ISSUE: 2023, No. 01

AVI Science, Technology, and Innovation Series

Cambodia | 21 November 2023

Design and Construction of Overseas Independent Lightning Protection and Grounding System according to IEC Standards

Liao Hongjing,
Gan Chongpao,
Liu Hao,
Wang Xisheng,
Leng Ke

ABSTRACT

This article takes the Project of Foreign Trade Bank of Cambodia as an example to introduce the design of independent lightning protection and grounding system according to the requirements of IEC standards. It introduces in detail the grounding hole and grounding rod practices, test box, downlead and grounding connection point practices, roofing lightning protection net and lightning arrester practices, grounding strip and downlead welding, and other key points of construction process. Therefore, the article may provide references for the bidding, design, construction, and operation of subsequent similar projects.

KEY WORDS

Super high-rise building; IEC standards; independent lightning protection and grounding system; lightning protection net; curtain wall lightning protection system; independent grounding system

1. Introduction: Project Overview

The Project of Foreign Trade Bank of Cambodia is located in Phnom Penh, the capital of Cambodia, with the floor area of about 76,000㎡ and the building height of 157 m. It is the headquarters of the World Trade Bank in Cambodia and also the landmark building of its capital. It is a project, in which multiple countries have participated. The design team of the project is Meinhardt (Singapore) Pte Ltd.; the management company is Bureau Veritas (BV); and the construction team is China State Construction Engineering Corporation (CSCEC). The project intends to construct the first Super-A Class financial office building of Chinese construction enterprises in Cambodia.

The design standards of the project refer to the British Building Standards (BS) and International Electrotechnical Commission (IEC) standards. Because Cambodia belongs to a

The authors work at China Construction Third Engineering Bureau Group Co., LTD, Wuhan Hubei, 430000.

region with frequent thunderstorms, and the building is also very high, the building safety requirements must be high, and the design and construction of its lightning and grounding works are of great significance (Kim et al. 2014).

Besides the compliance with IEC standards, this project considers the local thunderstorm weather characteristics and the lightning protection practices of similar high-rise buildings. Furthermore, it comprehensively considers the design of lightning protection work, explores the reasonable detailed design scheme, and optimises the construction process flow to guarantee the safety performance of the building.

2. Design of Lightning Protection and Grounding System

2.1 Executive Standards and Process Control of Lightning Design

2.1.1 Executive Standards

The project's design and construction executes the latest version of BS and IEC standards, including the International Building Lightning Protection and Construction Code (IEC 62305), International Lighting Protection System Materials Requirements (IEC 62561), Singapore Lightning Protection Design Code (SS.555), and British Grounding System Design Code (BS 7430).

2.1.2 QA/QC Document Requirements and Process Control

The priority sequence of documents is as follows: Technical documents provided by the design consultants, local regulations, construction documents, and requirements of other standards. The process control sequence is as follows: Submission of materials for approval, design and submission of drawings for approval according to the submitted materials, submission of construction schemes for approval, mobilisation and acceptance of materials according to the materials and drawings, handling of construction permits for divisional and sub-divisional projects, and acceptance of divisional and sub-divisional projects. According to the results of quality record, the qualified products are required to pass the test, and the rejected products shall be rectified, re-accepted, and finally tested.

2.2 Lightning Protection Design Requirements

2.2.1 Design of Lightning Arrester

All lightning arresters must adopt the special accessories to be connected with transverse conductors and grounded with the earth via the downlead. The conductor shall consist of the 25mm×3mm copper strip. Except for otherwise stated, they shall conform to the requirements of EN 13601 and IEC 62561-2. Besides, they shall be firmly fixed into the building structures, and the transverse conductors shall maintain the continuous length (Suryadi and Sudjono 2020).

All connecting conductors are bonded onto the aluminium coating walls with the dual metal clamps, which shall conform to the requirements of IEC 62561-1. If the roofs or equipment are made from steel, the required minimum thickness (subject to the direct lightning strike without breakdown) shall be no less than 4mm. If the thickness does not conform to the requirements, it is required to install the copper lightning protection net or independent lightning arrester on the roof.

