Open Access Research Journal of
Multidisciplinary Studies
Journals home page: https://oarjpublication/journals/oarjms/
ISSN: 2783-0268 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(REVIEW ARTICLE)

Check for updates

Design of resilient communication tower with retractable antenna mast

Toyado, Dexter M *, Magno, Norlito S, Torrente, Nelson T, Ocampo, Krizel Joy T, Butial, Francess Lauren and Manlagñit Ruiz M

Department of Civil Engineering, Catanduanes State University, College of Engineering and Architecture, Virac, Catanduanes, Philippines.

Open Access Research Journal of Multidisciplinary Studies, 2024, 07(01), 084–093

Publication history: Received on 18 December 2023; revised on 05 February 2024; accepted on 08 February 2024

Article DOI: https://doi.org/10.53022/oarjms.2024.7.1.0011

Abstract

Effective communication infrastructure is crucial for disaster response and management, particularly in typhoon-prone regions like the province of Catanduanes, Philippines. This study aims to design a resilient communication tower with a retractable antenna mast to enhance the communication capabilities of the Municipal Disaster Risk Reduction and Management Office (MDRRMO) in the island of Catanduanes during typhoon and disaster. The study adopts a capstone project design method. It includes qualitative analysis with an extensive review of literature and guidelines related to resilient communication infrastructure, typhoon preparedness, and disaster response strategies specific to the island of Catanduanes. Factors such as wind loads, structural stability, and mechanisms for deploying the retractable antenna mast pole are considered during the design process. Advanced tools such as computer-aided design software and structural analysis and design software application simulations are employed to model and assess the tower's structural integrity under extreme weather conditions. The outcomes study includes a detailed design plan for a resilient communication tower with a retractable antenna mast pole, specifically tailored for the typhoon-prone environment in Catanduanes.

Keywords: Communication tower; Typhoon resilient design; Retractable antenna mast; Pole; Steel framed structure

1. Introduction

Presidential Decree No. 1566, s. 1978, outline the strengthening of the Philippines disaster control and established the National Program on Community Disaster preparedness, thus, forming the National Disaster Coordinating Council (NDCC), or currently known as National Disaster Risk Reduction and Management Council (NDRRMC). As stated in Republic Act 10121, Local DRRM Offices must be established by our local government officials whole throughout the country – regional, provincial, municipal, city, and barangay levels. Their functions cover four (4) aspects including disaster preparedness, response, prevention and mitigation, and rehabilitation and recovery and create Local Disaster Risk Reduction and Management Plan comprised of this framework. The Provincial Disaster Risk Reduction Management Office (PDRRMO) for the provinces and Municipal Disaster Risk Reduction Management Office (MDRRMO) for municipality was established for this purpose and with responsibility to set direction, development, implementation and coordination of disaster risk reduction and management programs since we frequently experience natural disasters especially strong and super typhoons causing severe destruction of life and property. This agency is also in charge of all emergency and disaster communication system. The PDRRMO task is to communicate to consolidate updates and conduct emergency and rescue operations. They have three (3) communication towers in different municipalities of Catanduanes and plans to install communication/repeater towers on every municipality to improve and cater all the radio communication system throughout the province.

The common problems encountered with this communication towers are the materials and design used which are all destroyed and damage by a strong typhoon. During these natural disasters, the communication system is shut down

* Corresponding author: Toyado, Dexter M

because of the damage to the tower by strong winds, that eventually damages to the antenna and the equipment installed in the tower. Repair and reinstallation and maintenance takes a longer period of time and required extensive work to fully restore the system, thus the communication system which is intended for the relief and rescue operation is unusable. In a BBC news after Super typhoon Rolly in November 2011 reported that "Virac was the first urban area on Catanduanes to be hit by the storm. Communication has been down, and it has been difficult getting information out of the area.". Only a few private network communication survives to fill the gap for disaster and emergency communication.

In this study, the researchers design a resilient, self- supporting communication tower to enhance disaster preparedness with standard installation procedure that can withstand maximum wind velocity. The tower's resilience and self-supporting feature will ensure that communication lines remain operational during emergencies and disasters, providing critical information and aid to affected areas.

