcement bars located near the corner of the buildings.

For the protection of the remaining parts of the roof, it is recommended that horizontal air terminations (i.e. copper strips or L-shape cross-sectioned metal panels) be installed at the very edge of the roof or parapet wall and bonded to the metal panels at the corners (see example as shown in Figures 11 and 12). This is because most of the stricken points observed occur on the outer edges of the building.

5. CONCLUSIONS

The location of Kuala Lumpur in a very high thunderstorm activity region makes it an ideal testing ground for the proper evaluation of all types of air terminals and lightning protection design techniques.

The observed bypasses of the ESE air terminals show that the enhanced protection that is claimed for these air terminals is unfounded. The very high thunderstorm activity in this region coupled with the widespread use of the ESE air terminals has helped to reduce the observation period from tens of years to only a couple of years to obtain the results. Therefore, the ESE technology should not be used for the protection of buildings and structures, especially in an area of very high thunderstorm activity.

The study of stricken points also reveal a pattern of damages for various shapes of building parts and locations. This information will further improve the protection for any building by zooming in on the actual parts and locations that are at higher risk of being struck by lightning.

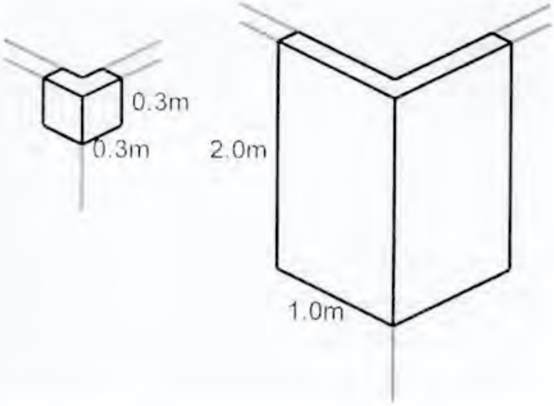

Figure 10. Recommended dimensions of the sheet metal caps for the protection of corner structures of low buildings (left) and tall buildings (right).

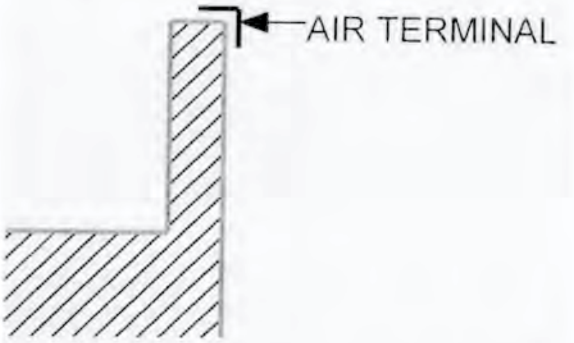

Figure 11. L-shape cross-section of air terminal for the protection of parapet walls and roof edges.

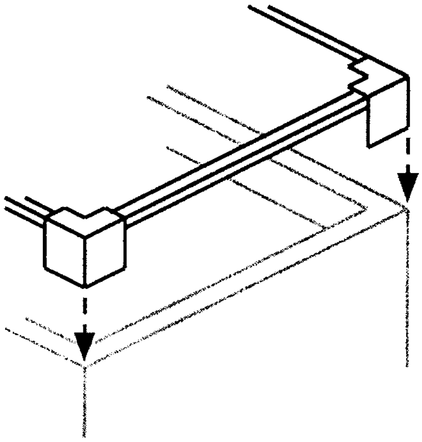

Figure 12. An example of parapet wall sheet metal caps used with L-shape cross-sectioned conductors to protect the building fabric from being struck by lightning.

This information will assist the lightning protection engineer in designing and implementing solutions that are practical, effective and economical in intercepting the lightning strikes. It will also assist engineers from other fields in determining a safe location on the roof to install plant and equipment such as air conditioning units, antennas, mobile telecommunication systems etc.

6. REFERENCES

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