The special clamp with the bottom strips shall be used on the masonry wall and set as expansion type. The copper lightning protection materials shall not be installed on the surface of aluminium roof, wall plates or other aluminium products. The fixed spacing of all roof conductors shall not exceed 900mm, and the overall layout and arrangements of the lightning arresters shall be marked on the drawings of buildings with different roof heights. It must be guaranteed that the entire lightning arrester system will cover the entire roof area, and it must also guarantee the absolute electrical continuity on the general route.

2.2.2 Downlead Design

The downlead or grounding electrode used between roof conductors shall be the oxygen free high conductivity copper with the purity of 99.99% and in conformity to the requirements of EN 13601. Besides, it shall be firmly fixed on the building structure and the spacing of supports shall not exceed 600mm. When the conductor penetrates through the roof, the holes shall be effectively sealed. The special sealant shall be used for waterproof treatment and approved by the lightning protection experts. All exposed metals shall be connected to the downlead, including, but not limited to, the chilled water pipe, hydrant pipe, tap water pipe, sewer pipe, cable tray and pipe, and components through which the other metals penetrate the buildings.

2.2.3 Joint and Connection Method

Try to reduce the joints. In case of any joint is needed, at least two fixed points shall be set at both ends of the joint. The fixed accessories of the joint shall be provided by the supplier, instead of being self-manufactured by the subcontractors. The copper connection shall be made through the exothermic welding of professional moulds.

2.2.4 Setting of Test Points

The test points shall be set for each downlead and placed at the location where it is convenient to carry out the test. The height of test point of exposed downlead shall be 2.5m, and the height of test point of ordinary buried downlead shall be 1.5m. Try to avoid using the unauthorised products for the test points. Instead, the approved types shall be adopted. They shall not cause any adverse impact on the resistance value of the lightning protection system. After the completion of installation and testing, all test clamps shall be applied with asphalt paint for anti-corrosion purpose (Rahim, Ghani, and Munaaim 2016).

2.2.5 Grounding Electrode

The grounding electrode shall be located no more than 2m away from the building and shall be placed in the grounding hole, the grounding hole and the components tested according to IEC62561-5 shall be flush with the ground and able to withstand the load weight of 5000kg. The connection between the grounding electrode and the copper strip downlead shall be protected by heavy PVC pipe, and all connections of the grounding electrode shall be exothermic welded. The grounding electrode consists of a solid copper rod with a diameter of 16mm and is buried at least 3.6m below the grounding hole to guarantee that the resistance of each downlead of the lightning protection system is no greater than 10Ω. All grounding electrodes pass through the waterproof layer of the basement. Special waterproof sleeves or materials shall be used to guarantee that the basement is waterproof. The sealing requirements shall comply with the requirements of IEC 62561-5.

2.2.6 Curtain Wall Lightning Protection

The curtain wall lightning protection system shall be continuous, and SS.555 test shall be carried out. Then, the test report shall be provided. All metal structures on the surface of the curtain wall must be provided with a wiring terminal every 30m to guarantee the reliable connection, continuity, and safety of the curtain wall lightning protection system and the downlead.

2.2.7 Test and Operation

The test is arranged by a subcontractor for professional certification, and the report is submitted to architect. The subcontractor shall submit a detailed layout diagram showing the test locations. The subcontractor shall inspect the lightning protection system, including the grounding hole, on a monthly basis, to guarantee that the system is in good working condition.

2.3 Design Requirements of Grounding System

Individual grounding systems shall include a complete grounding electrode/rod, grounding inspection room/hole, grounding downlead/conductor, and main grounding terminal, etc. The exact position and number of grounding electrodes shall be determined by measuring the soil resistivity on site, and the grounding inspection room shall be used to protect the electrodes. If the soil conditions of the grounding system are poor, prefabricated common grounding pads with a resistivity of less than 1Ω must be laid under the lowest floor structure before the ground is constructed. The joint connection of the grounding rod, copper strip, and grounding pad shall be exothermic, butt welded or soldered (Yusoff et al. 2014).