The design incorporated lattice design for the structure of the tower that can sustain harsh weather conditions, which provides greater stability and support than a traditional solid tower. This lattice design allows for the tower to be built with less material, reducing costs, and making it easier to transport and install. The tower has a motorized retractable antenna mast pole for the safety of the antenna; this feature allows for the antenna to be safely lowered during extreme weather conditions, such as high winds or storms, reducing the risk of damage to both the antenna and the tower itself. The motorized system also makes it easier and safer for technicians to access and maintain the antenna. Very High Frequency (VHF) and Ultra High Frequency (UHF) antenna is mounted on the tower, which provides better communication signals. Also a High Frequency HF antenna can be mounted at the midsection of the mast. The tower is designed to be self-supporting and scaled down to smaller dimensions, it means that it requires less ground area coverage than traditional towers. This makes it an ideal choice for locations where space is limited or where zoning regulations restrict the size of communication towers. The retractable antenna mast poles are essential components of the towers, which are used to support antennas. The pole is designed to be raised and lowered as needed for maintenance or to adjust the height of the antenna. Several factors can affect the resilience of retractable antenna mast poles, including material used and tower design.

The primary objective of this research is to design a resilient retractable antenna mast pole that can withstand these environmental conditions and provide reliable support for wireless communication antennas.

The results of this study will help improve the design and performance of retractable antenna mast poles, which will ultimately enhance the reliability and availability of emergency communication networks for disaster and emergency communication.

2. Conceptual Framework

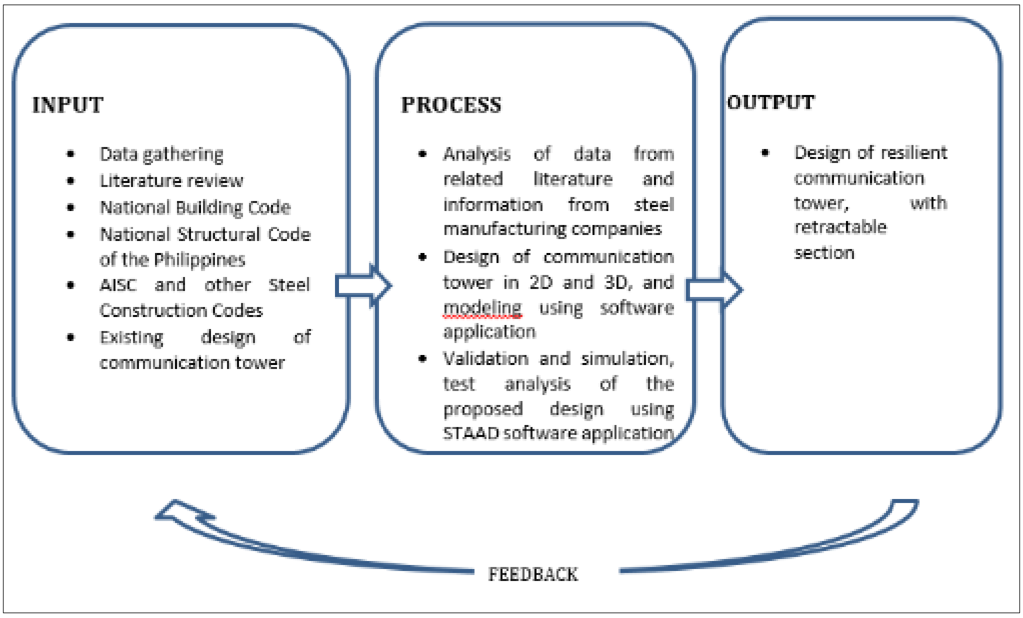

Figure 1 Conceptual Framework

The conceptual framework model is shown in figure 1, guide the researcher in achieving the required output of the project. The design of a resilient retractable antenna mast pole for communication towers requires consideration of several factors, including the height and weight of the antenna, wind load, and potential impacts from typhoon, earthquakes, and wear and tear factors.

2.1. Statement of the Problem

This study specifically aims to seek answers to the following questions:

- What is the type of design for communication tower that will withstand the effect of super typhoon?
- What are the appropriate materials for the design of communication tower?
- What motorized retractable antenna mast pole for communication tower be installed?
- What is the cost estimate for the design of the communication tower?

2.2. Project Scope and Delimitation

The geographical scope of this study is in the province of Catanduanes. This study will only focus on the structural and mechanical design of the communication tower, the electrical and soil investigation will not be included. The design of motorized retractable mast communication tower can withstand the maximum wind capacity for zone 4 in the Philippines.

2.3. Research Design and Methodology

Research design is a plan or structure for a list of specifications and procedures for conducting and controlling a research project. In other words, it can be described as a master plan that indicates the strategies for conducting research (Heppner et.al., 1992). This research is a Case Study Design, that involves detailed study and analysis in order to gain in-depth knowledge about the characteristics and implications of a specific case subject or phenomena. By investigating these existing designs and comparing to our proposal, we were able to differentiate and identify the gaps and come up with a more innovative design of a communication tower. Related literatures, thesis works, and test analysis results were used to support this study.

In the design, the methodology involves several steps. First step is to determine the requirements of the project, including the height of the mast, the weight it needs to support, and any environmental factors. Next is to select appropriate materials for the mast pole, considering factors such as strength, durability, and cost. After selecting the materials, the design process begins with creating a 3D model of the mast pole using computer-aided design software. This allows the researchers to test different designs and configurations before settling on a final design. The 3D model can also be used to simulate various environmental conditions, such as wind loads and seismic activity, to ensure that the mast pole will be able to withstand these forces. The frame will be a lattice frame, connected using bolts and welded connections. The design is a tubular lattice tower, with nine (9) meters height of the tower's body using GI pipe material, a 5.2-meter mast pole made up of aluminium material for lighter weight, foundation depth of two 200 mm, and a base dimension of 1.8 square meter. The materials used for this design is fabricated GI Pipe. Hot dip galvanizing or HDG will be the process of coating iron, steel, or ferrous materials with a layer of zinc to prevent corrosion. Because zinc carbonate is a strong material that protects iron, this method is used especially in manufacturing towers.

2.4. Data Gathering Procedures

The researchers coordinated with the PDRRMO staff and conduct interview regarding the needs of the agency for communication tower. They also provided recommendation and minimum specifications for the proposed tower. It will also have provisions for maintenance and installation of variety of antenna.

2.5. Locale of the Study

The locale of the study is the province of Catanduanes, as the PDRRMO and MDRRMO are planning to install resilient communication tower for their utilization. The tower must be resilient for both earthquake and super typhoon.

3. Result and Discussion

The design of communication towers should adhere to specific guidelines and standards to ensure their safety and effectiveness during emergencies. Some of the key considerations in designing communication towers include: 1. Structural integrity: Communication towers should be designed to withstand extreme weather conditions such as strong winds, heavy rain, and earthquakes. The tower's foundation should be sturdy enough to support its weight and withstand lateral forces. 2. Height: The height of the communication tower should be appropriate for the intended use, considering factors such as terrain, distance from other structures, and line-of-sight requirements. 3. Antenna capacity: The tower's design should consider the number and types of antennas that will be installed on it, including their size, weight, and orientation. 4. Access: The tower should have safe and secure access for maintenance and repair personnel, and, 5. Environmental impact: Communication towers should be designed with consideration for their environmental impact, such as minimizing disruption to wildlife habitats or scenic views.

3.1. Framing type design

The Self-Supporting Lattice Steel structure for the communication tower is the most suitable type of design that can withstand severe and harsh weather conditions for the province of Catanduanes. According to the study of “Effect of Wind Speed on Structural Behavior of Monopole and Self-support Telecommunication Tower” (Kumar et.al, 2017), it was stated that Self- support towers show that it has lower lateral displacements when compared to the Monopole towers with the same height, same amount of loading considering the dead and wind loads using STAAD Tower Software. Albayrak, U., & Morshid, L. (2020) stated that Self-support Lattice Structure has higher stiffness that provides more stability to the structure.

3.2. Mechanism of the Retractable Antenna Mast Pole

The proposed communication tower has a motorized retractable antenna mast pole for the safety of the antenna; this feature allows for the antenna to be safely lowered during extreme weather conditions, such as high winds or storms, reducing the risk of damage to both the antenna and the tower itself. The motorized system also makes it easier and safer for technicians to access and maintain the antenna. There are several different mechanisms that can be used, including hydraulic, pneumatic, and mechanical systems (Johnson et. al..2019). Each of these systems has its own advantages and disadvantages, depending on factors such as cost, reliability, and ease of maintenance (Madhusudhan C., 2018). In this study, the researchers used the mechanical system for the mechanism of the retractable antenna mast pole.

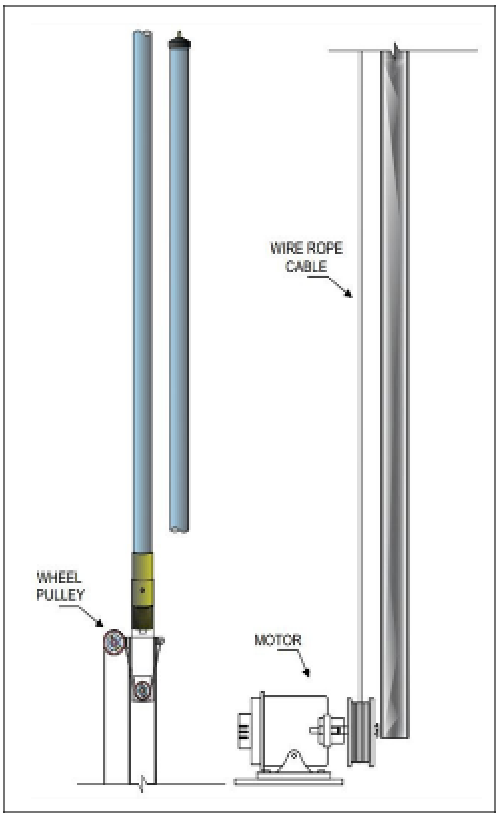

Figure 2 Illustration of the mechanical system for the mechanism of the retractable antenna mast pole