2.3.1 Grounding Busbar Design

Each grounding system loop must be equipped with an individual grounding busbar. The tin-plated copper strip with the 50mm x 60mm dimensions must be no less than 1,000mm long. The copper strip must be installed at a height of 300mm above the finished surface of the equipment room/switch room floor. All equipment housings, switches, relays, instrument housings, and all other metal housings of electrical equipment shall be equipped with grounding terminals connected to grounding busbars.

2.3.2 Grounding Protection Conductor Design

The circuit protection conductor shall be a separate yellow-green dual-colour sheathed wire or copper strip, and the minimum dimensions of the copper strip are 25mm×3mm. See Table 1 for the minimum dimensions of the main protective conductor. The dimensions of the main protective conductor shall comply with the existing regulations of SS 638 and SS.551.

Table 1. Minimum dimensions list of protective conductors

No.	Type	Minimum dimensions of conductor/mm²
I	Grounding conductor between grounding electrode and main grounding terminal of HV switch room	1×120

II	Grounding conductor between grounding electrode and main grounding terminal of LV switch room	1×120
III	Circuit protective conductor between HV main grounding terminal and neutral point of the transformer	1×240
IV	Circuit protective conductor between HV main grounding terminal and HV distribution panel	1×120
V	Circuit protective conductor between LV main grounding terminal and LV distribution panel	1×120
VI	Circuit protective conductor between grounding terminal and main grounding terminal of generator room	1×120
VII	Circuit protective conductor between grounding terminal of fire control room/data centre/ELV machine room and the corresponding grounding electrode	1×70

Facilities such as pipelines and natural gas shall be connected at equal potential and imported as close as possible to the grounding point where they enter the building. Main gas lines, risers for central heating and air conditioning systems, fuel tanks, and exposed metal parts of the building structure are submitted by the architect as required. The cross-sectional area of the main equipotential connecting conductor shall be no less than half of the cross-sectional area of the grounding conductor, and the minimum value is 6mm2 copper cable. If the dimensions of the conductor exceed 25mm2, it is not necessary to add the equipotential for copper cable.

2.4 Design of Lightning Protection and Grounding System

The lightning protection grounding system under the IEC standard is more inclined to independent grounding electrodes, so avoiding the use of structural rebar and effectively guaranteeing the continuity of the system is necessary. As the general professional design, the lightning protection grounding system is designed, constructed, and tested by qualified lightning protection units, and the whole system products certified according to the IEC standards will also be provided. All cables adopt the single-core independent grounding cables, and the busbars adopt the N+3 form external grounding terminals. The roofing lightning protection net adopts aluminium strip or copper strip, and the curtain wall surface is equipped with lightning protection pad to enhance the safety of the lightning protection system.

3. Key Points of Node Construction Technology

3.1 Grounding Hole and Grounding Rod Practice

The grounding system adopts an external grounding copper rod as the grounding electrode to be connected with the ground. Then, the protective conductor (cable) shall be connected to the grounding copper strip in the electric well and equipment room through exothermic welding. Test the resistance of the grounding electrode every six months and replace any grounding electrode that does not meet the requirements. To facilitate the maintenance and replacement of the grounding electrode, a heavy grounding hole must be added above the grounding electrode (as shown in Figure 1). The waterproof part of the grounding rod passing through the floor must be protected by a sleeving. After the grounding rod is completed, a special sealing

cover must be used to seal the grounding rod to prevent from water leakage. See Figure 2 for grounding hole waterproofing practice.