3.3. Materials Used

Galvanized Iron (GI) pipes are commonly used in the design of lattice communication towers due to their numerous advantages. One of the main advantages is their high strength-to-weight ratio, which makes them ideal for use in structures that require high load-bearing capacity. The galvanization process also provides excellent corrosion resistance, which is essential in outdoor environments where the tower may be exposed to harsh weather conditions. Another advantage of using GI pipes for lattice communication towers is their versatility in design. GI pipes come in different sizes and thicknesses, allowing engineers to select the appropriate dimensions based on the tower's height and load requirements. The pipes can also be easily cut, bent, and welded to form complex shapes, making them suitable for various tower configurations

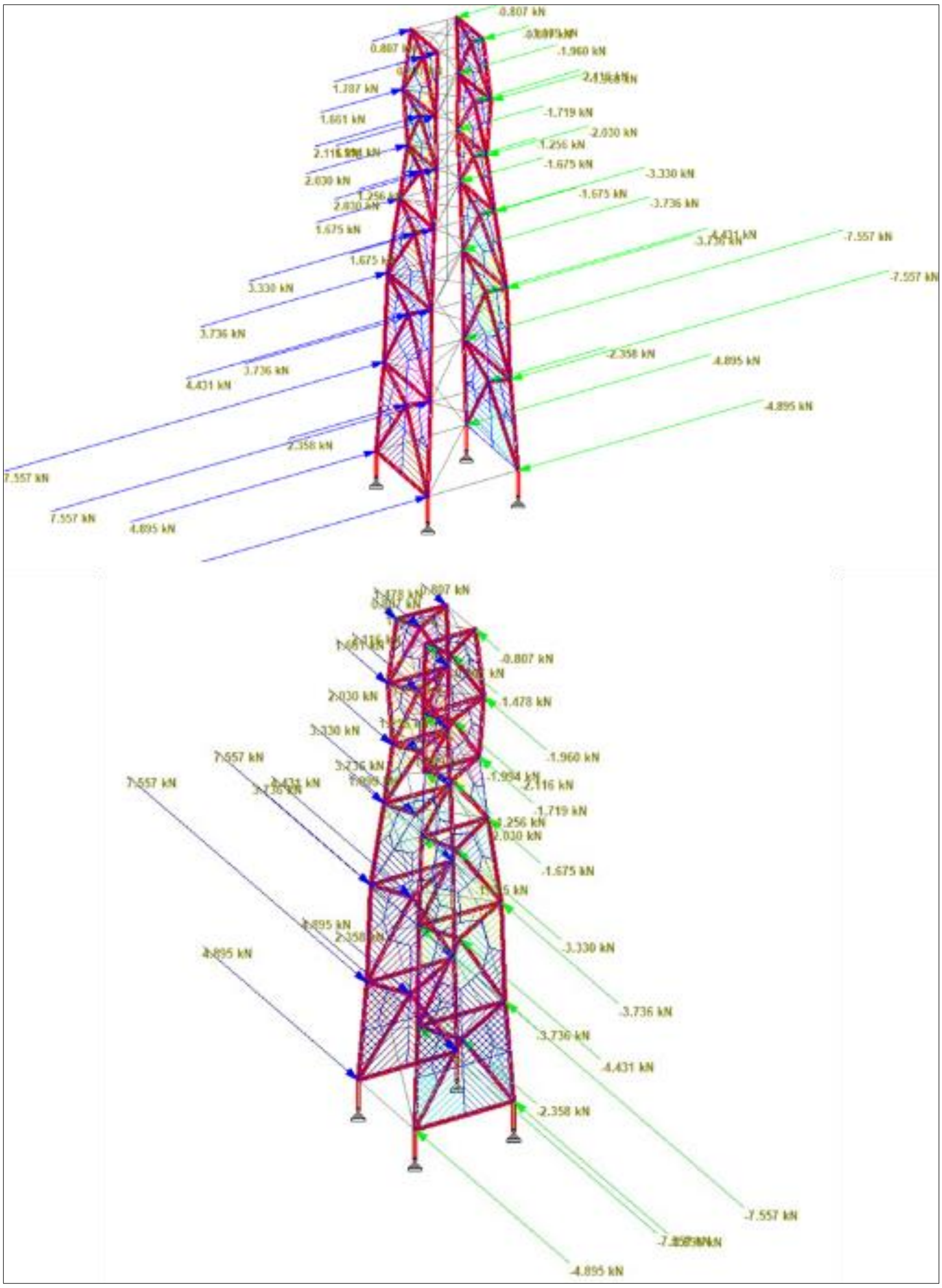

Figure 3 (A) Load Case Detail for Wind Load at X (Windward) Direction, (B) Load Case Detail for Wind Load at Z (Leeward) Direction

3.4. Motor for retractable system

For the motor of the mechanical system of the communication tower, an AC Motor will be installed made of cast iron/steel material, with a speed of 74-450 RPM, and a speed controller.

3.5. Type of Connection

For the type of connection used for the fabrication of the communication tower, combination of bolts and welding connection were applied.

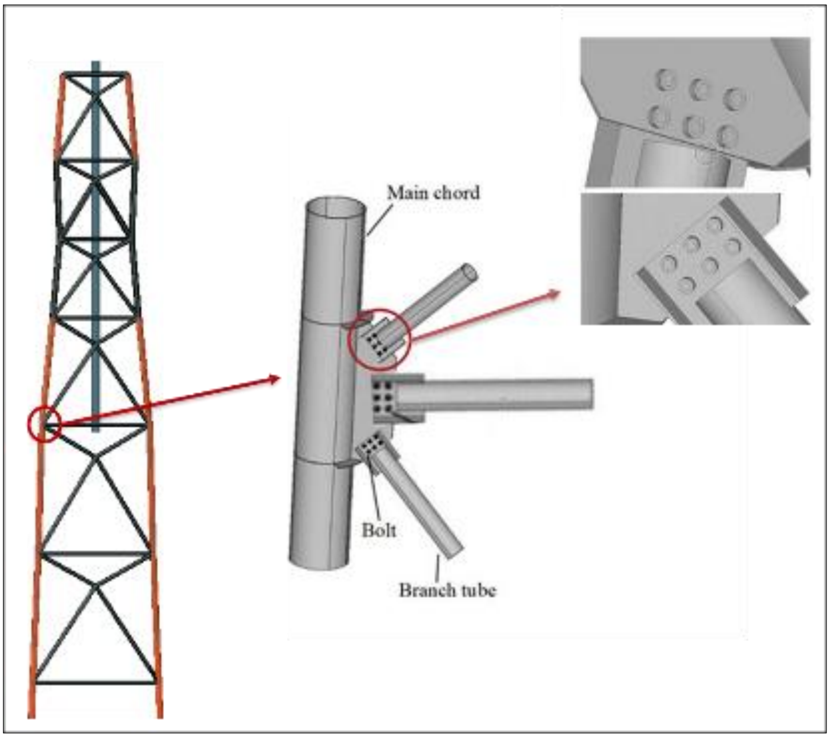

Figure 4 Schematic of the bolted and welded connection

3.6. Design of Bolts

Table 1 Maximum Member Load from STAAD Results

Beam	L/C	Node	Axial Force kN	Shear-Y kN	Shear-Z kN
76	12	76	8.097	-0.498	0.078
Torsion kNm			**Moment-Y kNm**	**Moment-Z kNm**	**Resultant Shear**
0.148			0.321	-0.14	8.112
Max. shear force coming on bolts				8.112	kN
Diameter of bolts				16	mm
Gross area of bolt Asb				200.96	sq-mm
Net Area of bolt				156.75	sq-mm
Diameter of hole				17.5	mm
Bolt Grade				A-4	

Ultimate tensile strength Fub	800	Mpa
Yield strength of bolt Fyb	600	Mpa
Minimum plate thickness for connection	5	mm
Ultimate strength of plate Fup	410	Mpa
End distance "e"	30	mm
Pitch distance "p"	40	mm
THREADS NOT EXCLUDED (N)' = Fnv =	360	Mpa
THREADS EXCLUDED (X)' = Fnv =	450.4	Mpa
ALLOWABLE STRENGTH DESIGN (ASD) Shear capacity of bolt =	45.26	kN
Bearing capacity of bolt =	76.8	kN
LOAD RESISTANCE FACTOR DESIGN (LRFD)		
Shear capacity of bolt =	54.26	kN
Bearing capacity of bolt =	115.2	kN

Shear capacity of bolt and Bearing capacity of bolt > Max. shear force coming on Bolts. Therefore, the design is acceptable. Using the diameter of 16 mm for the size of the bolts, and 17.5 mm for the diameter of the hole, we computed for the total Gross area of bolt (Asb) resulted to 200.96 sq-mm. Then we computed for the shear capacity of the bolt using Allowable Strength Design (ASD) with a total value of 45.26 kN. Therefore, the shear capacity of the bolt is greater than the maximum shear force coming from the bolts, thus, the design is safe and adequate.