Figure 1. Grounding hole practice

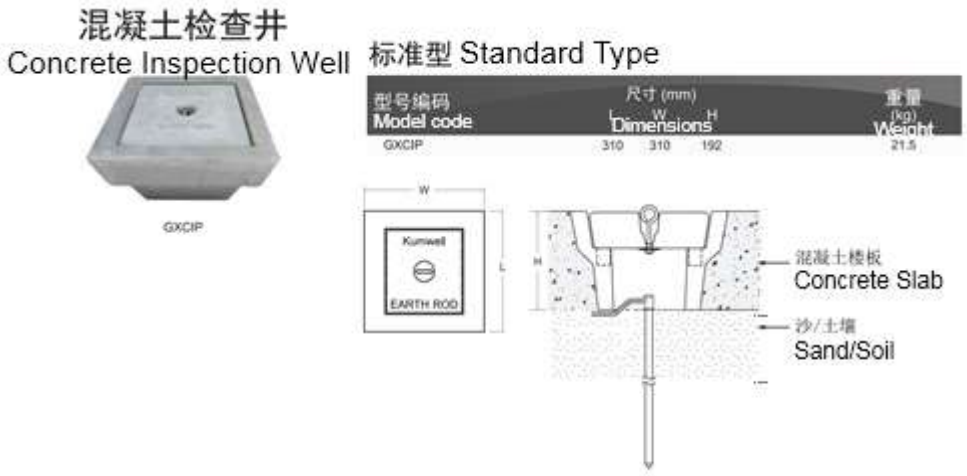
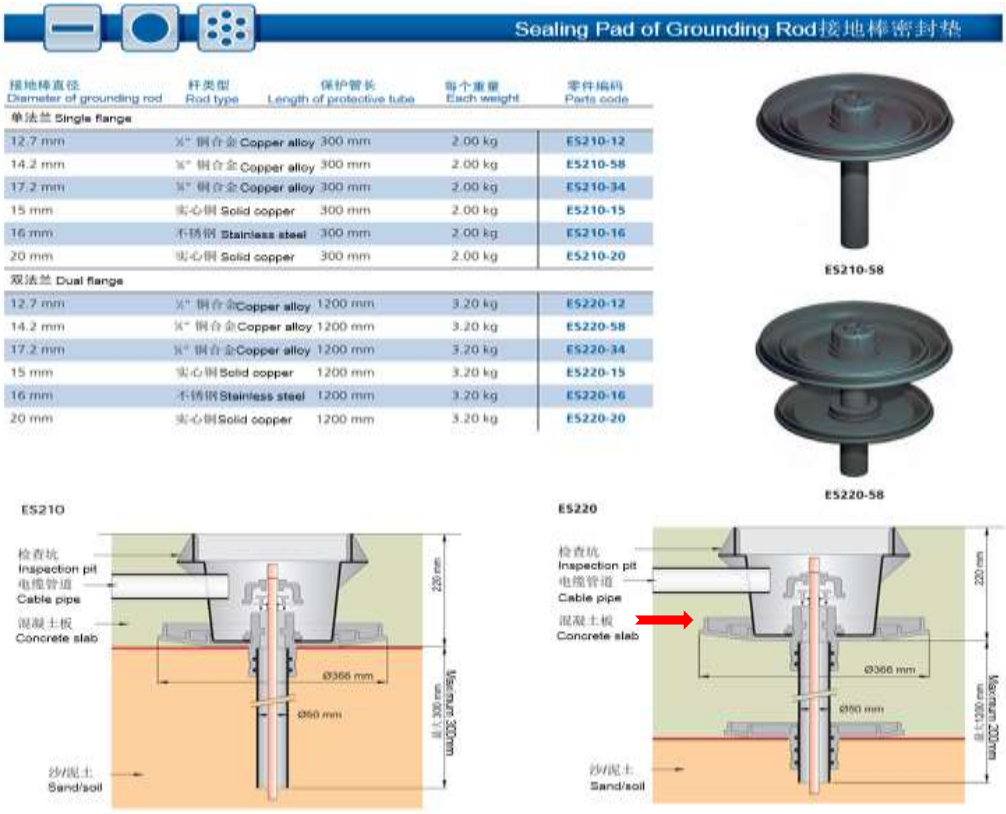


Figure 2. Grounding hole waterproofing practice



3.2 Test Box, Downlead, and Grounding Connection Points

IEC independent lightning protection design prohibits the use of building rebar as the downlead. Instead, it must use the special downlead of lightning protection system. Electric welding is prohibited for the downlead connection, and the two-way clamp shall be used. If the

floor height is more than 60m, the grounding point of each floor needs to be laid out and reserved for the future curtain wall and other grounding conductors, and the construction should be simple. See Figure 3 for special downlead connection node practice. At the bottom of each special downlead, the grounding resistance test box to be installed is installed at a position of 1.5m away from the ground of the first floor. This is convenient for future detection and recording. See Figure 4 for grounding resistance test box installation node practice.