3.7. Foundation Design

The foundation design of the communication tower will be a mat or raft foundation, that is essentially a continuous slab which the four-legged tower will be constructed. To ensure a relatively uniform load transfer of the tower and provided that the base of the tower is only 1.8 meters, the researchers used the mat slab foundation design.

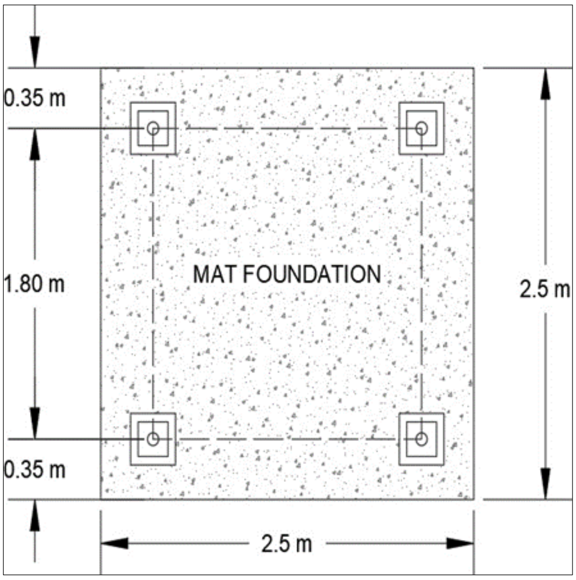

Figure 5 Mat foundation Design

Soil Bearing Capacity = 200 kPa , Deadload = 3.696 kN

$$\text{Area} = 3.696/200 = 0.018 \text{ m}^2$$

Area of Base Plate = $(2.5\ m)^2 = 6.25\ m^2$

Actual Soil Pressure (Psoil) = Psoil = 3.696/6.25 = 0.59 $\boldsymbol{kN}/\mathbf{m^2}$

$$f'c = 28\ MPa,\ fy = 400\ MPa$$

$$\rho min = 1.4/fy = 1.4/400 = 0.0035$$

$$w = \rho\ fy\ /\ f' = 0.0035(400)/28 = 0.05$$

$$Vu = 0.53\ kN,\ Mu = 0.04\ kN\text{-}m,\ -0.53\ kN\text{-}m$$

Design of the Depth (d)

For computing for the moment of the columns, the value was too small, therefore, the researchers assumed for effective depth of 150 mm.

Design of Reinforcing Bars As = ρmin = 0.0035 ρbd

$$Mu = \emptyset\ f'c\ w\ (1\text{-}0.59w)\ bd^2$$

$$26\ x\ 106 = 0.85\ (28)\ (w)\ (1 - 059w)\ (1000)\ (250)2$$

$$w = 0.018$$

$$w = \rho\ fy\ /\ f' = 0.018(400)/28 = 0.00126 \therefore Use\ \rho min$$

$$As = \rho bd = 0.00126\ (1000)\ (250) = 315\ mm^2$$

$$A\emptyset 12 = 113\ mm^2$$

No. of Rebars = 315/113 = 2.7 say 3 pcs

Spacing (s) = 1000/3 = 333 mm ∴ use 300 mm o.c.

3.8. Cost Estimate

Summing up the total cost of the materials used in manufacturing the communication tower, the materials used for the foundation design, including the labor cost and other expenses such as permits and insurance, the total rough cost estimate ranges up to Php 1M to 1.2M depending on the inflation and prices escalation. The cost was based on 2022 pricing.

3.9. Design Validation

The results of the test analysis using the STAAD Software is presented here, showing the performance of the proposed design of retractable antenna mast pole for communication towers; this includes information on its ability to withstand wind and earthquake loadings.

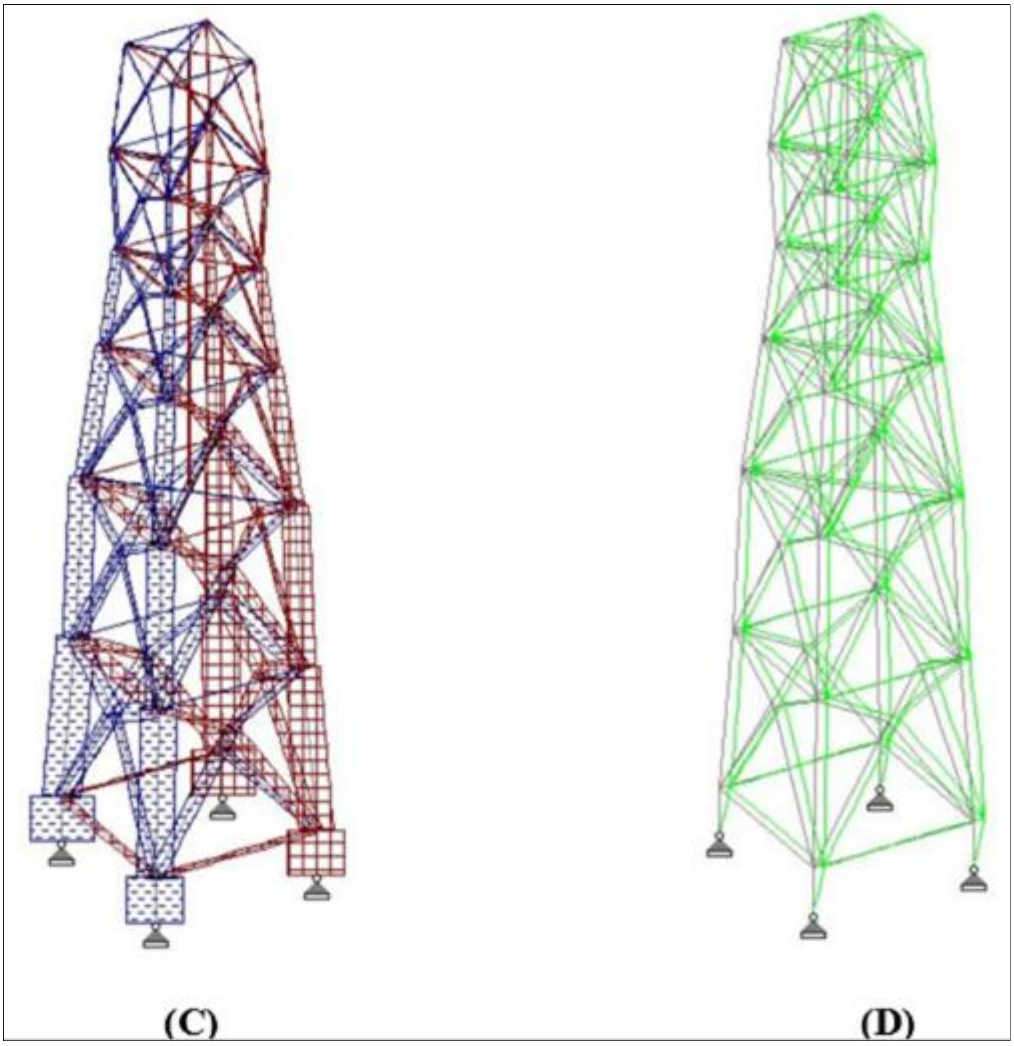

Figure 6 Seismic at X-Axis (A) shear, (B) moment, (C) axial and, (D) displacement

All | Summary

			Horizontal	Vertical	Horizontal	Resultant	Rotational		
	Node	L/C	X mm	Y mm	Z mm	mm	rX rad	rY rad	rZ rad
Max X	85	12 1.2D+0.5L	21.252	-0.344	6.170	22.133	0.000	0.000	0.013
Min X	86	12 1.2D+0.5L	-12.302	-0.509	5.473	13.474	0.000	0.000	-0.013
Max Y	142	8 D+L+0.6W	2.220	1.374	-4.151	4.903	-0.000	-0.000	-0.000
Min Y	100	6 1.4D	-0.029	-1.689	10.341	10.478	-0.018	0.000	-0.000
Max Z	87	14 0.9D+1EZ	-0.775	-0.303	15.093	15.116	-0.010	0.001	0.000
Min Z	88	6 1.4D	-0.003	-0.418	-25.168	25.172	0.015	0.000	0.000
Max rX	3	2 EQZ	0.000	0.000	0.000	0.000	0.020	0.001	-0.003
Min rX	100	6 1.4D	-0.029	-1.689	10.341	10.478	-0.018	0.000	-0.000
Max rY	16	6 1.4D	0.094	0.061	-5.451	5.452	0.004	0.017	-0.001
Min rY	17	6 1.4D	-0.096	0.066	-5.427	5.428	0.004	-0.017	0.001
Max rZ	97	12 1.2D+0.5L	20.422	-1.432	6.344	21.433	0.000	0.000	0.018
Min rZ	98	12 1.2D+0.5L	-10.952	-1.636	5.780	12.491	0.000	0.000	-0.018
Max Rs	88	6 1.4D	-0.003	-0.418	-25.168	25.172	0.015	0.000	0.000