Figure 3. Special downlead connection node practice

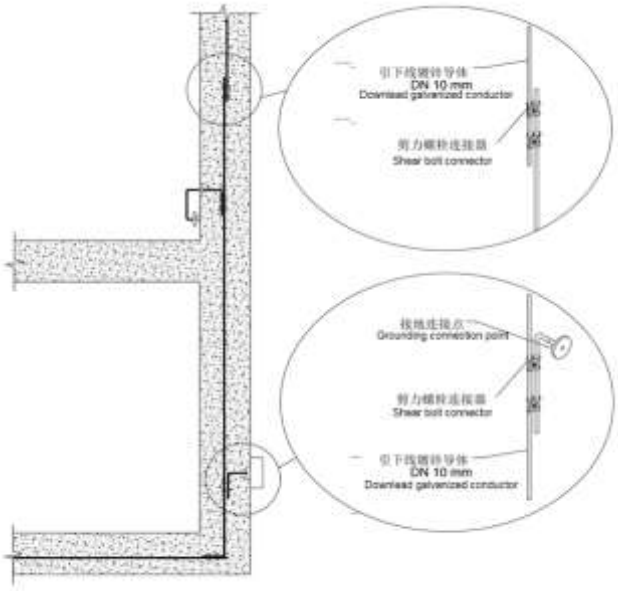
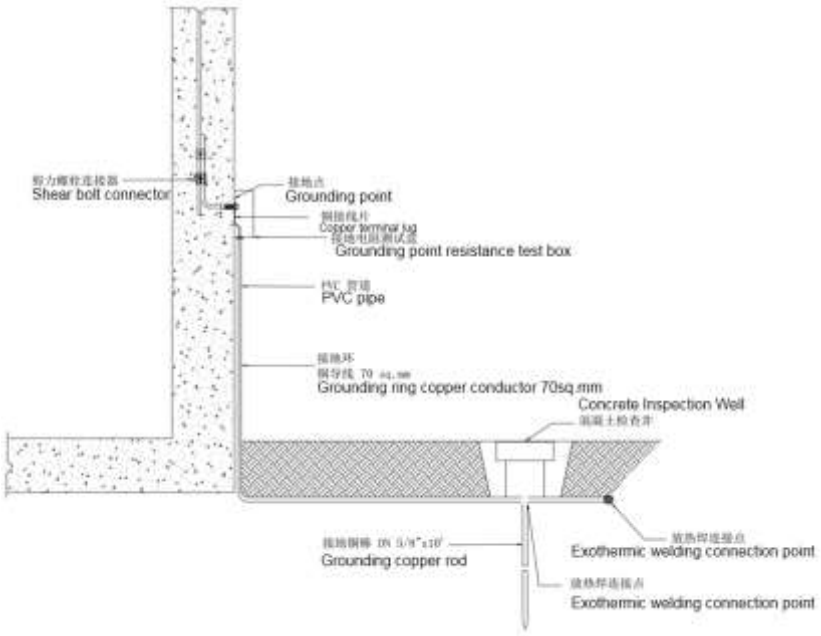