Figure 7 Summary of the maximum load combinations with its corresponding node numbers

The results of the study showed that the designed antenna mast pole was capable of withstanding wind speeds of up to 320 km/h without any structural damage. The pole was also able to withstand vibrations caused by nearby machinery and equipment, which is a common issue in communication towers. Additionally, the retractable mechanism of the mast pole was tested, and it was found to be reliable and efficient. The study also discussed the material selection process for the antenna mast pole. The researchers used a combination of fiberglass and carbon fiber materials to achieve the desired strength and flexibility. The use of these materials also made the antenna mast pole lightweight, which is important for ease of installation and maintenance. Furthermore, the discussion section presented a comparison between the designed antenna mast pole and other existing solutions in the market. The study showed that the designed antenna mast pole outperformed other solutions in terms of resilience, durability, and cost-effectiveness. Designing a resilient motorized retractable antenna mast pole for a communication tower is a complex process that requires careful consideration of several factors such as load capacity, wind resistance, durability, and ease of maintenance.

Recommendations

Explore innovative materials and design concepts that could enhance the resilience of telecommunication tower, such as the use of composite materials, modular designs, or smart sensors that can detect and respond to changes in load or environmental conditions. Conduct field testing of prototype communication tower to validate their design and assess their performance under real-world conditions. This testing could include measurements of wind loads, vibration, and other factors that can affect the resilience of the tower. Advanced structural analysis and simulation techniques, as well as wind tunnel testing, can help ensure the tower's stability and safety during extreme weather conditions.

4. Conclusion

In conclusion, the research study has provided important insights into the design of a resilient retractable antenna mast pole for communication tower. The study highlighted the importance of considering factors such as wind load, weight, and stability in the design process. By implementing the design recommendations outlined in this study, communication towers are made more resilient and better equipped to withstand extreme weather conditions.

Compliance with ethical standards

Disclosure of conflict of interest

I declare that I have no conflicts of interest, financial or otherwise.

References

[1] Albayrak, U., & Morshid, L. (2020). Evaluation of Seismic Performance of Steel Lattice Transmission Towers. Civil Engineering Journal.

[2] BBC, Typhoon Goni: Fears after Philippine town said to be 90% damaged, 2020, https://www.bbc.com/news/world-asia-54775430

[3] Heppner, Puncky & Wampold, Bruce & Kivlighan, Dennis. (2008). Research Design in Counselling.

[4] Johnson, A. et. al. (2019), Design and Analysis of Retractable Antenna Mast Poles Proceedings of the IEEE International Conference on Communications, pp.234-239,

[5] Kumar, M Pavan & Raju, P. & Navya, M & Naidu, G Tirupathi. (2017). Effect of wind speed on structural behaviour of Monopole and self-support telecommunication towers. Asian Journal of Civil Engineering. 18. 911-927.

[6] Madhusudhan C., 2018, Design and Analysis of Telecommunication Tower, International Journal Of Scientific Progress And Research (IJSPR) ISSN: 2349-4689 National Conference on Emerging Trends in Civil Engineering (NCETCE-2018) Conference Organized by: BGS Institute of Technology, Karnataka, INDIA - 571448

[7] Philippine Disaster Risk Reduction and Management Act of 2010, AN ACT STRENGTHENING THE PHILIPPINE DISASTER RISK REDUCTION AND MANAGEMENT SYSTEM, PROVIDING FOR THE NATIONAL DISASTER RISK REDUCTION AND MANAGEMENT FRAMEWORK AND INSTITUTIONALIZING THE NATIONAL DISASTER RISK REDUCTION AND MANAGEMENT PLAN, APPROPRIATING FUNDS THEREFOR AND FOR OTHER PURPOSES. REPUBLIC ACT No. 10121, 2009 https://www.officialgazette.gov.ph/2010/05/27/republic-act-no-10121/

[8] STRENGTHENING THE PHILIPPINE DISASTER CONTROL, CAPABILITY AND ESTABLISHING THE NATIONAL PROGRAM ON COMMUNITY DISASTER PREPAREDNESS. PRESIDENTIAL DECREE No. 1566 s. 1978, https://www.officialgazette.gov.ph/1978/06/11/presidential-decree-no-1566-s-1978/