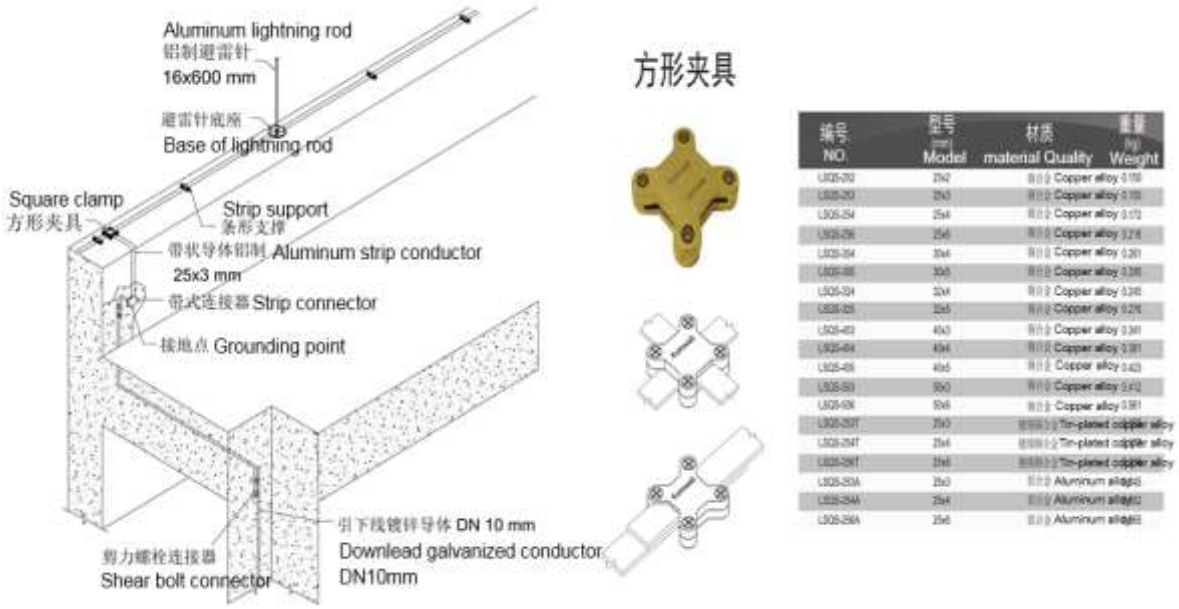
Figure 4. Grounding resistance test box installation node practice



3.3 Roofing Lightning Protection Net and Lightning Arrester Practice

The roofing lightning protection adopts aluminium strip as lightning protection strip, and it is laid in a circle along the parapet wall. A lightning arrester is arranged at the corner of the parapet wall every 15m. The lightning arrester is connected with the special downlead through an aluminium strip, and the aluminium strip is fixed on the parapet wall with a special buckle. See Figure 5 for roofing lightning strip and lightning arrester node practice.

Figure 5. Roofing lightning strip and lightning arrester node practice



3.4 Grounding Strip and Downlead Welding

All copper materials are connected with a special mould for exothermic welding, guaranteeing that the contact is firm, and the resistance value meets the design requirements. See Figure 6 for mould exothermic welding node detail. The grounding cable is connected to the grounding point through an independent grounding busbar and led into the ground. See Figure 7 for the grounding strip node practice.

Figure 6. Mold exothermic welding node detail

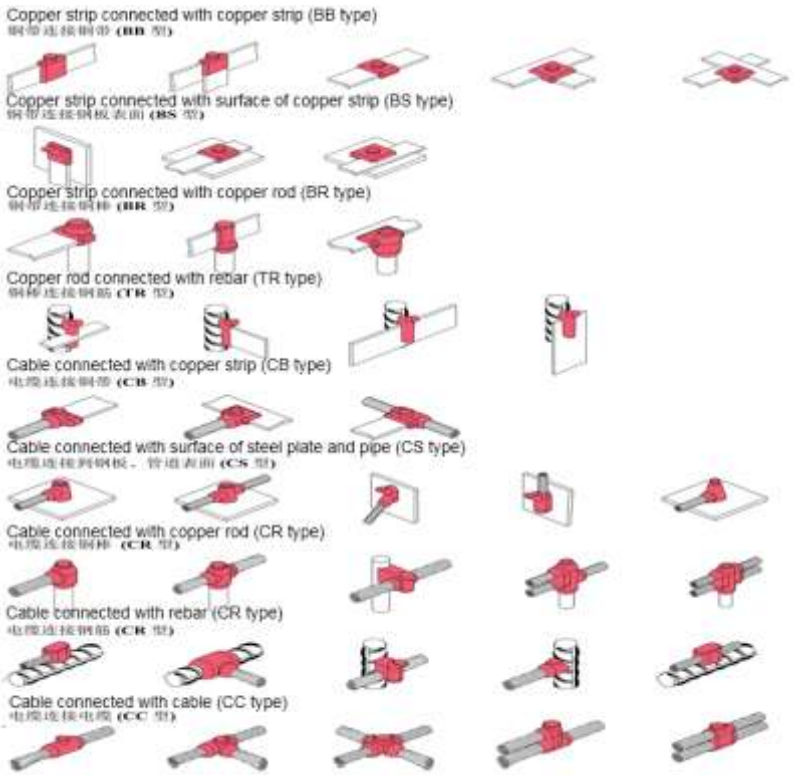
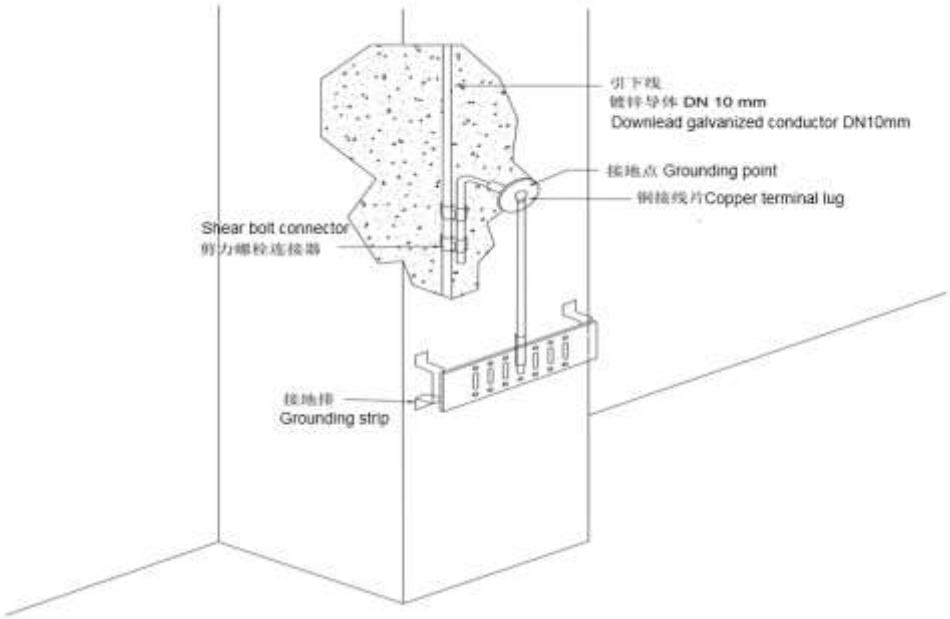


Figure 7. Grounding strip node practice



4. Conclusion

The design of the lightning protection grounding system of this project is based on the IEC standards and is relatively highly integrated and more professional. Due to the high requirements of construction quality, its cost, material organisation, construction technology, and schedule assurance have certain challenges.

In this project's construction, through the study and analysis of IEC standards and the full integration of domestic and foreign construction technologies, a safe, efficient, and low-cost construction scheme is illustrated.

This article can provide corresponding references for the bidding, design, construction, and operation of subsequent similar projects. Besides, it provides references for domestic lightning protection and grounding system practices, as well as the guarantee for the safe operation of buildings.

References

Kim, K., V. Veasna, C. Chan Oeurn, and S. Tharith. 2014. "Early Warning and Protection Systems for Lightning Strike in Cambodia Based on Meteorological Data and Human Action." International Journal of Lightning Research 6 (2): 58–72.

Suryadi, A., and D. Sudjono. 2020. "Evaluation of Parameters in the Development of a Building Protection System." International Journal of Electrical Engineering and Applied Sciences 3 (2): 2600–9633.

Rahim, M. A., A. N. A. Ghani, and M. A. C. Munaaim. 2016. "Lightning Protection System in Malaysia: Materials Selection for Down Conductor." Jurnal Teknologi (Sciences & Engineering) 78 (5): 7–13.

Yusoff, N. M., J. Jasni, B. Manson, and Z. Kadir. 2014. "A Study on Lightning Protection System–The Effect of Bending Degree of the Down Conductor." International Conference on Lightning Protection (ICLP). DOI:10.1109/ICLP.2014.6973410.